The Impact of Knowledge Creation and Technology Education on New Product Development

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Abstract
The aim of this article is to investigate and bring to light the constructive impact of Knowledge Creation and Technology Education on the process of New Product Development. This is done under the competence-based perspective of the organization, where knowledge is the point of departure and the individual – in this case the industrial employee – is the relevant unit of analysis ten research enablers were exploited in order to evaluate how New Product Development is influenced by knowledge (tacit and explicit), Knowledge Creation (socialization, externalization, combination and internalization) and Technology Education (competence, skills, commitment and fit). Surveys collected from 486 employees, of 51 industrial companies in Spain, were analyzed in order to test the hypothesis. The results of this study allow us to draw conclusions on the significance of the impact that knowledge, Knowledge Creation and Technology Education have, each one on its own and all three combined, on New Product Development.

Key words
Competence-based Perspective, Knowledge Creation, New Product Development, Technology Education, Industry

1. Introduction
The principal hypothesis of this article is that Knowledge Creation (KC) and Technology Education (TE) have a positive impact on the process of New Product Development (NPD). The research was conducted under the competence-based perspective of the organization, where knowledge is the point of departure and the individual the relevant unit of analysis. The main objective is to investigate the ways individuals – in their professional lives – use the subjective and experience based knowledge they bring with them, and how they build upon their TE background in order to create new knowledge aiming to design innovative new products.

In this introductory section the concept of technological literacy is introduced, and the meaning of knowledge explored. Then the competence-based theory, the theoretical framework of this research, is put forward. The complementary dimensions of competencies and capabilities are extensively examined and the concept of fit is introduced. In section 2, the research enablers are described: the KC process is analyzed and TE and its relationship with industry are examined from an economic and industrial understanding perspective. In section 3, the value chain is used as a facilitator to approaching the NPD process. The impact of KC and TE in every phase of this process is discussed in section 4, both through the literature and a questionnaire-based survey. The study results are analytically presented, and finally, in section 5, our conclusions are presented together with some suggestions for future research.

1.1 Technological Literacy
In the modern organization, effective use of technology is considered among the key variables that drive competitiveness. However, this investigation concerns not technology itself, but the technological literacy of the industrial employees. Dyrenfurth (1991) considers that technological literacy is ‘a multi-dimensional concept’ and as such it is addressed, in terms of its curricular implementation, in section 2.2. For Dyrenfurth, technological literacy is essential for everyone, while specific technical education only for those pursuing specific occupations. Modern organizations increasingly recognize the significance of TE in general schools, for reasons associated with the development of future employees.

1.2 Knowledge
There is no unanimity concerning the definition of knowledge. The difficulty in doing so originates in the very intangible meaning of the term: knowledge, wisdom, and intelligence are concepts constantly revised and redefined as parts of cognitive psychology and the philosophy of science.

Davenport and Prusak (1998) underline that knowledge, data and information are not identical concepts. Knowledge transcends both data and information in a number of ways. It derives from information – in a similar way that information derives from data – via a transformation that takes place in and within persons. Nonaka and Takeuchi (1995) and von Krogh, Ichijo and Nonaka (2000) define knowledge as a 'justified true belief'. When somebody creates knowledge, he or she makes sense out of a new situation by holding justified beliefs and committing to them. This interesting approach matches the perspective of this study. According to Sveiby (2001) this definition is building on Plato and arguing against the Descartian body and mind split. In previous works, Sveiby (1994, 1997) building on contemporary philosophers, Polanyi and Wittgenstein, defines knowledge as a 'capacity-to-act' which may or may not be conscious. The emphasis of the definition is on the action element: A capacity-to-act can only be shown in action. Each individual has to re-create his or her own capacity to act through experience. Defining knowledge as a 'justified true belief' or as 'capacity-to-act' provides an ideal ground for approaching knowledge creation under the perspective of the investigation hypothesis.

In the related literature, it is first Polanyi (1966:4) who makes the critical distinction between tacit and explicit knowledge, by noting that 'we can know more than we can tell'. The most comprehensive distinction is the one proposed by Nonaka and Takeuchi (1995:59-60) which, as they acknowledge, derives from Polanyi's work.

- *Tacit knowledge* is subjective and experience based knowledge that may not be expressible in words, sentences, numbers or formulas, often because it is context specific. This also includes cognitive skills such as beliefs, images, intuition and mental models as well as technical skills such as craft and know-how.
- *Explicit knowledge* is objective and rational knowledge that can be expressed in words, sentences, numbers or formulas (context free). It includes theoretical approaches, manuals and databases.

Both tacit and explicit knowledge have a daily presence in the TE classroom and, thereby, a significant input in the way technology education curricula are developed. It is for this reason that they have been selected as the two Knowledge Enablers, in this study.

1.3 The Theoretical Framework

In the last decade of the 20th century a resource-based theory of the firm (Prahalad & Hamel 1990; von Krogh & Roos, 1995) has received attention as an alternative to the traditional product-based or competitive advantage view (primarily of Porter, 1985). Both theories have served, equally well, as the basis for new product development, for almost a decade each. Prahalad & Hamel (1990:82) define core competences as the '… collective learning in the organization, especially how to coordinate diverse production skills and integrate multiple streams of technologies'. They add that: 'the force of core competence is felt as decisively in services as in manufacturing'. Competence, according to the Webster Dictionary (1981:63) is defined as the 'quality or state of being functionally adequate or of having sufficient knowledge, judgment, skill or strength for a particular duty'.

Evans et al (1992: 66), with a tendency to dispute and complete the above definition, emphasize the difference between competence and capability and the way the two concepts relate to each other:

> …*competencies* and *capabilities* represent two different but complementary dimensions... But whereas core competences emphasize technological and production expertises at specific points along the value chain, capabilities are more broadly based, encompassing the entire value chain. In this respect, capabilities are visible to the customer in a way that core competencies rarely are.

The authors base their remarks on a well-documented case study of Honda in comparison with Ford.

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Von Krogh & Roos (1995:62) note that the above definition is based on the pre-existence of a particular knowledge and a particular task, and referring to the Latin origin of the term *competencia*, actually meaning agreement, they state: 'Only where there exists an agreement or fit between knowledge (or subject) and 'task' may we speak of competence'. And they conclude that '...it is only meaningful to discuss competence in a specific knowledge-task context, or put another way, competence is both knowledge specific and task specific'. Tasks are carriers of information, and may vary in degree of complexity. There might be multiple paths leading to a desired end, and there might also be multiple desired ends, not always totally independent among themselves. Consequently 'competences' have been selected as the first of the TE Enablers in this study.

Pearson and Young (2002:3-4) give the following characteristics of the technologically literate citizen – the industrial employee, in this study – in connection to his/her skills. (a) Has a range of hands-on skills, such as using a computer and operating a variety of home and office appliances. (b) Can identify and fix simple mechanical or technological problems at home or work. (c) Can apply basic mathematical concepts to make informed judgments about technological risk and benefits. In line with this approach, 'skills' have been added as the second TE Enabler.

There is clarity and quasi unanimity amongst researchers in recognizing the importance of commitment in accomplishing a certain task. Fit, on the other hand, has not always had unanimous interpretation, although it has served as an important element for theory construction in many research areas. Venkatraman (1989:423) notes that although theorists are '...using phrases and words such as *matched with, continent upon, consistent with, fit, congruence,* and *coalignment*, precise guidelines for translating these verbal statements to the analytical level are seldom provided'. And he cites Galbraith and Nathanson's (1979:266) observation in order to further support his statement: 'although the concept of fit is a useful one, it lacks the precise definition needed to test and recognize whether an organization has it or not'. Despite the 27 years that have passed since this observation, it is still partially valid today. As we consider 'commitment' and 'fit' valuable to this study, we selected them as the last two TE Enablers.

Finally, von Krogh and Roos (1995:57), in a well-documented comparison of the resource and product-based theories, have gone one step further and proposed the competence-based theory, where:

> the point of departure is knowledge, implying that the relevant unit of analysis in a competence-based perspective is the individual. This is different from the unit of analysis used both within the competitive strategy perspective (the industry) and the resource-based perspective (the firm). Here knowledge is not seen as a resource in a traditional meaning...and differs from these types of resources in many ways.

This particular distinction is the main reason why the competence-based theory has been adopted to guide this research.

2. Research Enablers

Having introduced above the research enablers for knowledge (tacit and explicit) and TE (competences, skills, commitment and fit), the research enablers for KC are now discussed.

2.1 Knowledge Creation

Innovation and knowledge share a tight relationship that has been noted by Drucker (1985). The innovation process can be better described as a reoccurring activity in which inventors swing between ideas and objects. The real meaning of invention seems to be the dynamic interplay of mental models with mechanical representations (Gorman and Carlson, 1990). The above mentioned relationship is noticeable in the area of industrial competitiveness as a factor of development and as a fundamental element for the creation of value. In order to explore innovation and R&D from a knowledge management perspective, we have to understand the flow of knowledge in the industry. We consider the spiral of knowledge model proposed by Nonaka and Takeuchi (1995) as the best tool for doing so. Let us briefly present the historic evolution of the model.

Porter (1985:36-40) was the first to introduce the concept of the value chain, by dividing the firm into the discrete activities it performs in designing new products, producing, marketing and distributing them. He describes (ibid, 166-169) how a company – using the value chain as the basic tool for understanding technology – can choose and implement a generic strategy in order to achieve and sustain *competitive advantage*. He further explores the relationship between technology and competitive advantage (ibid, 169-171). Technology is pervasive in the value chain and plays a powerful role in determining competitive advantage, in both cost and differentiation prospects. He describes the variables that shape the path of technological change in an industry and demonstrates how technological change can influence both competitive advantage as well as the entire industry structure.

A few years later, Nonaka (1991:96) opens his article with the statement: 'In an economy where the only certainty is uncertainty, the one sure source of lasting competitive advantage is knowledge'. He defines knowledge creation, dissemination and quick embodying it in new technologies and products as the activities that define the *knowledge-creating company*. He also describes (ibid, 97) such a company as the environment where '…inventing new knowledge is not a specialized activity – the province of R&D…. It is a way of behaving, indeed a way of being, in which everyone is a knowledge worker – that is to say, an entrepreneur'.

There is a dynamic cycle of knowledge, which Nonaka and Takeuchi (1995:62-73) present in the form of a spiral of knowledge within the industry, which reflects the process of generation and its consolidation:
create >> capture >> organize >> share….

It is a never-ending process, which is continuously being updated, generating new spirals of knowledge creation. According to Nonaka and Takeuchi, the KC process, which is continuous and cumulative, consists of four main modes:

- *Socialization* is the process of sharing experiences and thereby creating new tacit knowledge which can be acquired directly from others without the use of language. The key, therefore, to acquiring tacit knowledge is experience.
- *Externalization* is the process of converting tacit knowledge into *explicit* concepts. This requires both technological and verbal aptitudes, and it is here where a strong technology education background can prove of significant importance.
- *Combination* is the process of combining different bodies of explicit knowledge through written or oral means of communication. Knowledge creation carried out in Technology Education and Vocational Training usually takes this form.
- *Internalization* processes explicit knowledge into tacit through experiences, where individuals absorb knowledge through *learning-by-doing*, a fundamental method developed in every technology education classroom.

In a later article, Nonaka and Konno (1998) named this ongoing process of interactions between tacit and explicit knowledge, the SECI model, which serves as an outline for knowledge creation. The four modes of knowledge conversion described by the SECI model have been used as the KC research enablers in this study.

2.2 Technology Education and Industry
In many countries, technology is taught as a compulsory or sometimes optional subject in one or more of primary, secondary or upper-secondary schools. TE is intended to develop competences, skills and insights for citizens in a society dominated by continuous change and, as an essential discipline, technology ought to be provided at all levels of the educational system, as well as by continuing and life-long

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educational programs (Dyrenfurth, 2003). The author believes that the 'primary outcome of participating in technology education is technological literacy – a characteristic that encompasses both understanding and capability' (120). Some TE curricula have been based upon the implementation of educational ideas, usually fuelled by socio-economic concerns, structured in fields of action: work and production; transportation and traffic; supply and waste management; information and communication; construction and built environment.

Recently revised curricula have been influenced by ideas like preservation of nature, technology and social conditions, equality for women and men, political, cultural and economic freedom. A turn towards more society-oriented curricula is noticeable. The following three propositions, made by Eggleston (1995:216) involve society and the education system in a very realistic way and they further support our investigation assumption:

1. Every society and every government wants more technology education because it is seen to be the key to a developed economy and to growth in national income.
2. Every individual wants more of the products of technology for their personal satisfaction, security, comfort, leisure and entertainment. The goods that consumers, in every town and city, desire are remarkably similar.
3. In consequence every education system is trying to develop technology education from the early years through to higher and post graduate education for boys and girls.

The pedagogical approach regarding technology education starts with children at the age of 5 to 6 and continues with the education of students from 7 to 11 and 11 to 16 on the above described fields. Technology education is also present within the university sector, where the focus of attention is the development of new technology education programs that seek to mould the next generation of engineers and technologists.

According to McCormick (2004:25-26) '…almost any technology education curricula will have problem solving as an important part …' He, nonetheless, notices differences among the various national curricula. In the USA the emphasis is on 'problem solving', while in UK 'design' is the central point. But McCormick considers both design and problem solving as kinds of procedural knowledge, although he distinguishes problem solving as '…the most important procedural knowledge that occurs in technology, and indeed, in many other areas of activity'. He also notices '…the desire to teach a general problem-solving skill. In Britain there is a notion of 'key skills' …with problem solving being one such skill'.

Benson (1995:224-225) defines the concept of Economic and Industrial Understanding (EIU). She argues that EIU plays a very important role in the life of both adults and young children, who '…will become consumers, workers and producers and it is important therefore that the experiences that they have at school prepare them for their economic and working lives'. According to Benson, '…EIU is broader than 'making money' through mini-enterprises and it is important that a broad interpretation of EIU is promoted if children are to gain from its inclusion in the curriculum'. Finally Benson refers to case studies in UK, aiming at examining among other factors the skills and the organization of the production line that are needed in a mini enterprise within a school. The results were not always positive as'…often the pupils saw it just as a way to make money for the school funds'.

So, the links between TE and Industry are not equally developed in every society. In countries with strong tradition in TE there have been organizations that played a major part in supporting these links. The United Kingdom is a good European example. Innes (1995:233-234) refers to SCSST (The Standing Conference on Schools' Science and Technology) and its national network SATRO (Science and Technology Regional Organization) as examples of two such organizations, which'… have played a major part in supporting industry links by exciting young people about science and technology…' To illustrate this, Innes brings up three examples:

a) Experienced engineers working on real and relevant projects in the classroom.

b)Young Engineers, a national SCSST program where students, members of school clubs for the 11 to 18-age range, become actively involved in real projects. Their achievements are recognized each year through National Awards Finals where their work is displayed and prizes presented.

c) The designation of 1986 as the Industry Year in the UK, which focused public attention on the value of Industry-Education links.

Nevertheless, the UK is not a typical European example. International approaches to technological education justify its implementation on the basis that it supports development of the human capital of the country where it is being applied.

3. New Product Development

Let us follow step-by-step the development, birth and critical first year of a new product's life. The focus will be on phases previous to what is commonly referred to as the Product Life Cycle (PLC) in relevant bibliography. We shall only enter the very first phase of the PLC which Porter (1980:157) calls 'the grandfather of concepts for predicting the probable course of industry evolution'. Porter relates the PLC concept to the industry and not only to individual products.

For the purpose of this investigation the first PLC phase has been divided into five sub-phases. Individuals, industrial employees in Spain, to whom our survey has been addressed, were asked to evaluate the impact of the knowledge, KC and TE enablers in each and every one of the following PLC sub-phases.

Phase One:

Ideas for new products can arrive from any number of sources: the scientist in the laboratory, the inventor who approaches the company, the irritated customer or a competitor's innovation. Heavy technological background as well as capability for knowledge creation is of significant importance in each of the above four possible sources.

Phase Two:

Key managers, with their best both technological and financial judgment, among other data sources, approve the idea, thus giving the green light to generate forecasts and other planning documents. If positive market and financial performance is predicted for the new product, the idea wins a place in the design laboratory.

Phase Three:

Management approval is not enough to launch the project. In addition, market research, that is useful in defining and positioning the new product and helps to forecast demand, has to be conducted. In this phase, technology is strongly supported by the creation and sharing of knowledge among the departments involved: marketing, research and development (R&D), quality control and manufacturing.

Phase Four:

A prototype is produced and the design for the final product is finalized. This is a phase where technological literacy plays a vital role and the analogy between the industry's prototype laboratory and the TE classroom is easily recognized.

Phase Five:

Production is launched and improvements have to be made as the sales force meets resistance from both the distribution channels and customers. Production problems occur with the first full run. In this phase, technology is present in the entire value chain of the company, as sales and distribution departments are now involved.

However, the emergence of new technologies and the increased rate of change in existing technologies tend to shorten the PLC. As new products emerge more rapidly to satisfy similar consumer needs, existing ones decline more quickly. Shortened life cycles put time pressure on the organization to plan and launch the next-generation product.

4. The Research

Two previous studies have triggered this investigation. Dyrenfurth (1998) surveyed approximately 200 businesses in the region of Kansas City, USA and found technological literacy as an 'increasingly important capability' assessed almost as high a need as the basic skills of arithmetic, communication and cooperation capabilities. These basic skills competences were cited by the research responders with frequencies ranging from 53 to 78 percent, compared to some 51 to 60 percent cited for the technological literacy competences, included in the study. The author even considers technological literacy as fundamental to being able to transfer knowledge and skill to unknown or new operational situations. Another important finding of this study is that specialized technical and industry-specific competences, like computer literacy, were all cited by the responders with frequencies below 50 percent.

The second study (Oskarsdottir, et al. 2000), in which we have also participated, is a comparative analysis on developments and skill requirements in 20 non-professional jobs in four European countries: France, Greece, Iceland and Italy. We interviewed, by means of a questionnaire, a total of 1600 individuals - 15 employees and 5 supervisors in each of the 20 jobs in every country. The results were similar to those in the above study. Basic skills (mathematics, communication, cooperation) were reported as very important by a 47 to 86 percent of the employees and 51 to 93 percent of the supervisors, whereas 52 percent of the employees and 63 percent of the supervisors opted for information mastery, the only technological literacy competence included in the study.

The individual, in our case the industrial employee, was the unit of analysis in the present investigation. The source for sampling was 82 major Spanish companies, covering 5 industrial sectors (automotive, chemical & pharmaceutical, electro-mechanical, food & beverages and textile). Staff members and experienced employees working in production, new product development (or R&D) and quality departments were asked to participate in the study. Due to the nature of the investigation we adopted both interviews and a questionnaire-based survey, the latter being our principal research instrument.

During the interviews the objectives of the investigation were explained to the above mentioned departments' managers and a two-page explanatory text was handed out to be distributed to all potential respondents. The text, apart from a brief description of the research project, provided definitions of the ten enablers and the five PLC sub-phases. The guideline was that only employees who, due to their everyday professional activities, were fully aware of the meaning and significance of all enablers should participate in the survey. Although data collected during the interviews are not analyzed statistically, they were valuable for our interpretations and conclusions.

Following the interviews, the questionnaire survey was conducted. Questionnaires, as shown in Table 1 were administrated via e-mail to a total of 876 staff members and experienced employees of production, new product development (or R&D) and quality departments within the 82 companies of our sample.

Table 1 Questionnaire

Table 1 Questionnaire

Use the following scale to evaluate the impact of the Knowledge, Knowledge Creation and Technology Education enablers in each and every one of the PLC sub-phases:

1	2	3	4	5	6
Very Weak	Weak	Moderately Weak	Moderately Strong	Strong	Very Strong

1. Knowledge enablers

Enabler	Question				
	In our organization, possession and management of Tacit and/or Explicit knowledge, in each of the five PLC phases, is evaluated:				
Tacit	Phase 1:	Phase 2:	Phase 3:	Phase 4:	Phase 5:
Explicit	Phase 1:	Phase 2:	Phase 3:	Phase 4:	Phase 5:

2. Knowledge Creation enablers

Enabler	Question				
	In our organization and in the course of the Knowledge Creation process, I assess the appropriate use of Socialization, Externalization, Combination and Internalization in each one of the five PLC phases, as:				
Socialization	Phase 1:	Phase 2:	Phase 3:	Phase 4:	Phase 5:
Externalization	Phase 1:	Phase 2:	Phase 3:	Phase 4:	Phase 5:
Combination	Phase 1:	Phase 2:	Phase 3:	Phase 4:	Phase 5:
Internalization	Phase 1:	Phase 2:	Phase 3:	Phase 4:	Phase 5:

3. Technology Education enablers

Enabler	Question				
	In our organization, I assess the development of Competences, Skills, Commitment and Fit (all four due to Technology Education background) in each one of the five PLC phases, as:				
Competences	Phase 1:	Phase 2:	Phase 3:	Phase 4:	Phase 5:
Skills	Phase 1:	Phase 2:	Phase 3:	Phase 4:	Phase 5:
Commitment	Phase 1:	Phase 2:	Phase 3:	Phase 4:	Phase 5:
Fit	Phase 1:	Phase 2:	Phase 3:	Phase 4:	Phase 5:

4. An Additional Question

4.1 Have you had any kind of Technology Education at:

a) Primary School?: YES NO

b) Secondary School?: YES NO

4.2 Have you had University studies and/or Vocational Training on a Technological subject?: YES NO

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Six to twelve employees from each company were surveyed depending on its size. Finally, 486 responses from 51 companies were received and analyzed. Table 2 shows the industrial sectors represented, the number of companies contacted and those who finally participated, as well as the number of employees who received and finally responded to the questionnaire.

Table 2 Research Participants by Sector and Unit of Analysis

Sector	Companies		Employees	
	Contacted	Participated	Contacted	Participated
Automotive	8	6	83	51
Chemical & Pharmaceutical	7	5	63	36
Electro-Mechanical	25	18	339	182
Food & Beverages	26	14	212	112
Textile	16	8	179	105
Total	**82**	**51 (62%)**	**876**	**486 (55%)**

The participation rates achieved in the research (62% at company level and 55% at the unit of analysis level) were satisfactory. Table 3 shows the respondents' characteristics in terms of sector, company and departments.

Table 3 Study Participants by Sector, Company and Department

Sector	Companies		Employees	
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Automotive	8	6	83	51
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Total	**82**	**51 (62%)**	**876**	**486 (55%)**

4.1 Reliability and Validity
Cronbach's alpha has been used to test the reliability of the measurement instrument. As all enablers have higher than 0.7 cut-off alpha values (in Table 4, below, they range from 0.8375 to 0.9254), they meet the criteria set by Nunnally (1978) for previously adopted instruments. As only single-item enablers were used, there was no need for convergent and discriminant validity tests to be applied.

Table 4 Descriptive Statistics and Reliability Test

Enablers	**Mean**	**S.D.**	**Reliability (Cronbach's *alpha*)**
Knowledge enablers			
Tacit	4.2307	0.4476	0.9235
Explicit	5.0125	0.4149	0.9136
Knowledge Creation enablers			
Socialization	3.8642	0.3956	0.8534
Externalization	4.1327	0.4176	0.8375
Combination	3.9468	0.4064	0.8963
Internalization	3.6534	0.5743	0.8766
Technology Education enablers			
Competences	5.5432	0.5287	0.9254
Skills	4.1542	0.5367	0.8688
Commitment	3.8534	0.4098	0.9142
Fit	4.3482	0.5268	0.8653

4.2 The Impact of KC and TE on NPD
The relationship between KC, TE and NPD – the focus point of our study – has not been sufficiently investigated up-to-date, especially regarding the contribution of TE. In this section first we present the overall research findings in Table 5 and then, in Tables 6 and 7 we summarize and highlight those findings that best support the investigation hypothesis.

Table 5 Research Results

Enablers	**New Product Development**				
	Phase One: Ideas	Phase Two: Approval	Phase Three: Market Research	Phase Four: Prototyping	Phase Five: Product Launch
Knowledge enablers					
Tacit	**HIGH 72.4** MEDIUM 16.7 LOW 7.9	HIGH 9.8 MEDIUM 12.6 **LOW 65.6**	HIGH 12.5 **MEDIUM 70.4** LOW 10.1	**HIGH 61.1** MEDIUM 10.2 LOW 21.7	HIGH 9.4 **MEDIUM 66.9** LOW 16.7
Explicit	HIGH 8.2 MEDIUM 11.3 **LOW 70.5**	**HIGH 56.4** MEDIUM 17.1 LOW 22.6	**HIGH 81.3** MEDIUM 10.5 LOW 3.2	**HIGH 74.3** MEDIUM 18.4 LOW 2.3	**HIGH 85.1** MEDIUM 8.4 LOW 2.5
Knowledge Creation enablers					
Socialization	**HIGH 62.8** MEDIUM 11.7 LOW 20.5	**NA 36.7**	**NA 74.5**	**NA 82.4**	**NA 54.9**
Externalization	HIGH 10.5 **MEDIUM 72.8** LOW 9.7	**NA 54.5**	**NA 64.3**	**HIGH 56.2** MEDIUM 13.2 LOW 20.6	HIGH 13.5 **MEDIUM 65.9** LOW 8.6
Combination	**NA 65.8**	HIGH 9.3 **MEDIUM 66.9** LOW 16.8	**HIGH 67.9** MEDIUM 15.4 LOW 10.7	HIGH 11.8 **MEDIUM 76.7** LOW 1.5	**NA 49.7**
Internalization	**NA 72.5**	**NA 47.9**	**NA 87.9**	**NA 33.2**	**HIGH 67.7** MEDIUM 18.8 LOW 4.5
Technology Education enablers					
Competences	**HIGH 88.4** MEDIUM 6.8 LOW 1.8	HIGH 11.6 **MEDIUM 77.5** LOW 4.9	**HIGH 68.8** MEDIUM 21.6 LOW 2.6	**HIGH 67.5** MEDIUM 12.8 LOW 10.7	HIGH 11.7 **MEDIUM 65.2** LOW 10.1
Skills	HIGH 7.7 **MEDIUM 80.6** LOW 5.7	HIGH 8.5 **MEDIUM 56.7** LOW 30.8	**HIGH 75.6** MEDIUM 12.9 LOW 4.5	**HIGH 65.4** MEDIUM 18.5 LOW 9.1	HIGH 8.7 MEDIUM 17.4 **LOW 56.9**
Commitment	HIGH 5.5 MEDIUM 9.2 **LOW 79.3**	**HIGH 70.9** MEDIUM 15.6 LOW 7.5	HIGH 11.3 **MEDIUM 58.8** LOW 20.9	HIGH 5.8 MEDIUM 7.9 **LOW 74.3**	**HIGH 69.8** MEDIUM 11.1 LOW 12.1
Fit	HIGH 12.7 **MEDIUM 61.8** LOW 17.5	HIGH 14.7 **MEDIUM 71.8** LOW 8.5	**HIGH 81.9** MEDIUM 9.7 LOW 2.4	**HIGH 60.7** MEDIUM 10.6 LOW 15.7	**HIGH 73.8** MEDIUM 11.7 LOW 4.5

The investigation hypothesis was that there is a constructive impact of KC and TE on the process of NPD and this assumption has been scrutinized under both theoretical and empirical perspectives. Tables 6 and 7 bond the literature remarks made previously upon describing the NPD phases with the research findings, in a way that supports the hypothesis. This will be further demonstrated in the conclusions section.

Table 6 summarises research findings regarding the impact caused upon each one of the five NPD phases by the two knowledge and the four KC enablers. The use of a three-grade range (Low, Medium, and High) has been adopted for simplicity purposes. Its relation to the six-point Likert scale stands as follows: Low = points 1 and 2, Medium = points 3 and 4, and High = points 5 and 6. Adoption of a six-point Likert scale, which does not include the midpoint About Average, prevents respondents from using a neutral default option. The rating Low, Medium or High, depicted in the cells of Tables 6 and 7 for each one of the enablers, is the dominating one according to the research findings presented in Table 5. KC enablers that do not appear in the cells of Table 6 were considered as Not Applicable (NA) by more than 30% of the respondents, for the relevant phase.

Table 6 The impact of knowledge and KC upon NPD

Enablers	**New Product Development**				
	Phase One: Ideas	Phase Two: Approval	Phase Three: Market Research	Phase Four : Prototyping	Phase Five : Product Launch
Knowledge & Knowledge Creation Impact	*Tacit* **HIGH 72.4%**	*Tacit* LOW 65.6	*Tacit* MEDIUM 70.4	*Tacit* **HIGH 61.1%**	*Tacit* MEDIUM 66.9
	Explicit LOW 70.5	*Explicit* **HIGH 56.4%**	*Explicit* **HIGH 81.3%**	*Explicit* **HIGH 74.3%**	*Explicit* **HIGH 85.1%**
	Socialization **HIGH 62.8%**	*Combination* MEDIUM 66.9	*Combination* **HIGH 67.9%**	*Externalization* **HIGH 56.2%**	*Externalization* MEDIUM 65.9
	Externalization MEDIUM 72.8			*Combination* MEDIUM 76.7	*Internalization* **HIGH 67.7%**

Table 7 summarizes research findings regarding the impact caused upon each one of the five NPD phases by the four TE enablers: competences, skills, commitment and fit.

Table 7 The impact of TE upon NPD

Enablers	**New Product Development**				
	Phase One: Ideas	Phase Two: Approval	Phase Three: Market Research	Phase Four: Prototyping	Phase Five: Product Launch
Technology Education Impact	*Competence* **HIGH 88.4%**	*Competence* MEDIUM 77.5%	*Competence* **HIGH 68.8%**	*Competence* **HIGH 67.5%**	*Competence* MEDIUM 65.2%
	Skill MEDIUM 80.6%	*Skill* MEDIUM 56.7%	*Skill* **HIGH 75.6%**	*Skill* **HIGH 65.4%**	*Skill* LOW 56.9%
	Commitment LOW 79.3%	*Commitment* **HIGH 70.9%**	*Commitment* MEDIUM 58.8%	*Commitment* LOW 74.3%	*Commitment* **HIGH 69.8%**
	Fit MEDIUM 61.8%	*Fit* MEDIUM 71.8%	*Fit* **HIGH 81.9%**	*Fit* **HIGH 60.7%**	*Fit* **HIGH 73.8%**

An additional question inquiring about the TE responders had during their primary or secondary schooling, as well as the possible technological nature of their University studies and Vocational Training, demonstrated that: Only 3.4% of the responders had contact with TE at primary school level, while a significant percentage (42.6%) had TE during secondary school. Finally 58.5% of the responders had either a University degree or Vocational Training related to technology. The latter high percentage is explained by the fact that in the industrial sectors under investigation staff members are typically engineers, chemists, physicists, doctors or economists, with a technical orientation.

5. Conclusions
Research findings, as presented in Tables 5, 6 and 7, prove that there is a constructive impact of knowledge, KC and TE on the NPD process. To demonstrate this more clearly we are 'interpreting' Tables 6 and 7, here below, in reference to each one of the ten research enablers used in this study.

Regarding the two knowledge enablers: 'tacit knowledge' is reported as highly beneficial in the NPD phases of Ideas and Prototyping, while possession of 'explicit knowledge' is recognized as such in four out of the five NPD phases (Approval, Market Research, Prototyping and Marketing). The nature of explicit knowledge, as described in section 1.2, is a good reason why it is not considered beneficial in the Ideas phase, where tacit knowledge plays the dominant role.

In reference to the four KC enablers: 'socialization' is considered highly beneficial in the Ideas phase; 'externalization' in the Prototyping phase; 'combination' during Market Research and 'internalization' in the Product Launch. Here again, the nature of the four enablers, as described in section 2.1, explains why that happens and why some enablers were considered as Not Applicable (NA) by more than 30% of the respondents, in certain phases. For example, this complies with Nonaka & Takeuchi's interpretation that socialization ranks high in the Ideas phase (tacit to tacit knowledge), while it receives low rating in every other phase, where explicit knowledge is relatively dominant.

Finally, interpretation of results regarding the four TE enablers is a little more complex. 'Competences' rank high during Market Research and Prototyping (which is in accordance with the theoretical perspectives), but is also considered essential in the Ideas phase, this time challenging theory. 'Skills' are considered essential during Market research and Prototyping; 'commitment' is reported as highly required for Approval and Product Launch; 'fit' is believed to be beneficial for Market Research, Prototyping and Product Launch. They all abide by theory, although interpreting Venkatraman, one would expect 'fit' to be beneficial during the Ideas phase, as well.

The previously presented analysis allows us to observe the three concepts under investigation (KC, TE, and NPD) not as three unrelated entities, but as parts of an equilateral triangle, as it is shown in Figure 1. It is difficult to decide which one of the three comes first, but if the triangle is seen as the rotating heart of a Wankel motor, then the problem vanishes.

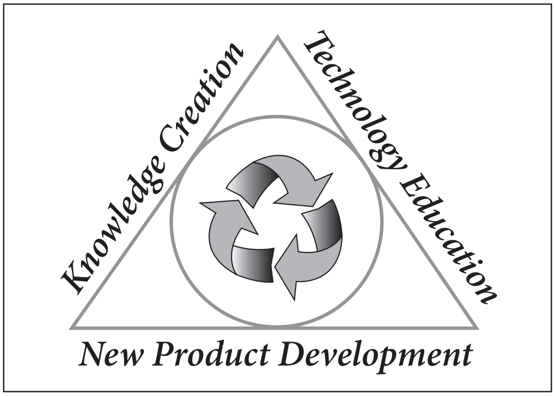

Figure 1. The Wankel motor analogy.

Research findings indicate that knowledge, KC and TE have, each one on its own and all three combined, a very constructive impact on NPD. On the other hand, authors from both the marketing standpoint (Kotler, 1991) and the industrial engineering perspective (Porter, 1980 and 1985) of NPD emphasize the positive impact that active participation in NPD teams has on the knowledge sharing or KC capabilities of the individuals. Combining this observation with the results of the present research we can conclude that there is freewheeling among KC, TE and NPD. Knowledge sharing and KC combined with a strong TE background can positively influence NPD; this in turn, nourishes knowledge sharing and KC and improves the technological literacy of individuals participating in NPD teams. Long-established tools, like brainstorming, and contemporary ones, like groupware, keep facilitating the flow in this exchange of knowledge, experiences and innovative ideas.

Although the results of this study are based on a large sample, two issues of concern remain. First, the constructive impact that knowledge, KC and TE have on NPD was evaluated at a static point in time (spring 2005) whereas the basic enablers vary over time. And second, the study was conducted in a single country, Spain. A future multinational study, and if possible periodically repeated, would be of greater value for the research and the TE communities.

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