Integrative Technologies Complicate Communication during Development Work Context: Industry-Academy Collaboration

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ABSTRACT

A competition in the electronics industry is hard. For most companies, strong technological know-how will be a competitiveness factor in the future. The future technologies will be increasingly based on a combination of innovations from several branches of science. Also, many innovations are based on external technology integration. The days are over when one company could internally create all of the technology it needs to maintain its competitiveness. One approach of promising framework for the development of a new integrative technology is an industrial R&D network combined with industrial-academic collaboration. However, this kind of collaboration is a challenging undertaking.

Companies in a value network might have very different expectations regarding a new technology due to differences in their position in the value network or their company strategy. One of the main challenges in an R&D network is to translate the expectations of all parties involved into new technology solutions so that all in the R&D network feel they have obtained benefit. One of key factors on creating successful industrial-academic collaboration is open and trustful communication. But, there are communication challenges, intellectual property sharing problems, and discussions regarding the sharing of cost and benefits. Developing a new integrative technology structure requires seamless teamwork, holistic and interdisciplinary understanding, and open communication throughout the R&D team and the industrial-academic network. The focus of this paper is on network communication, knowledge communication and team communication. The results of this study indicate that successful communication in an industrial-academic R&D network to develop a new integrative technology improves knowledge creation and accelerates commercialization of the technology.

Keywords: Communication, Industrial-Academic Collaboration, IPR Management, Knowledge Management, R&D Network, Technology Development

1. INTRODUCTION

Technological environment is changing rapidly. In the field of portable electronics, consumers are demanding fashionable products that epitomize their personality and individuality, and not forgetting multi-functionality. In addition, many long-serving technologies are no longer efficient enough to fulfil these ever-growing expectations of future customers. A competition in the electronics industry is brutal. High technological competence level creates competitive edge for a company. One way to survive in this tight competition is to integrate technologies to produce a new functional concept for products. Many future technologies will be based on a combination of innovations from several branches of science. [4-8]

This paper reflects communication challenges created by technology integration to the development process of one new integrative technology, a digital printing. Because of this multidisciplinary approach, one company cannot internally create all the competences needed to utilize these new integrative technologies. For example, new nanomaterials combined with a well-known digital printing technology have enabled the introduction of feasible printable electronics manufacturing process. Also, many new technological innovations are based on integrating technologies developed by others, so that it is impossible for one company to develop and integrate these technologies alone. Thus, many companies are increasingly focusing on creating technological competence in fewer areas but in ones that support their technology strategy or core business area, and they are expanding their competence background by networking. In the field of new technology development, companies

are relying on networking to ensure the timely creation of technology infrastructure and to provide supporting capabilities for their core business. On the other hand, universities have become increasingly depend on funding from the industry. Moreover, government policy of research funding is encouraging closer industrial-academic collaboration than before. One approach of promising potential for the development of a new integrative technology is industrial-academic collaboration, where the university can be a neutral body when value capture rules have not yet been established and can hold a necessary competence node in times of change in R&D networks. The idea is to accelerate the creation and generation of knowledge and to transfer knowledge obtained in publicly funded research to industry. [2, 4-8]

Integrative technologies are often hybrid technologies, in other words novel combinations of existing and new manufacturing processes which involve crossing the boundaries of industries and value chains. Technologies of this type have to be developed and produced within networks. Unfortunately, networks are always a challenging undertaking. There are communication challenges, intellectual property sharing problems, and discussions regarding the sharing of cost and benefits, among others. The focus of this paper is on communication challenges. These communication challenges exist at many levels: team communication in a multidisciplinary R&D team, industrial-academic communication, and communication between industrial partners. Also, globalization makes it necessary for networks to be created over continental and language barriers. [2, 4-8]

Even though these environmental changes have increased the willingness for closer cooperation between universities and the industry, many attempts of this type of knowledge creation are unsuccessful. Furthermore, complexities associated with knowledge creation in industry-academic collaboration and knowledge transfer from universities to the industry are not adequately studied. This research paper summarizes the results of five case studies conducted during the years 2000-2007 in the telecommunication industry and highlights the challenges of communication in the R&D network developing a new integrate technology. The research is based on practitioners' observations of communication challenges in the R&D networks during new technology development work. Also, over a hundred leaders, managers, or experts were interviewed. The key focus of this paper is on interdisciplinary and cross-organizational communication during development work on a new integrative technology having portable electronic applications as its target. The structure of the paper is two-fold. First, as a background, it introduces special characteristics of new integrative technologies and the process of technology development. Second, it discusses communication challenges during development work on new technology and the process of new product creation. The context of the cases is industrial-academic collaboration in a development of new electronics production technologies for the telecommunication industry.

2. INTEGRATIVE TECHNOLOGY

In the field of electronics, future technologies will be very different from the present ones. User experience and architecture of the future products will be very different than in the present devices. New technologies must be developed so that products fulfilling consumers' expectations also in the future can be designed and manufactured. The electronics industry is on the brink of changes. In the field of portable electronics, consumers are demanding fashionable products that epitomize their personality and individuality and manufacturers expect new technologies to be produced cost-effectively in the global logistics network. One way to satisfy such requirements is to integrate manufacturing technologies to produce a new functional concept for products. [1, 4-8]

An electrical device is a complex system that has several mechanical, electrical, and software functions. In this study, a system is defined as a set of concepts, parts, or functions that must work seamlessly together for a particular set of functions. In a wider perspective, the system design includes product definition (setting functional requirements, industrial design, user interaction design, etc.), product creation (electronics, mechanics, software, design for manufacturing, etc.), product delivery (manufacturing, supply line management, logistics, etc.), and the brand management of the end product. In this paper the focus is on hardware integration. Although many new integrative technologies are based on innovations in material science and new production technology, a new kind of approach to system design is needed as well, because each part of a system interacts closely with all other parts of the system. Therefore, the design of an integrated structure requires seamless and interdisciplinary teamwork as well as cross-organizational networks. [1, 4-8]

In this study, an integrative technology is defined as a possibility of crossing the boundaries of existing business lines by exploiting existing and new technologies as well as the competences provided by new and old R&D network parties. The example case technologies are a digital printing are 3D MID technologies. A digital printing is a well-known technology in the graphics industry. New nanomaterials combined with digital printing technologies have enabled utilization of this flexible manufacturing method for electronics applications also. The principle of 3D MID technologies is to use injection molded thermoplastic mechanical parts as carriers for electrical elements. This paper discusses these technologies as a new integrative technology.

Typical benefits of such technologies are reduced cost, increased weight/size/performance ratio, shorter manufacturing cycle time, and improved functionality and flexibility compared with traditional technologies or established process flows. [4-8]

Digital printing technologies will change existing value networks or create new ones. These technologies are integrating not only hardware functions, but also the players in the value network. It is inevitable that some players will be displaced, or their roles will be narrowed down or expanded, and some new players will make their entry. Developing a HW technology that integrates electrical and mechanical functions into one unit requires cooperation between electrical and mechanical component suppliers, or the existence of a party willing to create necessary knowledge. If the new technology is aimed at the established market, the fact must be faced that some companies may lose part of their business. Thus, conflict is born. According to our results, these contradictions arose just before the commercialization phase in the process of the technology's development, because these conflicts are directly linked to business opportunities emerging from new integrative technologies. It is crucial in an R&D network to arrive at a well-discussed and jointly defined vision in which value capture and targets have received due consideration. [1, 3-8]

3. DEVELOPMENT PROCESS

Developing new technology is often like taking a leap into the knowable and do-able, but nevertheless the unknown and not-yet-done, and it is very difficult to estimate in advance the commercial success of a new technology. Technological or ecosystem immaturity, other more competitive emerging technologies, failure in execution, lack of passion or focus, and competitive volatility are risks which belong to the process of developing new technology. When market uncertainty is added to these risks, the difficulty of estimating the success of new technology is greatly increased. In this work a development process of a new technology is divided in three main phases; technology anticipation, technology development, and technology commercialization. The focus is on the development phase. [3, 4, 6, 12, 13]

Well-focused industrial-academic collaboration is a very efficient way to develop a new integrative technology. To accelerate commercialization of a new integrative technology it is necessary to develop simultaneously both an infrastructure and technological characteristics. Also, education of multidisciplinary experts is essential in order to commercialize these new integrative technologies in an effective way. The main reasons for establishing industrial-academic collaboration combined with an industrial R&D network are accelerated competence creation, intensified knowledge transfer, and education of multidisciplinary professionals. [6, 7, 11]

Functioning R&D networking accelerates knowledge generation of the one participant, because every party of the network can allocate their own resources into their strongest knowledge area and share their knowledge with all other parties. In return they can learn from other parties about all other knowledge areas. This intensifies the generation of knowledge. We would like to emphasize that this kind of working mode requires truly trustful cooperation between participants and respectful attitude to each others.

Figure 1 illustrates the principle idea in the industrial-academic collaboration. At the core of the collaboration is academic basic research work, while in an outer layer surrounding this research is the industrial network, i.e. value network that can create and deliver commercial applications. In this figure, the middle layer illustrates industrial-academic collaboration and its function as an accelerator in knowledge creation and the transfer of this knowledge from academic basic research to the industry for commercial applications.

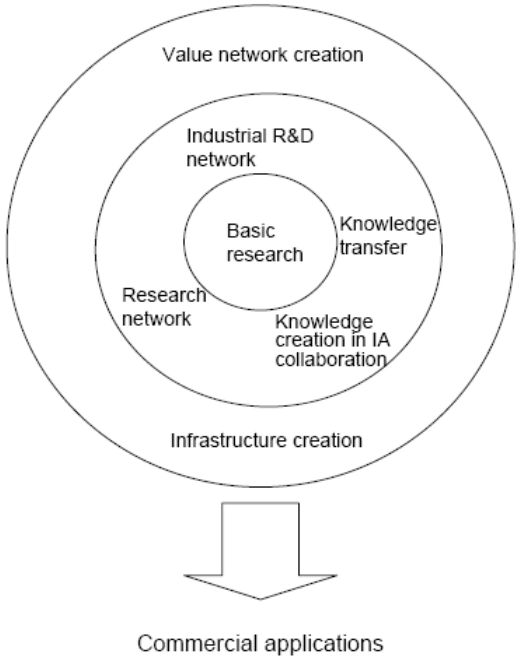

Figure 1. Principle idea in the industrial-academic collaboration

The challenge is how to create an open and confidential discussion forum for industrial-academic collaboration. The road to a partnership in new integrative technology development begins with a common vision and the need for a partnership. These fundamentals will build trust, and

a strong will for cooperation that will last through difficult times in development projects. Creation of open, trustful, and communicative industrial-academic collaboration is hard work, but successful collaboration is accelerating commercialization of a new integrative technology.

Collaborative R&D work is growing rapidly. Exploitation of a new integrative technology requires the establishment of inter-company R&D and manufacturing networks. In the creation of technology networks there are always challenges and obstacles to overcome. Sharing of the proprietary intellectual assets is a key question in a collaborative R&D network. The basic assumption is that all parties concerned want to maximize their benefits, but at the same time to protect their own interests. Companies will protect their intellectual property rights, existing customer relationships and business, competences, know-how, and so on. Companies are using legal as well as non-legal methods to protect their intellectual assets. In a R&D network, crafting a series of agreements could become an insuperable challenge. The companies might have hidden agendas to push through. In addition, cost-profit sharing is always problematic. The effects of establishing the new technology may vary considerably among the network participants. For some companies, the new technology might represent a threat to their existing business and might require extensive investments for new equipment, whereas for other companies the technology might offer great improvements or cost-savings from the point of view of their existing products. [3, 5, 6, 9-13]

One major challenge in the case of integrative technology is the difficulty in estimating the benefits of the technology over time. If an integrative technology provides only minor improvement on an end product, the short-term financial gain is not positive due to the expensive infrastructure changes needed in the value network. However, if an integrative technology provides major benefits, this usually causes fundamental changes in revenue capture potential for the network parties. Cost-benefit estimation is a continuous task during the development of new technology and the process of its commercialization. Every party in the network does its own cost-benefit assessment repeatedly. In other words, the network has a number of different assessments of the technology's commercial potential. For one company the technology represents more changes to its processes, larger investments before utilization, or bigger competence deficit than for others. Challenges related to correct partner selection for the network, and how to maintain everyone's will to develop the technology. [4, 6, 7]

Despite all possible challenges and problems, technology networks can offer a great competitive advantage for the companies involved. Networking with well-selected partners increases a company's knowledge base. Also, a successful technology network creates new business opportunities for all of the participating companies. However, as a daily routine open communication over the borders of organizations, companies, and fields of expertise is demanding.

4. COMMUNICATION IN TECHNOLOGY DEVELOPMENT PROCESS

Integrative technologies are often novel combinations of existing and new manufacturing technologies, meaning that the boundaries between industries have to be crossed. And value networks are mainly multinational. Even inside one multinational corporation, the behavior of members of the top management varies according to their national background. Technologies crossing business and nationality lines complicate communication at many levels during development work. This paper discusses knowledge communication, network communication, and team communication challenges. [1, 7]

In the case of new integrative technology according to the observations of the practitioner, one major challenge is the lack of an established joint vocabulary. Words can have different meanings or refer to different phenomena for each party involved. Also, multi-nationality complicates the language problem.

The main findings of the study are discussed next.

Network Communication

Companies in the value network might have very different expectations or targets regarding a new technology due to divergences in their current or planned positions in the value network. Also, research institutes have their own ambitions to fulfill. The main challenge is to translate all these expectations into new technology solutions or competence creation of such a kind that every party involved feels it will gain benefit. This requires honest, open, multidisciplinary, and inter-company communication. [4, 8]

A technology represents different a kind of strategic decision for every party involved in the R&D network. Often a company's assessment of technology is colored by its own vision of the future and by its knowledge of the most active fields in technology complicating also structuring and negotiating agreements for an R&D network in development work of a new integrative technology. The most crucial and important agreements in an industrial R&D network combined with industrial-academic collaboration are collaboration agreements, IPR agreements, and content agreements including a present cost and future profit sharing paragraph. Each participant has a different kind of competence background, which influences a great deal each company's preparedness to function in the network and to adopt the technology. Each company is good at what it does and understands its own

business, but understanding of the other partner's business is difficult. According to the results of this study, one company is required to take a leading position in the network. This is necessary when the goal that has been set requires dynamic development of the network over time and when the technology requires that each party of the network play a different kind of role. It is also a great risk. If the network lacks open communication, the parties could lose their trust in the network or in each other. The challenge is to create a common vision that supports each participant's own vision. The network should jointly specify the targets and responsibilities, and this requires lots of discussions, negotiations, meetings, and debates. In fact, collaboration is always a trade-off. [4, 8]

The development of new integrative technology requires constant interaction of competence groups due to constantly changing cumulative knowledge. When integrative technology changes how a product is made, design for manufacturing requires the manufacturing aspects be incorporated into the technology development process. Similarly, to exploit a commercially successful integrative technology, the new product creation process requires cooperation with various knowledge groups. The integration of electronics and mechanics must be taken into account at an early design stage to maximize the benefits. In well-established industries, industrial designers, material specialists, electrical designers, mechanical designers, and process specialists can work in partly independently if they exchange information regularly and in a systematic way. In contrast, in integrated technologies, all design work should be done simultaneously and following the same design guidelines since departure from such guidelines will lead to significant number of design variants. Especially, those designing the end product must be intimately involved in the technology development process. In the case of new integrative technology, these knowledge groups are located in companies that are from several fields of business. Communication challenges are increased due to lack of established business relationships between the new partners. Also, culture of working in the companies may differ considerably and there might be a lack of common technological language. [4-6]

Knowledge Communication

Technological evolution can be accelerated by strategic knowledge communication, i.e. research publications and presentations. Unfortunately, in industrial-academic collaboration, knowledge communication can prove a serious stumbling block. In the academic world, research groups and individual researchers are mostly evaluated according to their activeness in the publishing of knowledge. Research groups and researchers want to publish all good emergent ideas as soon as possible, whereas the main interests of industrial partners are to strengthen their competence background, increase their company's competitiveness, and protect created intellectual property rights. They may also need time to grasp strategic implications. [9, 10]

The challenge is to create an environment in which each party has a desire to propel technology development towards a common target without sharing their own inventions too early. Laying down the principles for knowledge communication is one of an R&D network's most strategic management decisions connected with the process of developing a new integrative technology. IPR policy creation is a complex and wide task. Patent protection is an effective way to strengthen a company's competitiveness. In certain situations, the publishing of innovations without intellectual property protection is the best way to exploit inventions. That hinders other companies from claiming to have rights to intellectual property in certain specific area. Thus, important decision for a company is whether or not to publish or to protect by patent. In an R&D network, companies occupy different positions in the value network, with the result that their acuteness in protecting inventions can vary considerably. Also, each company has its own IPR policy to follow. The IPR policy creation requires trust and open communication in a network. [7, 8]

In accelerated technology development, creation of expectation value for the new technology attracts new players to join the technology development network. In development of new integrative technologies, creation of infrastructure or value network is also necessary in order to accelerate utilization of these technologies. An efficient way to increase interest in a new technology is strategic and well-timed knowledge communication.

Team Communication

Development of a new integrative technology requires open and interdisciplinary communication at many levels and connected with e.g. the common vision, strategy, operations. Communication at the personal level is also important. Seamless teamwork, interdisciplinary understanding, and open communication within the development team and throughout the technology network are needed. [1, 4, 6]

A major challenge for experts in a development team of an integrative technology is interdisciplinary thinking, especially in the early stages of the work, analytic modeling, and expert judgment and estimation. Relationships in such teams are even more symbiotic than in other types of cooperation. The system design process demands wide technological understanding, an unbiased attitude, and horizontal personal technological orientation. As integrative technologies become more common, there will be an increased need to educate interdisciplinary professionals. [1, 4, 6]

Domain experts must be capable of communicating their knowledge to decision makers in connection with the

launching and marketing of new technology. The risk of non- or misunderstanding is considerable due to differences in terminology and valuation of the technology's properties. Domain experts are by their education and experience more focused on technological characteristics, and decision makers have more horizontal technological orientation. Decision makers are more interested in business opportunities, the market's reactions and needed investments. There are often considerable time constrains. In the development of a new technology time is, indeed, money. Nevertheless, the parties have to have enough time to learn common language and build up a trustful ground for collaboration. Also, in industrial-academic collaboration or in an R&D network, there might be a situation when a domain expert is from different organization than a decision maker. In these situations, openness in communication earlier and trust between collaboration partners defines the end results of the negotiations. [1, 5, 7, 9]

Team communication could become a great risk also. Know-how and innovations are in people's minds and every person is categorizing information into proprietary and non-proprietary knowledge by themselves. It should be recognized that know-how is fun to talk about. Domain experts and business peoples want excel in their know-how and many times they are drawn into discussions of technological principles or business details. In an inter-company R&D network rules of the game for team communication should be defined very carefully in order to avoid a leakage of organization specific information. [10]

5. CONCLUSIONS

Technology integration is increasing due to fast informatization. This technological change is inevitable, because the performance of the present technologies is not good enough for future products. New technologies must be developed so that products fulfilling consumers' expectations also in the future can be designed and manufactured. In this study, an integrative technology is defined as a possibility of crossing the boundaries of existing business lines by exploiting existing and new technologies as well as the competences provided by new and old network parties. Integration is already being used for many parts of portable electronic devices. Technologies of this type have to be developed and produced within networks. The creation of a valuable R&D network requires the right attitude from the parties involved, respectful confrontation of other parties, excellent communication skills, and a strong will to work together.

The key focus of this paper is on interdisciplinary and cross-organizational communication during development work on a new integrative technology having portable electronic applications as its target. According to our findings the main communication challenges are related to language barriers, negations over the sharing of cost and profit, cross-organizational communication, and multidisciplinary working mode.

During research and development work on a new integrative technology, knowledge communication strategy is more challenging than in the case of established technologies. The timing for publishing a new technological invention is always a strategic decision for an R&D network. Also, IPR management decisions within a network could create tensions between parties due to differences in opinion on how to valuate an invention, and on whether an invention should be protected or not, or concerning the rules for utilization of the created IPR. Often a company's assessment of technology is colored by its own vision of the future and by its knowledge of the most active fields in technology.

The results of this research indicate that communication between the domain experts and decision makers is strategically important during the new technology development and commercialization. Unfortunately, technology commercialization is also a task in which the differences in the personal technological orientations of experts and managers increase communication challenges. Also, open communication in an R&D network enables intensified creation of a new value network along with technology development.

Utilization of integrative technology, i.e. new product creation process or system design approach requires seamless teamwork, interdisciplinary understanding, and open communication within the development team and throughout both the industrial-academic and new value networks. In addition, the system design process demands wide technological understanding, a common vision, and horizontal personal technological orientation from people involved in it.

As integrative technologies and modularization become more common, there will be an increased need to educate interdisciplinary professionals that are capable of communicating in multidisciplinary and cross-organizational network project environments. This will be a great challenge to the engineering education system. In fact, these new integrative technologies will create a need for multidisciplinary experts at many educational levels; all the way from floor-level operators up to top management. Industrial-academic collaborative R&D networks and projects are efficient educational environments for multidisciplinary experts.

Well-focused industrial-academic collaboration is a very efficient way to develop a new integrative technology. To accelerate commercialization of a new integrative technology it is necessary to develop simultaneously both an infrastructure and technological characteristics. The main result of this study is that successful communication

in an industrial-academic R&D network to develop a new integrative technology improves knowledge creation and accelerates commercialization of the technology.

ACKNOWLEDGMENT

The authors would like to thank the IIIS organization for the possibility to evolve the research paper in the conversational conference session at the KCC'06 Conference. Mansikkamäki would like to acknowledge Nokia Foundation for the support.

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