EVOLUTION OF A BOUNDARY OBJECT THROUGH EXPERIMENTAL LEARNING IN A NETWORKED ENVIRONMENT

Meri Jalonen[1]
Aalto University School of Science
Department of Industrial Engineering and Management, BIT Research Centre
P.O. Box 15500, Espoo, 00076 Aalto, Finland
e-mail: meri.jalonen@tkk.fi

To be presented at the International Conference on Organizational Learning, Knowledge and Capabilities (OLKC), 12-14 April 2011, Hull, United Kingdom

Abstract

The paper studies the evolution of a boundary object, a new product concept, through a product development process that included actors from different organisations. The case study presented in the paper concerns the emergence and development of a new product in a packaging company. The new package was developed by a product development team of the company in collaboration with a network of researchers, customers, and subcontractors. By analysing the interplay between the symbolic product concept and the material product, the study shows how the product under development is influenced by the participation of different actors in the process.

Keywords: Boundary objects, experimental learning, product development, networks

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[1] Meri Jalonen, Aalto University School of Science, BIT Research Centre, P.O. Box 15500, 00076 Aalto, Finland, telephone: +358 505258487, fax: +358 947023665, e-mail: meri.jalonen@tkk.fi,

1. INTRODUCTION

Studies on product development processes have shown that external partners can act as important sources of new knowledge when the object of development provides common ground for learning efforts (e.g. Lehenkari 2006). In the paper, we study a product development process starting from the creation of a new product concept until the co-development of commercial products with customers. We discuss this evolution as a networked learning process which gathered experts from different companies and research institutions. We analyze the phases of the development process by focusing on how the object of development work, the emerging innovative product, evolved during the process through the engagement of different participants. We discuss how the product functioned as a boundary object (Star & Griesemer 1989) for different actors in the development of the new product. The studied case demonstrates the significance of experimenting as source of learning about the product: an important part of the product development took place in trial runs on factory floor, in laboratory tests and on customers' production lines. This kind of experimenting provides knowledge on how the product behaves in different conditions, which can be used in further product development (Miettinen et al. 2008).

The paper is based on a case study of an innovation process in packaging industry. The innovation is a hybrid product, a package combined of two materials, paperboard and plastic, with a novel production method. The innovation results from using manufacturing technology that has been adapted from a different field of industry. This product and process innovation enables the manufacture of new kind of packages that fulfil the hygienic requirements of food industry. The new package was developed by a product development team in a packaging company in collaboration with a network of researchers, customers, and subcontractors. We analyze the evolution of the network that emerged during the product development process by focusing on the product concept as an evolving boundary object that was transformed in different phases of the development process.

Our case demonstrates how a new product is developed in a network of participants and how the interplay between a symbolic product concept and a material product enables learning during the process. We show how this learning was experimental by nature: the new combination of materials and manufacturing technologies demanded many rounds of testing in order to find the right combination that functioned in the whole production process. In the studied case, the product development essentially included building the production environment, as it became evident that the critical properties of the product could only be examined in real manufacturing conditions. That is, the product concept as a symbolic boundary object needed to be transformed into a material boundary object, a material product, in order to evaluate its potential to commercial success.

In the paper, we first discuss the role of boundary objects in new product development based on previous research. Thereafter we present the case study through the consecutive phases of the product development process and discuss the experimental work that enabled further development of the product concept and the production environment. Based on analysis of the role of boundary objects in the process we then discuss the implications of the study on research on product development and the role of objects in organisations.

2. BOUNDARY OBJECTS IN PRODUCT DEVELOPMENT

In organization studies, research in new product development (NPD) has focused on its role as a potential source of competitive advantage and sought models, processes, and practices for making effective and successful products (Brown & Eisenhardt 1995). These models include for example process models for NPD (e.g. Cooper 2008) and sets of practices for different kinds of NPD processes (Seidel 2007). One stream of research has focused on the practices related to the use of product concepts (e.g. Orihata & Watanabe 2000, Seidel 2007). *Product concepts* are representations of the goals for the development process, and they are seen important for successful NPD projects especially in cases of radical innovation. The product concept has been studied as a means to define the desired outcome of the development processes, e.g. definition of the features of the product and their translation into design specifications (Seidel 2007). Orihata and Watanabe (2000) have defined the primary functions of the product concept in the NPD process as (1) integrating the technologies inside the product, the product performance and user expectations, (2) bringing innovation initiative to drive the process, (3) translating the performance expectations of the product into technical requirements, and (4) giving definition to marketing strategies.

In NPD research, interest in product concepts has lied in studying their creation for successful product development projects. In these studies, the creation of product concepts has mainly been discussed within an organisation's product development team. However, recent research on innovations has observed that the locus of innovation has shifted from a single organisation to a network of actors who collaborate in different ways during the innovation process (Lehenkari 2000, 2006, Miettinen et al. 2008). Participation of actors with distinct professional and cultural backgrounds poses challenges for collaboration. Research shows that new objects and methods mean different things in different contexts, and therefore actors participating in the development process need to reconcile the different meanings in order to cooperate (Star & Griesemer 1989). In the case of product concepts, their creation in a network of participants requires negotiation over their features and meanings.

For their collaboration, interdisciplinary groups thus need objects that are both flexible enough so that each social world – a professional group or community – can give specific meaning to them and at the same time sufficiently robust to maintain common identity across groups (Star 1989). Star and Griesemer (1989) have named this kind of objects as *boundary objects*, as they "both inhabit several intersecting social worlds and satisfy the information requirements of each of them" (p. 393). These characteristics of boundary objects enable actors in different communities both to communicate about their work across the community boundaries and to gain autonomy to continue their work within the specialised domain. Therefore, the creation and management of boundary objects is a key process in developing and maintaining coherence across intersecting communities. When various participants create representations together as part of the collaboration, their different commitments and perceptions become visible and are resolved into representations through a negotiation process.

The role of boundary objects has been recognized in the NPD literature especially in relation to cross-boundary coordination and knowledge sharing (Zeiss & Groenewegen

2010). However, these studies emphasize the meaning of concrete, tangible artefacts such as design drawings and product prototypes (e.g. Bechky 2003, Carlile 2002, 2004) and neglect the symbolic and abstract forms and dimensions of boundary objects identified by Star and Griesemer (1989). In their study, Star and Griesemer identified the following four types of boundary objects noting that their classification is not exhaustive: repositories, ideal types, coincident boundaries, and standardised forms. None of these types correspond to material prototypes or end products, which Bechky (2003) discusses as boundary objects between product design and manufacturing personnel.

Ewenstein and Whyte (2009) have recognised this tendency of focusing on concrete, definite objects in recent literature on the role of boundary objects. They extend the typology of objects as part of knowledge practices in organisations by distinguishing between three kinds of objects. According to their classification, *boundary objects* are concrete objects that are able to mediate knowledge across a boundary. *Technical objects* represent another type of concrete objects: they are complete and unproblematic material artefacts. In contrast, the third type of objects, *epistemic objects*, is abstract and conceptual in nature. Epistemic objects are characterised by lack and incompleteness and they can be only partly expressed in material instantiations. Epistemic objects require concrete material artefacts through which they can be manipulated and evolved; they can also become technical objects once they are not changed through epistemic work any longer. According to Ewenstein and Whyte, an object can also be at the same time a boundary object and a technical object, or a boundary object and an epistemic object.

In our study, we are interested in the interplay between abstract and concrete objects, that is, the symbolic product concept and the material manufactured product. Our research follows development of a new product and formation of its production network during a NPD process. The process is studied as collaborative construction of an object, the new product and product concept, and formation of the production network (Miettinen et al. 2008). This development process required experimentation and testing, as the product and its manufacturing process were novel to the network participants, and the resulting learning was translated into the product concept and the design and production of new products.

3. RESEARCH SETTING AND METHOD

The paper is based on an ongoing single-case study of emergence and development of new product in packaging industry. This case study is part of an interdisciplinary research project called Learning Production Concepts. The project is carried out during 2009-2011 and it includes both research and development activities first in two case companies and later on in a learning network of different organisations.

The study is situated in packaging industry that is searching new business opportunities. The case study concerns the emergence and development of an innovation in a packaging company. The innovation is a hybrid product, a package combined of two materials, paperboard and plastic, with a novel production method. The innovation results from using manufacturing technology that has been adapted from a different field of industry. This product and process innovation enables the manufacture of new kind of packages that fulfil

the hygienic requirements of food industry. The package is marketed, developed and manufactured by a recently founded business unit in the case company.

The hybrid package combines features of different materials, fibre and polymers, without multiple layers such as existing packages made of paperboard and plastic. The package can be used for different kind of products in food industry for example: it can be heated in an oven or a microwave and can also be frozen. The package can be used for products that require preservation with packaging gas or must be protected from light. The hybrid package provides distinguishable packaging solutions to be customised according to customers' needs. The package is manufactured from paperboard blank and plastic rim in automated production environment. It is made in production equipment by using a tool that combines plastic with paperboard and forms the package into the required shape. The production process of the materials, tools and manufacturing equipment to produce the hybrid package is distributed in a production network of subcontractors that has formed during the product development process.

The case study is based on rich ethnographic data that has been collected in a longitudinal qualitative case study. The research process includes an action research approach: the phases of the study have been negotiated with company representatives and they have included interventions. Data collection in the case study has been done in two phases. The first phase comprises of the basic analysis of the activities of the case company and its production network. The second phase covers development activities in the case company, including both interventions and data collection. Table 1 describes the phases of data collection and the interventions during the process.

In the case company, we have studied the product development process by focusing on different customer projects of the business unit. The following of concrete projects on practice level enables studying the development of the product, the evolution of the associated network in each project, as well as learning that emerges in the development process (Miettinen et al. 2006). We have studied three customer projects: the first created commercial product and two of the following commercial projects.

The first phase of data collection, basic analysis, started when the first commercial product of the new business unit had just been launched. We started the data collection with two workshops to understand the product and its production in the network. In the workshops, we discussed the process of an ongoing customer project with central members of the business unit's development team. Thereafter, we studied the development process of the first commercial product by interviewing key participants of the process. Informants included development team members, product developers of the pilot customer, and central subcontractors of the materials, tools, and machinery. The interviews enabled us to study the evolution of the product concept and the development of the first package at the same time with the forming production network. In order to study work practices in the business unit and its production networked, we followed a beginning customer project from its start. This project was studied by observing central events of the project including development team's project meetings, their meetings with important subcontractors, and trial drives of the product. The phase of basic analysis ended with a workshop where the researchers and the development team members discussed the results and identified possible themes for development.

The second, developmental phase of the case study comprised of a series of workshop interventions with the development team. In the workshops, researchers and development team members discussed the evolution of the business unit's product concept and production concept based on collected data. The workshop discussions form part of the case study data but are used in this paper as background material.

Table 1. Data collection and intervention process of the case study.

Timetable	**Object of data collection**	**Viewpoint of data collection**	**Methods and participants of data collection**
October - December 2009	**Current project**	Illustrating the production as a network	*2 workshops* - Sales, product design, tool design, production (6 persons)
December 2009 - January 2010	**Past project (first commercial product)**	Portraying the network activities	*Interviews* *Development team of the case company*: - Sales, product design, tool design, production, management (8 persons) *Pilot customer:* - Package development (2 persons) *Production network of the pilot project:* - Printing houses, graphical design, tool manufacturer, production equipment manufacturer, automation equipment manufacturer (9 persons)
December 2009 - August 2010	**Beginning project**	Describing practices and knowledge production in the network	*Observation of key events of the project* - Kick-off meeting of the project - Tool design meeting with a subcontractor - Tool review meeting at the tool manufacturer - Trial runs and meetings - Production ramp-up *Interview* - Product designer
May 2010	**Projects as illustrators of the product and production concept**	Collaborative interpretation of the data, identification of development targets	*Intervention: Workshop* - Sales, product design, tool design, production, management (9 persons)
September 2010 – February 2011	**Development of the product and production concept**	Exploration of learning production concepts and development of supporting tools	*Interventions: 3 workshops* - Sales, product design, tool design, production (7 persons)

In the following, we discuss the product development process of the hybrid package in more detail. We describe the evolution of the product concept and the material product during the process. We also discuss the formation of the production network and the learning of its participants in the course of the process.

4. THE PRODUCT DEVELOPMENT PROCESS

The following process description is reconstructed mainly based on the participants' narratives. We have divided the process into three phases, (1) development of the product

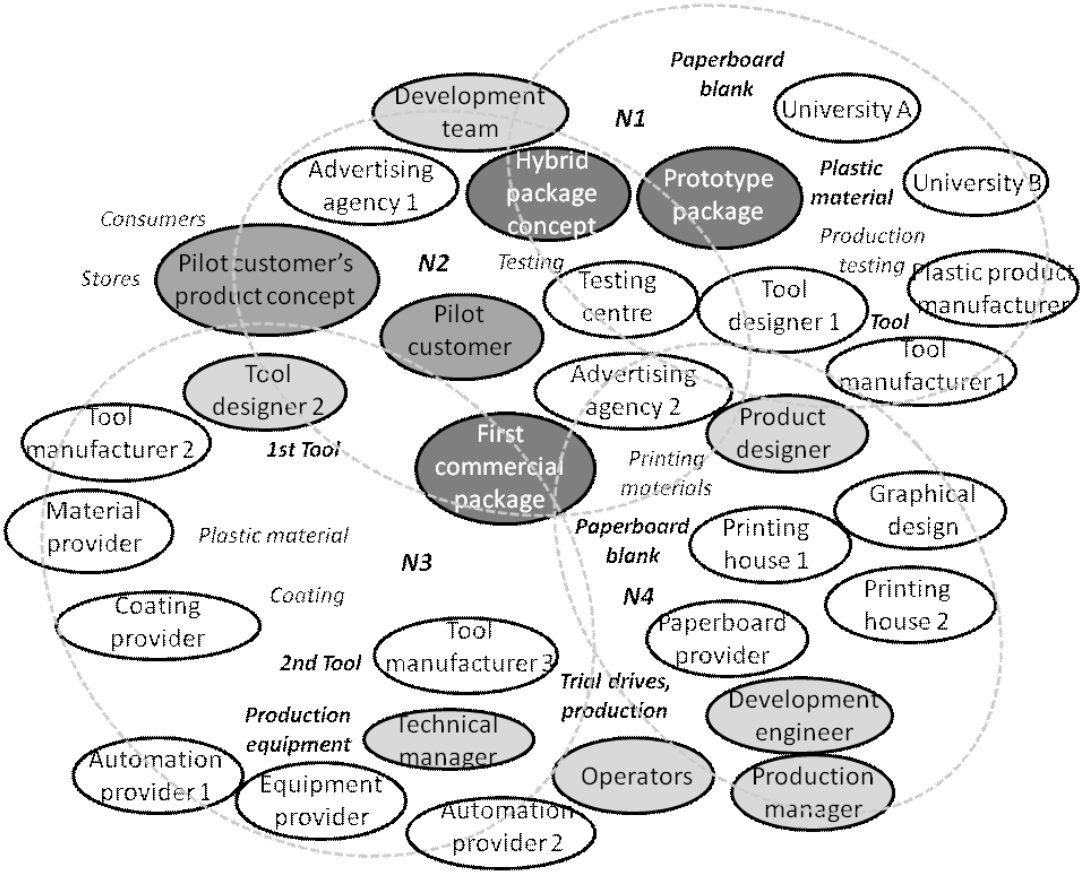
concept, (2) production of the first commercial product, and (3) continuing product development in customer projects. The first two phases are based on retrospective interviews of the participants after the project had ended, whereas the third phase is based on our observations and discussions with the participants during the projects.

4.1 Development of the Product Concept

Over the years, the case company has funded different product development projects to explore new uses for the materials it produces and to develop the functionalities of these materials. One central area of product development has been package development including studies on materials and new types of packages for different kinds of uses. The development of the innovative hybrid package, which is the focus of our study, has its roots in the preceding development projects, and it belongs to the ones that have successfully been commercialised. The development project for the hybrid package started in a R&D centre of the case company but at the time of the first commercial product launch, the project transferred to a business area of the company and became a new business unit.

The product concept for the hybrid package was developed in a three-year product development project (the R&D project), which was funded by the case company and by a national funding agency for technology development. The funding covered research and development principally in the case company and in two participating universities, but also other organisations participated in the development work in different phases of the process. Collaboration with the universities brought the case company knowledge about the properties and behaviour of plastics that could be used in the package, on the one hand, and expertise in product modelling and manufacturing technology, on the other. Another essential partner in the R&D project was a pilot customer from food industry that joined the project in its early phase. As the project proceeded, new areas of expertise were needed and sought both from within the case company's units and from external partners. Some of the partners had participated in the preceding product development projects of the case company, others were found during this R&D project. As a result, a network of partners became formed, where collaboration with certain partners was intensive at different times. The evolution of the network is depicted in Figure 1. In the course of the project, some of the experts who had been working in the partner organisations were recruited to the case company in order to maintain the knowledge achieved during the development work in the organisation. Thus the development team in the case company was formed from experts of different fields.

Figure 1. Formation of the production network during the product development process.



The aim of the R&D project was to develop a new kind of package for a growing business area in food packaging. Already from the beginning, one of the goals of the case company was to build a competitive production environment that enables the cost-efficient production of the new packages. That is, the R&D project focused both on developing a new product concept and on constructing an efficient production environment. The development work was organised in several subprojects, which studied for example the right materials for different uses of the package, possible designs of the package, manufacturing environment, and the testing procedures to ensure the quality requirements of the package. In Figure 1, the network of the initial phase of the R&D project is marked with *N1*. Development of the product concept concentrated on the study of possible uses of the new package and requirements imposed by such uses. Main focus was food industry, and therefore requirements concerning hygiene and tightness of the package were emphasized in the development of the package.

During the early phases of the R&D project, a prototype package was developed for testing purposes. This prototype was used for testing the materials and their behaviour for different uses in the case company. With this prototype package, it was possible to demonstrate the

product concept of the hybrid package to a potential customer. The customer got interested in the development of the hybrid package for two reasons; the material and its production properties. The product concept was introduced to them as a tight paperboard package that is precise in dimensions and enables packing products with packaging gas. Therefore the package can be worked with maximum speed on the customer's production lines. The paperboard material itself had interested the customer already for a longer time, as they saw it as potential packaging material. However, earlier paperboard packages had not fulfilled the food industry requirements.

When the pilot customer joined the R&D project, it started to test versions of the prototype package on its production lines for several products. At the same time, technical package development by the development team and the university partners continued. Different materials and their behaviour in different kinds of uses were studied, as well as modifications of the manufacturing technology. Testing centre of the case company was an important partner in the material tests throughout the process. Additionally, market studies about packaging preferences and requirements of potential customers were made. The development team also collaborated with an advertising agency to develop the product concept for different packaging uses.

Later on, the pilot customer decided that they will use the hybrid package for a new product that was under development. They told the case company about the size and the shape of this new package and its end use without revealing the product itself. This decision started a new phase in the R&D project – the hybrid package was going to be commercialised. The product concept was stabilised and the development focused on fulfilling the requirements defined by the pilot customer's needs. This meant that the development team had to build the production environment, as the production and launching schedules were agreed on with the pilot customer.

4.2 From Product Concept to Material Product

By the definition of the first commercial package, the R&D project proceeded to an intensive development and testing phase that concerned the production of the package. The new phase required new kinds of expertise in the material and tool production process as well as in building of the production environment. Therefore, the production network of the hybrid package expanded significantly in this production-oriented phase. This expansion is depicted in Figure 1 as three new networks: the customer-centred network is marked with *N2*, whereas the network of the tool production process is marked with *N3* and the network of the paperboard production process with *N4*.

Production of the first commercial package required that the paperboard material and the tool corresponded to the design of the package. The production processes of paperboard and the tool took place in parallel. The new tool was designed by a tool designer in the case company and manufactured in a company specialised in such tools. The development process of the paperboard blank involved a product designer, a development engineer and a production manager of the development team who worked with material providers and printing houses. An advertising agency used by the pilot customer made the graphical

design of the package. For the production environment, new equipment was required and this demanded collaboration with equipment providers.

After the tool had been delivered to the case company, a series of trial drives with the tool, the plastic material and the paperboard material began. Testing was done in larger scale than with the tool that had been used in manufacture of the prototype packages, and it revealed new problems. In order to solve these problems the development team sought new partners who were experts in their fields. Thereafter alternative solutions were tested through iterative trial drives. During the trial drives of the new package, samples of packages were sent to the pilot customer for testing and acceptance. The customer made own testing by packing the intended products in the sample packages. They tested the use of the packages in similar ways as consumers who would buy the products to see how the product and the package functioned and how the product was preserved in the package. Through the testing done by the customer and the testing centre of the case company, the development team received feedback about the functioning of the new package and was able to improve the package.

When the development and testing of the first commercial package had already continued for several iterative rounds, the pilot customer revealed the actual end product to be packed with the hybrid package. The end product belonged to a new brand which the customer had been developing – their new product concept. During this development process, they had tested alternative packages for their new products with consumers. As the hybrid package was preferred by the consumers, the pilot customer decided that it would be the new kind of package solution that had been looked for the brand. The product development by the customer had proceeded in parallel with the R&D project of the hybrid package, and when the customer decided to use the hybrid package for its new product, the two product concepts met. This turn of events focused the development process in both companies on the production of the material product.

When the timing of the launch was agreed on, the case company started preparations for the mass production phase while trial runs and testing of the package still continued. Later on, the pilot customer multiplied its volume forecast for the product, which meant that the case company needed to invest in a larger tool in order to comply with the delivery of packages in the agreed schedule. As a result, the development team was under a lot of pressure before the product launch, as the introduction of the package into mass production was demanding within the short time span. Despite the problems, the product was successfully introduced to the market according to the planned schedule.

4.3 Product Development in Customer Projects

Since the beginning of the R&D project of the hybrid package, the project had been part of the case company's R&D centre. Later on, when the launch of the first commercial product approached, the R&D project was transferred from the R&D centre to a business area of the case company. With this transfer, the development team became a business unit and therefore had to prove its commercial viability. This meant that they had to achieve new package projects from new customers and build capabilities for mass production at the same time as the product development continued.

After the first commercial product was launched, the product and process development continued but on a different basis. The development activities were now conducted in shorter customer projects that aimed at delivering a new product to the customer within a defined schedule. Collaboration with the pilot customer continued with the development of new packages for other products, but the team also started projects with new customers. These customers were from the food industry as well, but their products represented new uses for the hybrid package, thus bringing new requirements for the product design and manufacture. The new packages were challenging also because they were to replace existing packages with the hybrid package, which had to be adjusted to the customers' existing production lines. The new customers did not participate in package development as actively as the pilot customer had, and therefore the development team needed to find new ways of cooperation with their customers. Working with the new customers also taught the development team about their industry and the conditions under which they make decisions about introducing new packages.

In these new customer projects, development work continued but in different environment. The product concept that had been developed during the R&D project became tested by the new customer products. At the same time as the new products were designed and manufactured for certain customers, these products brought new issues to be solved. In this way, the new customer projects both expanded the understanding of the development team about the possibilities of the product concept, and specified certain limitations of it.

Similarly to the development of the first commercial product, these new customer projects proceeded through rounds of trial runs and testing both within the case company and on the customers' own production lines. As the new packages were developed for different uses than the first commercial package, the combination of materials needed to be studied further, which required additional testing. During this process, also new partners joined the production network and had to become familiar with the requirements that the package imposed on their work.

5. LEARNING ABOUT THE PRODUCT AND THE PRODUCTION ENVIRONMENT

During the different phases of the development process of the hybrid package, many external collaborators participated in the development work. The creation of the product concept and the material product itself were result from phases of experimenting and testing. The production of materials, tools and equipment required both the development team and their partners in the production network to develop new knowledge by getting experiences of the novel combination of plastic and paperboard. This can be considered as a collective learning process that was based on experimenting and testing to a large extent. Both the development team and their network partners characterised the R&D project as being about searching and testing. They described their learning about the product and its production requirements as "trial and error" learning. The significance of experimental learning originated in the parallel development of the product and its production environment, as described in the following.

Trial runs were the main means of defining the shape and the material of the package under development and its manufacturing parameters. As each new customer project brought new requirements that the hybrid package was to fulfil, the development demanded experimenting in the production process. Thus rounds of trial runs and testing were required in each package development project. During the consecutive trial runs and tests, correct measures of the developed package and proper parameters of the manufacturing equipment were found. Even after the trial runs, however, some changes were sometimes still needed, because for mass production of the packages the production was moved to different production equipment. The functioning and quality of the package needed to be assured also in the proper production environment.

Production of the hybrid package required learning from both the development team members in the case company and members of the production network. In the development team, members were experts in different fields such as product design, marketing, paperboard production, tool design, plastic properties, and manufacturing technology. In the production network, different parties had knowledge about tool manufacturing, paperboard manufacturing, equipment manufacturing, and automation design and manufacturing. None of the team members or production network parties had experience of how the novel combination of paperboard and plastic with the manufacturing equipment would behave and therefore they needed to experiment.

In the paperboard material design and production process, different parties of the network needed to learn about the behaviour of the material. One expert of paperboard processing characterized the learning process as several rounds of "rehearsing". Participants in the paperboard production network needed to make inquiries through their own contacts. During the development process of the first commercial package, many issues regarding the paperboard material and its processing were solved. However, new packages with different uses required continuing testing with paperboard.

In the tool design and production process, experimenting with the prototype tool and later with the first tool for the customer project brought important experiences that could be used in the mass production phase. Due to the novelty of the materials and the manufacturing technology, trial runs were still required in the following customer projects.

Also the pilot customer had to examine the behaviour of the package in its own production. The customer was testing the package in several ways during the development process, including runs on production lines. However, when testing proceeded to the real production environment, needs for further development of the package were discovered.

The development of products for both the pilot customer and the new customers taught the development team also about the product concept. Although the product concept and the production environment were already defined during the production of the first commercial package, the development team members thought that the product concept would never be ready. Both the product design and its manufacture are significantly influenced by the use of the package, which defines the material selection for each package. The team members expected that they would achieve new knowledge about the behaviour of materials and shapes during the production process with each new product and as this learning would accumulate, they would be able to develop new packages more efficiently with less testing

rounds. In the projects that followed the launch of the first commercial product, the earlier designs could already be used during the design phase of the package, so that the size and shape of the package could be made more accurate before the trial runs.

6. ANALYSIS AND DISCUSSION

We found our analysis of the development process on the notion that objects in organisations have a multidimensional character and can therefore take many roles (Ewenstein and Whyte 2009). We have treated the product concept and the product separately in the description of the development process of the hybrid package, but following this approach, we can discuss them as both one object and as separate objects. If we analyse the product concept of the hybrid package as an epistemic object, the material products – the prototype package, the first commercial package, and the following commercial packages – can be seen as instantiations representing and modifying the conceptual product concept. The product concept integrates the goals of the product development project with the technologies that are to realize these objectives in the end product (Orihata & Watanabe 2000, Seidel 2007). As this case study shows, however, the product concept is a dynamic conceptual representation of the product that can be interpreted in distinct ways by participants of the development process. The product concept thus acted as a boundary object for the participants.

In addition to its symbolic properties as an epistemic object, the product concept of the hybrid package obtained material properties during the development process. The development of the product concept began with ideas of a new kind of package made of a new material combination that could fulfil the requirements of an important market segment. These ideas were given form in the design phase of the prototype package, but the search for alternative forms for the product concept continued for longer. The result of product design, the model, was the first visual representation of the product concept. As an object it is both a technical object that can be worked with and a boundary object to which participants can assign different meanings. Based on the model, the development of the material product concept began. The material concept consists of four artefacts: the package, the paperboard part, the plastic part and the tool that makes the package by combining the paperboard and the plastic material in the production equipment. The ready product, the hybrid package for certain use, is a combination of the other three artefacts and at the same time, a material representation of the product concept. The product concept thus covers these material artefacts, and when the development of a new package begins, requirements concerning all of these objects need to be considered.

The evolution of the product concept is connected with the formation of the production network of the hybrid package through the development of the objects that represent the product concept. This can be seen in Figure 1. The development of the hybrid package concept started in the N1 network in order to develop the first prototype package. The product concept and the prototype functioned as boundary objects for the participants. The result of the collaboration, the prototype package, is a technical object that stabilised the product concept into one material representation. The product concept and the prototype package worked as boundary objects also between the development team and the pilot customer. The customer was able to compare the hybrid package with its own product

concept, the new brand. This collaboration formed the focal network N2 in Figure 1 that produced the first commercial package, which functioned both as a symbolic product concept and became a material object through the production process. The production of the artefacts formed their own networks: the N3 networked emerged during the production of the manufacturing tools and of the production equipment, and the N4 networked formed around the paperboard production. The networks got connected during the trial drives and the production phase, where the packages were made first for testing and later for the customer. As the production efforts required the development team to focus on building the production environment, the first commercial package actually stabilised the product concept of the hybrid package: it was only slightly modified by the following customer projects, as the customers represented the same industry.

Both the symbolic product concept and the material artefacts were modified in the development process through experimental learning. The product concept as an epistemic object was open and indeterminate enough to allow exploration of its possibilities during the process (Ewenstein & Whyte 2009, Knorr Cetina 2001). This exploration was done by experimenting and testing with the material artefacts in the production process. These artefacts functioned as objects of experimentations, technical objects, which allowed observation of behaviour and comparable measurements. Experiences from the experiments were then taken into account in the design and manufacture of these artefacts, and again tested in next experiments. This learning in the production network was then translated into the product concept as its possibilities and limitations could be defined more accurately.

We think that our work has implications for understanding the nature of product development work in organisations and the role of objects in networked environments. Our case shows how complex product development processes in organisations can be and how the product under development is influenced by the participation of different actors in the process. As an industrial product whose end users are consumers and not the customers of the developing company itself, the hybrid package is an example of a product whose success not only depends on the development team or actors in one organisation but on an extensive constellation of interconnected factors. In this development, the product concept had a significant role as an object to which the development team, the pilot customer and other partners in the production network could relate to. The case thus emphasises the many roles of objects within and across organisations: they allow for collaboration, experimentation, and motivation. As Ewenstein and Whyte (2009), we call for more empirical studies on the role of different kinds of objects in organisational practices. We think that the notion of objects should be understood more broadly, considering also abstract and conceptual objects in addition to concrete ones. In further studies, it would be fruitful to discuss also possible differences between objects, representations and artefacts by drawing on insights from other traditions such as activity theory (e.g. Engeström 1987, Miettinen et al. 2008).

ACKNOWLEDGEMENTS

The author would like to thank the personnel of the case company and its partners for their participation in the research project. This research is supported by the Finnish Funding Agency for Technology and Innovation and the Academy of Finland.

REFERENCES

Bechky, B.A. (2003), 'Sharing meaning across occupational communities: The transformation of understanding on a production floor', *Organization Science*, vol. 14 no. 3, pp. 312-330.

Brown, S.I. and Eisenhardt K.M. (1995), 'Product development: Past research, present findings, and future directions', *Academy of Management Review*, vol. 20, no. 2, pp. 343-378.

Carlile, P.R. (2002), 'A Pragmatic View of Knowledge and Boundaries: Boundary Objects in New Product Development', *Organization Science,* vol. 13no. 4, pp. 442-455.

Carlile, P.R. (2004), 'Transferring, translating and transforming: An integrative framework for managing knowledge across boundaries', *Organization Science*, vol. 15 no. 5, pp. 555-568.

Cooper, R.G. (2008), 'The Stage-Gate Idea-to-Launch Process–Update, What's New and NexGen Systems', *Journal of Product Innovation Management,* vol. 25 no. 3, pp. 213-232.

Engeström, Y. (1987), *Learning by expanding: An activity-theoretical approach to developmental research*, Orienta-Konsultit, Helsinki.

Ewenstein, B. and Whyte, J. (2009), 'Knowledge practices in design: The role of visual representations as 'epistemic objects', *Organization Studies*, vol. 30 no. 1, pp. 7-30.

Knorr Cetina, K. (2001), 'Objectual practice', in T.R. Schatzki, K. Knorr Cetina and E. von Savigny (eds), *The practice turn in contemporary theory*, Routledge, London, pp. 175-188.

Lehenkari, J. (2000), 'Studying innovation trajectories and networks: The case of Benecol margarine', Science Studies, vol. 13 no. 1, pp. 50-67.

Lehenkari, J. (2006), *The networks of learning in technological innovation: The emergence of collaboration across fields of expertise*, Academic Dissertation, Department of Education, University of Helsinki.

Miettinen, R., Lehenkari, J. and Tuunainen, J. (2008), Learning and network collaboration in product development: How things work for human use, *Management Learning*, vol. 39 no. 2, pp. 203-219.

Miettinen, R., Toikka, K., Tuunainen, J., Lehenkari, J. and Freeman, S. (2006), *Social capital and trust in innovation networks* (In Finnish: Sosiaalinen pääoma ja luottamus innovaatioverkostoissa), Research reports 9, Center for Activity Theory and Developmental Work Research, University of Helsinki, University Print, Helsinki.

Orihata, M. and Watanabe, C. (2000), 'The interaction between product concept and institutional inducement: a new driver of product innovation', *Technovation*, vol. 20, pp. 11-23.

Seidel, V.P. (2007), 'Concept shifting and the radical product development process', *Journal of Product Innovation Management*, vol. 24, pp. 522-533.

Star. S.L. (1989), 'The structure of ill-structured problems: boundary objects and heterogeneous problem solving' in L. Gasser and M. Huhns (eds), *Distributed artificial intelligence*, Pitman, London, pp. 2-37.

Star, S.L. and Griesemer, J.R. (1989), 'Institutional ecology, 'translations' and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39', *Social Studies of Science*, vol. 19 no. 3, pp. 387-420.

Zeiss, R. and Groenewegen, P. (2010), 'Engaging boundary objects in OMS and STS? Exploring the subtleties of layered engagement', *Organization*, vol. 16 no. 1, pp. 81-100.