'Knowledge flows and innovative capacity: the case of the Netherlands'

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The innovative capacity of firms, which is considered as an essential element of the national competitiveness is challenged when faced with technological and market changes. Disruptive technologies often represent major hurdles for an established industry. Alfred Chandler demonstrates that, under circumstances of technological discontinuity, the position of leading firms can be jeopardized.[2] In the literature, we find several explanations for the difficulties involved in adopting radically new product or process innovations.

First of all, especially during a period of rapid technological change, it is very hard to anticipate the direction it will take. A period in which new technologies are still evolving is full of technical and commercial uncertainty. Mary Tripsas, in her study of the typesetting industry, describes the decision by the director of Monotype, a leading manufacturer of hot-metal phototypesetters, not to invest in the digital CRT phototypesetter, because he was not convinced of the superiority of the new generation of typesetting machines.[3] Another reason not to invest in a new technology may be its poor profit potential. According to Braun and Macdonald, in the early 1950s the profitability of the tube market dissuaded tube companies from investing in transistor technology.[4] Therefore, perceptions and expectations play an important role in guiding strategic decisions.[5]

Moreover, to meet radical technological and market changes the acquisition of new capabilities and adjustment of existing ones are critical. As Nonaka concluded 'the potential to innovate of a business would depend on its capacity to create new knowledge, spread it through the organization, and incorporate it in new products, services, and processes.’[6] We have to realize, however, that the expression 'to create new knowledge' not only includes investments in in-house research, but all the knowledge seeking and acquiring activities. Innovation is considered, as formulated by Jorde & Teece ‘as a incremental and cumulative activity that involves building on what went before, whether it is inside the organization or outside the organization, and whether the knowledge is proprietary or in the public domain’. Innovative firms interact with other organizations in an institutional setting to gain, develop and exchange various kinds of knowledge and information and other resources.[7] One of the most extended studies on the major success factors for innovations in the chemicals and scientific instruments sectors, the project SAPPHO of the 1970s pointed at the importance of internal relations within firms, external collaboration with users and with external sources of technical knowledge. Since then these main results have been also confirmed by studies in other industries. A recent study on the search strategy of U.K. manufacturing firms strongly suggests that 'the lack of openness of firms to their external environment may reflect an organizational myopia': managers overemphasize internal sources and underestimate the value of external sources.[8]

Without prospects, however, the desire to search for and adopt knowledge will be minimal. Hamel calls this the receptivity or 'intent to learn'.[9] Without receptivity the function of inter-firm relations to get access to external knowledge will be minimal. However, an accurate valuation of the knowledge sources becomes even more difficult when the state of technology is in flux. And especially, under conditions of rapid and uncertain technical change, beliefs and

promises about the future play an important role. Nascent technologies still have to prove their technological attainability, economic viability and social acceptation.[10] As Lipartito illustrates in his article on the picture phone 'Technology on the wide track confront actors with too many choices, too many options, and an uncertain future. With such ambiguity and uncertainty, technology cannot be shaped by rational knowledge and a clear distillation of experience alone. [] Users and producers base their choices on what they think might happen, or how they feel about images of technology not yet brought to closure.'[11]
This brings us back to the importance of beliefs and promises or more generally of expectations, for innovative behavior. Expectations play a crucial role in the exploration of (technological) options. Van Lente distinguishes three nested levels of expectations. First, expectations about (future) artefacts, processes and materials, which are problem-oriented and guide search processes. Second, expectations about the general direction of a new field, and about opportunities the field offers. An example of this second kind of expectations are ideas about the future market dominance. Finally, expectations about societal forces and trends and technology as a whole, which are broader and more general are important. The current consensus that environmental problems can be fatal can be labeled as such an expectation.[12] While expectations determine the search for and transfer of knowledge, information and knowledge flows also play an important role in the actual formation of expectations. For the sake of simplicity we don't want to make a distinction between the three forms of expectations in this paper.

The importance of accumulation and exchange of knowledge for the two important requirements for innovative capacity – expectation formation and capability development - supports the focus of this paper, viz. the flow of knowledge and information.

The capabilities needed are not only technological or related to research, development, and production; organizational and market capabilities are also important. Familiarity with the customer base is critical. As Clayton Christensen demonstrates in outlining “the innovator’s dilemma,” leading firms often fail to detect new markets created by technological innovation and thus do not initiate relationships with new customers. Existing customers are systematically favored at the expense of potential future purchasers.[13] Firms sometimes find it difficult to switch to new market concepts.[14]
Not surprisingly, different capabilities also need different kind of knowledge. In line with the work of Gibbons, Johnston and Faulkner show how important various kind of scientific and technological knowledge is for capability development.[15] While, for example, chemical knowledge can be sufficient to come to a new product, manufacturing it may need new mechanical knowledge. Moreover, innovations, especially when they are radical, can require changes in the organization, market innovations or commercial approach, for which other kind of knowledge is acquired.[16] Most literature concerning knowledge pays attention to the distinction between explicit and tacit knowledge. While explicit knowledge is highly codified,

tacit knowledge is, as pointed out by Polanyi in the 1950s, the knowledge which exceeds what can be expressed verbally. Most studies illustrate that the transferability of tacit knowledge is much more difficult than that of codified knowledge and demands considerable effort.[17] Also important is the distinction between more general and more specific knowledge, which is closely related to codified versus tacit knowledge. Often, but not always, general knowledge is codified in character and specific knowledge incorporated in instruments, machines or people.

Universities and research institutes have always been important sources of scientific knowledge, although the importance can differ in time. Homburg illustrates in his inaugural lecture how before World War II especially through contacts with university professors the direction was from universities to industry, while this changed after the War.[18] However, we are not only interested in these sources but pay special attention to knowledge transfer between companies, suppliers, clients, and (competing) firms in the same sector. When we talk about suppliers we should include material-, components-, instrument and machine suppliers.

This forms the background of the questions for the case studies in this paper:
-How important were knowledge flows for the formation of expectations?
-How important was the transfer of knowledge for capability development?
-What were the important knowledge sources?
-What kind of knowledge was important?

This paper

In the remainder of this paper we pay attention to the importance of knowledge flows for particular innovation processes at three Dutch companies. The electronic multinational Philips, a medium-sized canning factory Hero and a small printing company Budde are studied. A lot of studies have stressed the importance of external information for small companies without own R&D facilities. Parsons and Rose, for example, illustrated how personal networks contributed to the innovative capacity of small entrepreneurs in the British outdoor trade.[19] However, various studies have shown that external knowledge and information were just as important for large firms as well as for those who had their own R&D infrastructure. Moreover, Cohen and Levinthal suggested that a firm's knowledge sourcing activities is closely related to its internal knowledge building. We therefore focus on a company with its own R&D (Philips), on Hero, which parent company had a research laboratory, and on the small printing company Budde, which had no research facilities.

The innovations take place in a variety of sectors and in various periods. All three companies were confronted with major challenges. The economic depression in the 1930s necessitated Hero to come with a new product at short notice, which led to the introduced of the apple drink 'Perl'. In the early 1950s the Philips company had to acquire the capacity to make transistors, which formed a thread for the existing tube market. In the 1980s the printing industry was confronted with new developments in automation of composing equipment. Especially for a small company the large investments made the decision when to start with the new equipment even more difficult.

The introduction of Perl at Hero and the importance of cross-border knowledge flows (1930s)

For the introduction of the apple drink 'Perl' by the Dutch fruit and vegetable canning company N.V. Hero Conserven Breda (Hero Canning Breda Ltd.) information and knowledge from various foreign sources was important. Next to companies and institutes from Switzerland also firms from other branches were crucial to make the switch to this new product innovation.

Hero, established in 1914 had its roots in an export trading company in vegetables and fruit. Its director A.G.T. Jansen had contact with the Swiss canned fruit company Lenzburg, which directors Henckell and Roth proposed to establish a factory in the Netherlands and financed it. Jansen's son Reinier became the first director. Although the factory in Breda could make its own decisions, the ties with the Swiss 'mother factory' were quite strong. The Swiss heavily invested and the majority of the board of commissioners was Swiss.[20] The factory, which due to WWI had only started early 1920s grew considerably at the end of the decade to around 500 employees and 600 seasonal workers.

Early 1930s the deteriorating economic situation was also noticeable in the Dutch canning industry. Hero too was confronted with decreasing exports and profits.[21] To overcome the crisis Hero decided to introduce a radical new product.

At that time production of 'Sweet most' (zoete most): a non-alcoholic fruit- and vegetable juice made off e.g. apples, grapes or tomatoes was well on stream outside the Netherlands. Via the branch magazines information about producing 'sweet most' (= filtered and sterilized fruit or vegetable juice) came available.

Another reason for Hero to consider the introduction of this new product was the request from the horticulture branch in general and in particular from a large company in this sector. The decreasing economic situation led the market-gardeners to the search for new fields for fruit processing. The Westland Association, representing the market-gardeners who suffered from by the decreasing export of fruit, especially grapes to England, tried to promote the producing and drinking of fruit juices. It used its influence with the Dutch government who approached – amongst others – Hero to consider to process glasshouse grapes, for which there was not market at that moment. [22] In 1931 when the profit from grapes decreased substantially Hero was also approached by the market garderner New Honsel with the request to start producing 'sweet must' out of grapes. New Honsel, situated in a Dutch horticultural region between Rotterdam and The Hague (The Westland), was one of the countries biggest producers of grapes and (to a smaller extend) tomatoes.[23]

Hero was also strengthened in the opinion that investing in 'sweet most' would be a good option, because next to the Association of the market-gardeners this idea was also embraced by actors in the national agricultural knowledge infrastructure. Partly as a result of government's interest, Prof. Sprenger started in 1932 extended research on wine- and juice production in his horticulture laboratory in Wageningen. Part of his work was promoting ‘sweet most’ in popular publications and in radio-talks.[24] Except by Government subsidies, Sprenger’s work was financially supported by different interest groups and firms. Amongst them where several horticultural auction companies, agricultural associations, a reclamation company, two societies for the abolishment of alcoholic drinks, as well as companies in the liquor business. Sprenger’s laboratory was also supported by a company for which drinks (alcoholic or non-alcoholic) weren't the core-business; the fruit processing company De Betuwe.[25] De Betuwe was one of Hero's three major competitors and also wanted to expand into fruit juices.[26] De Betuwe had close contacts with a whole network of nutritionists via its laboratory, established in 1928. De Betuwe cooperated closely with Sprenger and for producing fruit juices the research done at Sprenger's laboratory was of prime importance.[27]

In contrast to De Betuwe, Hero did not subsidize Sprengers' work and did not rely on the Dutch agricultural research network for its innovative activities. Although Hero had considered to make a fruit juice of grapes, as New Honsel had asked for, it decided to develop 'sweet most' from apple. In March 1932 the board of directors of Hero made the decision to start producing a sparkling apple-drink. In about one year time Hero was able to build a production line and in February 1933 the company launched ‘Perl’. To make it a marketable product at relative short notice Hero's existing knowledge base had not been sufficient and acquiring knowledge proved to be essential.

Although in the Netherlands information about the production in foreign factories of 'Sweet most' was available through branch magazines, this information was not very specific and not sufficient for actual production. Filtering and sterilization of the pulp and juice were crucial factors, which had to gave the drink a good taste and made it not perishable.

For Hero its relationship with its Swiss ‘mother’ company in Lenzburg proved to be essential to get access to the available knowledge of the production process in a relative short time. The mother company in Switserland not only had its own chemical laboratory it also had contacts with producers of fruit juices. The Swiss company Jules Schlör A.G., established in 1888 as a brewery had developed a method for producing non-alcoholic appel juice in the 1920s and produced this on an industrial scale. The Hero factory in Lenzburg was located near the Schlör A.G. in Menziken and its director Gustav Henckell knew Schlör’s apple drink and was enthousiastic about it.

In the spring of 1932 Hero signed a licence agreement with the family firm Schlör. This official relationship implied that Schlör was obliged to share its knowledge about and experience with the production of non-alcoholic apple-, grape and other fruit juices with Hero in exchange for compensation and part of the profit.[28] The signing of an agreement was attractive because of several reasons. While the research in Wageningen had just been started and was accompanied with financial problems, the Schlör process had already proved itself. This could give Hero a head start compared to The Betuwe. Speed was also necessary because outside the Netherlands competition was well on stream. Moreover, via the licence agreement the knowledge and experience was exclusive, whereas the knowledge developed in Wageningen would be accessible for other competitors.[29] Jansen, also preferred the Schlör process to the more common Seitz process, on which the Wageningen laboratory elaborated. He considered the result of the former as tastier, better perishable and therefore commercially more interesting.

Well aware of the tacit elements in production knowledge Hero insisted on recording the various ways of knowledge transfer, including exchange of personnel. Convinced of the importance of personal presence Jansen fortunately received the right to visit the Schlör company frequently and to gather knowledge about the production process. The director Schlör himself had to instruct Jansen or one of his sons in the factory in Menzingen from July 1st 1932. Moreover, when Hero would start the production Schlör personally or one of his sons had to be in the factory in Breda to '*persönlich mitzuarbeiten*.' By guaranteeing the involvement of experienced persons Jansen tried to minimize the risk of starting with this unknown production process.[30] Visiting the factory and personnel assistance from the licensing party, however, was a common practice in licensing.

The fact that Lenzburg had a laboratory and contacts with other sweet most producing companies proved to be important when the first samples in Breda were not optimal and Schlör was not very active in solving the problem. The Lenzburg laboratory investigated the possible causes of the troubled juice and Meyer, the chemist of the laboratory went to the Mosterei Müller for advise. Mosterei Müller was a company which also produced 'sweet must' using the Schlör process. Subsequently, its director Müller brought Meyer in connection with Widmer, who advised Müller when he had production problems. Widmer was director of the chemical department of the Swiss experimental station for fruit and wine in Wädenswill. In sum, via its Swiss mother company and Mosterei Müller, Hero got access to other valuable sources of knowledge.[31]

Although the Swiss contacts were most important for Hero to acquire the necessary knowledge for producing fruit juices, it did not neglect the developments in the Dutch innovation network. Also the laboratory in Switzerland made use of the information from the laboratory of Sprenger in Wageningen. In the spring of 1932, for example, Jansen informed Lenzburg about the the sugar- and acid level in grapes.[32] Heckell on the other hand convinced Jansen that he should be careful and keep the Schlör process secret from the competition.[33]

An important aspect in the knowledge acquiring activities of Hero was that it realised in an early phase of the project that next to the process of making 'sweet must', also other capabilities were essential. Bottling, for instance had never been important for the canning company. To get access to this new field Hero searched for new contacts outside its usual ones and got in contact with the beverage industry. In April 1932 Jansen visited the neighbouring beer factory 'De drie hoefijzers' (The three horseshoes) to investigate the production line. Although he judged the 'bottle washing machine' suitable and ordered a comparable one, he found the machines for bottling and labelling (also coming from the company Holstein and Kappert) not suitable. These machines came from Sümak (Süddeutsche Maschinen- & Metallwarenfabrik) in Stuttgart and were also used by Schlör. In fact Schlör acted as a mediator between Breda and the machinery supplier and got a financial compensation for this role.[34]

The total costs of the new factory and inventory were more than 400.000 guilders, of which almost 250.000 were for machines and equipment.[35] Apart from financial investments also investments in the training of the personnel was necessary, which was not without problems.[36] Contacts in the beverage industry also proved to be important as a source for new personnel. In February 1933 the majority of the management wanted to appoint an expert from the brewery branch as technical manager to assist the manager of the Perl-production plant.[37]

The decision to produce fruit juices meant that Hero had to enter an unknown market. To get an idea of the market opportunities Jansen not only relied on its own market research, but also got access to market knowledge via its Swiss mother company. When New Honsel had approached Hero to consider producing juice, champagne or wine from their grapes Jansen initially thought non-alcoholic grape juice would be successful because he knew that the Dutch drank relatively a large amount of orange juice.[38] Furthermore Jansen did some explorative research that convinced him that there was a demand for this product in the Netherlands.[39] How he got the information on the market expectations of orange juice or what this explorative research implied, is unknown, but a fact is that Jansen was always very active in gathering market information. When in 1931 Jansen heard that the sales of Hero products decreased he wrote to Henckel '*in den letzten 8 Tage viel im Lande herumgereist, um denselbe soviel wie möglich wieder zu beleben.*'[40]

About the chances of tomato juice, which was also considered as a new Hero product in the beginning of 1932, he also tried to gather as much information on the market as possible. Jansen discussed this topic with the Swiss mother company. Based on articles and reports they read, combined with tests done in their laboratory Lenzburg judged that the market possibilities for tomato juice were bright. Especially in the United States there was already a market for the product. On the other hand, the Lenzburg company doubted the quality of the Dutch tomato's as the raw material for a successful tomato juice. Jansen himself admitted that he was only informed about tomato juices by articles and promised to make a visit to England for some samples of tomato juice that were produced there. But Jansen considered the market potentials for grape and tomato juices too uncertain. Moreover, the need to be quick on the market with a new drink which had already proved itself on the Swiss market as well as the quality of Schlör's apple drink, contributed to the decision to make an 'proven' apple drink first.[41]

Although Henckel and Jansen were convinced of the quality of their apple juice - e.g. Henckell wrote to Jansen that '*Schlör Apfelperl weitens das am besten schmeckendes alcoholfreie Apfelgetränk ist.*' -, they left nothing to chance and started an intensive promotion campaign on Perl. Hero brought its new product under the attention of potential customers during events, such as the ‘nutrition and hygiene’ fair which was held in Amsterdam from 21 to 30 April 1933. Also an advertisement campaign was started in various daily and sportpapers ‘[to] introduce Hero Perl as the new national drink.’[42] Hero was one of the first companies that realized the importance of advertisements and used this to reach its future customers. For the advertisement campaign Hero made use of the skills of a certain Herr Roth, who as a kind of company artist was attached to the Lenzburg firm and designed much of the promotion material.

Also for distribution purposes Hero got in contact with the beverage industry, because the existing network of food retailers was not appropriate for the distribution of Perl. Hero realised that it had to make use of the distribution channels of the beverage industry. This industry was aware of the possibilities of Hero and in the summer of 1932 the brewery Heineken approached Hero to explore the possibilities for cooperation. Hero, however, misjudged the eagerness of Heineken, who was in fact only interested when they could jointly produce Perl. Heineken withdrew and Hero had to look for other distribution channels. In the end of February 1933 Hero signed an agreement with an Amsterdam firm called Bronnenbelang for sales in the large cities and the West of the Netherlands.[43] The rest of the Netherlands was served by local sales men. Part of them also represented Heineken, who were advised by Heineken’s management to do this. Although not directly the contacts with Heineken had been useful for the distribution of Perl.[44] The production, promotion and sales of Perl proved to be very successful. In 1933 4.2 million bottle’s were sold (around 1,7 million litres).[45]

Perl formed a successful innovation for Hero. Hero was well aware of the market possibilities in the Netherlands of a fruit juice. Hero was strengthened in its opinion that it would be a profitable innovation (directly as a result of the requests of the horticulture sector and indirectly by the attention paid by the government and the agricultural innovation network). Hero decided to introduce a sparkling apple juice, but realized that it did not have sufficient knowledge to produce, bottle and distribute a new product. To keep ahead of the competition, Hero realised that market introduction should be as soon as possible and a 'proven product' would be better than searching for its own production process. Access to general as well as specific knowledge became available by its Swiss mother company, directly as well as indirectly. The beverage industry proved to be an important source for more specific knowledge and information. Lenzburg pointed Hero at the Schlör product and it kept Breda informed about developments in the ‘sweet must’ industry in Switzerland and abroad, while to get sufficient knowledge about how to bottle and market the apple juice Hero got in contact with firms in a for Hero new branch, the beverage industry. Hero successfully made use of its own and Lenzburgs' expertise and experience in marketing.[46]

International knowledge flows for Philips' innovative activities in transistors (1950s)

Despite Philips' Research and Development capabilities knowledge from American electronic companies proved to be essential for the production of transistors. Without these capabilities, however, establishing these contacts would have been impossible.

In June 1948 in the Physical Review announced that at the Bell laboratory of AT&T Shockley, Bardeen and Brattain had encountered the amplifying effect by experimenting with a germanium crystal with two contacts close to each other, the so-called point-contact transistor. And soon Western Electric (the production part of A&T) started production. At the end of the 1940s it became clear that transistors would supplant valves in electronics.[47] As is illustrated by the economist Tilton the adoption of American knowledge in the field of semiconductors was essential for European electronic companies.[48] This was also true for Philips, established in 1891 as a light bulb factory and diversified in electron tubes and radio sets in the 1920s.

The Philips Natuurkundig Laboratorium (Philips Physics Laboratory) usually abbreviated to Natlab was established in 1914. In the 1920s and 1930s it had become an industrial laboratory with an excellent academic climate. A good library, frequent seminars with sometimes well-known foreign speakers, the possibility of regular visits to foreign research centres and good contacts with universities contributed to a lively exchange of knowledge. Natlab researchers frequently attended conferences and published in scientific journals. Although the Natlab had an academic climate, its first director Holst found it important that the research would be fruitful for Philips. He stimulated this awareness by encouraging his laboratory staff to submit ideas for patents, to publish in the Philips Technical Review established for circulating research outcomes within Philips, and to maintain contacts with other parts of the company.[49] In the first decades of the 20th century the Natlab had built a solid reputation. Its prestige as a research institute with talented researchers and state-of-the-art knowledge had contributed to the exchange of technical-scientific knowledge with other electronic companies through cross-licensing.

During the 1930s the Natlab had started to explore research into the chemical and physical properties of solid state materials. This new research line was important for the developments in the field of transistors in various ways. First, its contacts with AT&T (the American Telephone and Telegraph Co, later known as Bell) at the end of the 1940s were the result of Philips' research on magnetic materials. Research on non-metallic magnetic materials used for permanent magnets and kernels in electromagnets, so-called ferrites led to a new process and material. This so called Ferroxcube could successfully be used for loudspeakers and telephone cables. It led to a good patent position for Philips and contributed to the further improvement of the reputation of the Natlab researchers.[50]

The new research focus of the Natlab also contributed more directly to the development of semiconductors, because next to magnetic materials also semiconductor materials came on the research agenda. A special group for research on semiconductors was established, under supervision of dr. W.Ch. van Geel. Ample attention was paid to the chemical and physical problems related to the development of rectifiers, made of selenium and copper oxide. This resulted in several articles. Attempts to develop a solid state amplifier at the end of the 1930s and a field-effect transistor in the 1940s were not successful, however. With hindsight its significance had been lying in building research capabilities in the field of solid state materials.[51] The only exception before WWII was the research on selenium diodes. This led to the hesitant start of production within the group Electronic Tubes, which was able to build up some experience in the field of semiconductor diodes. The necessary improvement of quality, hampered during occupation, was realised in 1947.[52]

Next to the setting up of research and production capabilities it was of prime importance to keep informed about the latest developments in especially the United States. While during World War II at Philips as in most European electronic companies developments were slowed down, postponed or stopped, important progress was made in American companies. The research into radar technology led to a focus on crystals and the use of germanium and silicon. Triggered by this news and informed by reports and articles available after the War, the chemical group of the Natlab did some experiments with silicon rectifiers. This research on other crystals did not lead to success, however.[53]

In addition to reading articles and attending conferences, visits to American companies were essential to remain informed about the state-of-the-art. These visits were simplified by the good international reputation of Natlab researchers. After the war several visits were made to the United States. Among one of the first visitors was E. Verweij, who was one of the successors of Holst after the war.[54] The chemist Verweij became responsible for chemical research at the Natlab. After his journey he reported that several companies he had visited produced germanium rectifiers. He also brought a few grams of germanium with him. He stressed that germanium had wonderful prospects and research should focus on this semiconductor material. Philips should produce germanium diodes instead of selenium diodes as soon as possible. Soon the Natlab was able to develop germanium diodes, which were transferred to the development laboratory of product division Electronic Tubes. The expertise on selenium diodes facilitated the production of germanium diodes and in 1950 the first Philips germanium diodes appeared on the market, on which Philips was already active. Moreover, part of its diodes were purchased by its own apparatus department.[55]

At the end of the 1940s the Natlab as well as the product division Electron Tubes were aware that that transistors would become of prime importance in the electronic industry.[56] The various departments agreed that Philips' semiconductor expertise was lagging behind those of its American competitors. The production experience was minimal.[57] The backlog of Philips' R&D and production capacities, however, did not immediately become visible.

After Bell's announcement in the Physical Review Philips made some organizational adjustments. Within the Natlab a special transistor group was established next to the vacuum tubes group, to speed up research in this field to make up arrears.[58] The group semiconductors in the field 'materials', under supervision of Haaijman was enlarged and started to focus their research mainly on germanium.[59] For the transistor group under supervision of F.H. Stieltjes a young graduate from Delft was hired, L.J. Tummers, who later became head of the semi conductor research group and also professor in transistor technology in the 1960s.[60]

The growing importance of the semiconductor devices also had consequences for the product division Electronic Tubes. In 1951 the product division that since 1950 had produced the germanium diodes, established a year later a subdivision dedicated to the fabrication semiconductors under supervision of J. van der Spek. The initial skepticism in the product division Electronic Tubes, expressed by the technical director had made room for more optimistic expectations not only by Hazeu but also among the staff members of this subdivision. They were very optimistic and only saw advantages of the transistor; lower energy use, smaller dimensions, longer life, greater efficiency, no buzz, mechanically strong, high amplification with low frequencies and no heating up time. At that time, they overestimated the advantages of the transistors, especially the early ones, which proved to be less durable and less resistant. [61]

The investments in research and production capacity paid off. Based on external knowledge via scientific articles Philips made its first steps in the transistor world. Tummers was the first at the Natlab who made transistors which resulted in a patent submitted together with P.J.W. Jochems in Germany. The relevance of this and other submitted patents, however, was minimal. The importance of the articles from Bell and RCA for the internal knowledge acquisition is illustrated by the literature list accompanying the patent application. In the beginning of 1952 the Natlab was able to hand over the point-contact transistor to the development laboratory of the product division Electronic Tubes.[62] A year later a factory dedicated to the fabrication of semiconductors (falling under the subdivision semiconductors) was established in Nijmegen. Here were made the point-contract transistors, the OC 50 and 51. The total number produced was limited to 10.000 a year. [63]

Although Western Electric (the production part of A&T) started production soon, making reliable point-contact transistors with equal qualities proved to be very difficult. Moreover, the point contacts were fragile and the point-contact transistor was sensitive to external influences. In 1949 Shockley presented the idea of the layer transistor; a sandwich of emitter, base, and collector integrated in one crystal. It was called the junction transistor. Shockley published the theoretical foundation ‘The Theory of P-N Junctions in Semiconductors and P-N Junction Transistors’ in the *Bell System Technical Journal* and in his book *Electrons and Holes in Semiconductors* which appeared a year later. To produce junction transistors, however, proved to be difficult until the Bell researchers Sparks and Teal developed the grown junction transistor by using the so-called ‘double doping’ technique, in which impurities were added in two stages to the semiconductor material. Due to its complexity this technique was not very useful for mass production.[64]

At the beginning of 1952 the development laboratory had some semiconductor expertise and about ten academics were working at the Natlab on various aspects of the transistor. But although this, in combination with the available scientific documentation, had been sufficient to come to producible point-contact transistors, it soon became obvious that a gap in physical chemical knowledge prevented Philips to produce the layer transistor on its own. As Haaijman from the Natlab recalled “We continued bravely and we had transistor action but it was of little importance, those guys at Bell were much better."[65] Codified knowledge from published sources was not sufficient to come to producible layer transistors.[66] The idea that without external assistance this was not possible, while layer transistors were expected to supersede the point-contact transistor was shared by the product division Electronic Tubes. The possibility to get access to the knowledge of Bell by participating in the Bell Symposium, was therefore more than welcome.

Scientists and engineers could get access to the knowledge of Bell labs not only through publications but also during visits of the Bell labs and at the transistor technology symposia held in 1951 and 1952. AT&T disclosed its knowledge of transistors to avoid the accusation that it was hoarding knowledge. The latter could harm the running antitrust suit and because the armed services wanted that the knowledge became available for their contractors. Moreover, at AT&T they assumed that because of the far-reaching consequences of the new technology it would be impossible to develop all the technical developments in house. As the vice-director of the Bell labs, Jack Morton recalled, "It was to our interest to spread it around. If you cast your bread on the water, sometimes it comes back angel food cake". Finally also the understanding that secrecy was difficult to maintain, a liberal license policy was preferred.[67]

The first two symposia were held in 1951. The first was attended by the military field and civil servants, at the second later that year representatives of the government, universities and industrial firms were welcomed. The subjects discussed during these conferences were transistor properties and possible applications. No background on manufacturing processes was given. After several requests this item was put on the agenda of the 1952 symposium. After the issuing of Shockley's patent on the junction transistor in September 1951, the rights to manufacture transistors were licensed for a $25,000 fee. This group of licensees received an invitation for the Transistor Technology Symposium held in April 1952. Participants came from twenty-six US companies, among which General Electric, Texas Instruments and fourteen foreign companies. Philips was one of these foreign licensees.

Although it was beyond question that Bell had an essential position in semiconductor technology there were some doubts as to whether all the relevant knowledge was available at Bell. The development laboratory of the product division Electronic Tubes, for example, showed its concern. Nevertheless, everyone agreed that to make up arrears acquiring as much knowledge as possible was necessary and the contract was signed.[68] The Philips delegation to the Bell Symposium consisted of three Natlab researchers (Stieltjes, Haaijman and J.S. van Wieringen) and J.C. van Vessem, director of the development laboratory of the product division Electronic Tubes. This guaranteed that the knowledge was not only concentrated in the central research laboratory.[69]

The symposium gave Philips access to the necessary information, although using it also required having strong internal capabilities. The lectures and demonstrations during the symposium gave insight into the manufacturing techniques and their theoretical background. The proceedings of the symposium which 'stood for years as the most comprehensive description of the state of transistor manufacturing art' became known as "Mother Bell's Cookbook".[70] Because of its military importance this information was classified 'confidential' and was only freely accessible for Philips employees who had attended the symposium.

Everyone realized that attending the symposium would not be enough to be able to use the information. "We have to push on our R&D to build up sufficient knowledge necessary for the adoption of Bell information".[71] And after the Philips delegation returned from the US still a lot of work was needed before delivery of layer transistors would become possible. Most part of 1952 was devoted to acquire the necessary capabilities to develop the layer transistor using the double-doping technique and at the end of 1952 the Natlab came with about 100 samples of pnp-transistors.[72]

After the first transistors were handed over to the development laboratory of the product division various measures were taken to strengthen the capabilities of the product division Electronic Tubes in the field of semiconductors and especially transistors. To name a few: people were transferred to or hired for the transistor group and the application group had to start paying attention to the transistor. For an adequate development of knowledge in the field of semiconductors it had been important that Van Vessem, the director of the development laboratory had also attended the Bell Symposium and was informed about the processes developed in the Bell laboratory. And while the Natlab focused on developing pnp-transistors using the double-doping technique from Bell, Van Vessem preferred to give attention to other processes. The orientation of the management of the subdivision transistors and the researchers of the development laboratory was mainly aimed at coming to a transistor producible in large quantities.[73]

Already in an earlier phase doubts were expressed as to whether the contract with Western Electric could provide all the necessary transistor knowledge. Moreover, the application of Western transistors was mainly concentrated on telephone systems. Research and development in the field of radio was done at RCA and the strong current applications were the expertise of GE, both important fields for Philips.

The researchers at RCA labs being aware that the junction transistors would be very promising for the future, but that the grown junction method was not appropriate for producing transistors in large quantities, had put a lot of effort in developing other techniques.[74] Around the same period as General Electric RCA developed the alloying technique, using pellets of indium which were heated and formed an alloy with the germanium. This so-called alloy junction transistor had better switching capacities. Choi illustrates in his forthcoming article on the Making of transistors at RCA, that 'manufacturing considerations had a high priority in the RCA transistor R&D program.'[75] Therefore it was no surprise that Van Vessem hoped to get access to the developments at RCA. Due to the anti-trust policy, however, Philips had difficulties in continuing its pre-War exclusive licence agreement with RCA. Although negotiations were held to sign a new contract with RCA, the caution not to offend Bell hampered these. According to Verbong negotiations were also hampered by RCA's refusal to sign Philips' standard contract for ferroxcubes. The symposium held by RCA to offer its licensees 'all basic information to make germanium junction and point-contact transistors on a pilot production basis' could therefore not be attended by Philips representatives.[76] The development lab had to wait until the information was officially published and in 1954 the factory in Nijmegen started to produce junction transistors using the alloy process. Despite this delay; Philips was number one in the European transistor market around 1955.

Information and knowledge for the introduction of computer aided composing machinery at the printing company Budde (1980s-1990s)

The introduction of computer aided composing machinery in the printing process had far reaching consequences for the graphic industry. Especially for the many medium and small companies. The introduction of composing techniques at a small printing office, called Budde illustrates how important information and knowledge from different sources was for the firms' innovative strategy. Co-operation and intermediary actors played a decisive role in the transfer of knowledge and information.

Budde was a small family firm, founded in 1947 in Utrecht by Sijbe Budde. A staff of around 10 people in 1980 were responsible for the production of familial print, leaflets, brochures, books, theses of the Utrecht University and multi-lingual brochures for the Open University (Open Universiteit (OU)). In the 1980s general management was in the hands of Jan Koudijs, son in law of the founder. The knowledge and information searching activities of Koudijs were important factors in the strategy formation.

The publicly available sources of knowledge proved to be important to come to changes in its printing process. These were in part provided by branch organisations. Branch magazines as *Compress*, *Grafisch Nederland*, *Repro & Druk, Graficus* and others served as a platform for the wholesalers, trade organisations and other stakeholders and gave ample information for the graphic industry. In articles, general developments were discussed in terms of opportunities and dangers, meetings of the different panels and the various trade fairs were covered. Announcements by dealers, coverage of the trade fairs and a sporadic interview with a printer or typesetting shop, showed new applications of technology.

Attending trade fairs was a more personal way to keep oneself informed. Producers showed their latest products and were approachable for getting background information. Sometimes experts gave lectures on the latest and future developments on symposia and business meetings organised during these trade fairs. Trade fairs functioned not only as a centre of knowledge exchange, but also to form interesting relationships, as is also illustrated by Parsons and Rose in the case of the British outdoor industry.[77] Most important were the international fairs *Print* in Chicago and *Drupa* in Düsseldorf. For Koudijs the fairs were less important for relationbuilding but contributed to Koudijs' knowledge about the new and future developments in printing.

At the end of the 1970s Koudijs realised that the company should make the changeover from leaden typesetting to photo typesetting. Linotype, one of the largest producers of photo typesetting machines, launched a computer-aided photo typesetting machine aimed at small firms, the Linotype CRTronic or 'Babytronic'. In 1980 Koudijs visited, together with some printer friends the *Print* trade show in Chicago, to see this 'Babytronic'. Although impressed by the technical features, Koudijs decided not to purchase the Babytronic. He discovered that it could not produce foreign characters and accents (frequently used in for instance Spanish and Scandinavian languages) essential for the multi-lingual brochures for the Open University. Moreover, Koudijs found the investment costs too high. And even though it became clear at the trade fair that computer-aided photo typesetting and composing would be the future, he bought the latest conventional Compugraphic Editwriter, which he used until 1990. Koudijs also realised that closely monitoring the new developments in computer technology would be essential to keep in business.

Its contacts in a broad branch oriented network have been important to acquire the necessary business information and knowledge. Koudijs had always been very active outside the firm boundaries. He participated as a local representative in the branch organisation The Royal Dutch Association for the Printing and Allied Industries (Koninklijke Vereniging van Grafische Ondernemingen (KVGO)) and also became board member. His participation in the 'cost committee' of the KVGO that executed time and motion studies and cost calculations on printing equipment for the associated firms, made him familiar with cost calculation and the latest technological developments in the printing industry and their cost-benefit. Due to his participation in the 'cost committee' Koudijs was in 1984 invited to joint 'Club Twelve', a collaboration of twelve small graphic firms up to 40 employees, mostly printers. These printers who new each other through the Dutch Association of Copiers and Small Offset Printers (Nederlandse Bond van Copieerders en Klein-offsetdrukkers (NBCK)) had founded Club Twelve in 1969. They met twice a month to discuss cost calculations, company results, new technologies, future developments, and other firm related issues. Also external experts were invited to give advise concerning new process innovations to printing firms.

Club Twelve had also an important bridge function for knowledge and information flows from and to the printing equipment industry. It was used as a user group to provide the printing machine dealers and suppliers with relevant market information, while in the meantime they were informed about their latest development by the supply side. In 1986, for example, the members were invited by Henk Gianotten the market manager of Tetterode to visit the Linotype plants in Frankfurt Germany. Tetterode was the largest wholesale business in graphic equipment. In the meeting, where also a representative of the American Adobe company was present, the possibilities of an integrated setup of Linotype composing machinery with an Apple Macintosh computer was discussed with the Club Twelve members. This connection had become possible with the use of Adobes development of the PostScript page description language, a software interface that described the composition for output equipment. The generated PostScript file was fed into a Raster Image Processor a single suited computer system that translated the PostScript instructions into a bitmap describing the whole page. This bitmap was processed by the phototypesetter that produced films.[78] Overwhelmed by this new setup the Club Twelve members subsequently cancelled all recent orders for other computer-aided typesetting and composing machineries. One of the members, the typesetting shop Reproka in Amersfoort bought the new set up including a linotype composing equipment, while its experiences were shared in the Club Twelve meetings. Due to its membership of Club Twelve Budde got access to specific knowledge about the actual implementation of a new process innovation, without taking any risks.

For more specific information and knowledge contact with suppliers proved to be important. For example, when the new methods were applied within the company. The wholesaler Tetterode functioned not only as a bridge to get access to the new technical development, but also to those responsible for training and education. To get access to the information and knowledge about the Apple computer, Gianotten put Club Twelve in touch with MacVonk. MacVonk, a former printer who was one of the first to use Apple computers had become an Apple and software dealer in the second half of the 1980s and also organised courses for printing firms. In 1989 he demonstrated the Macintosh-2 computers in combination with a 19" Sony Triniton Screen. On Reproka's advice Jan Koudijs took a course at MacVonk '*to check out what I am up to buy. First a course, than a purchase.*' After the course Koudijs purchased a Apple Machintosh-2 system, with an extra disk drive for 500 sorts of type, a floppy cracker, a laser printer, and a 19" screen at a total cost of about € 27.000-36.000 ($ 22.000-30.000).[79] In 1990 the equipment was installed. Two female employees went to MacVonk for training how to use DTP software. The first products at Budde for the new setup were black and white productions. In nine months time production went smoothly.[80]

Remarkable is the 'division of labour' in Budde's essential branch network, Club Twelve. The cooperation in Club Twelve gave Budde the opportunity to invest solely in the Apple computer equipment while it used the type setting equipment of Reproka. Until Budde invested in 1993 in phototypesetting equipment, Reproka transferred the computer file sent by Budde into a print on photo paper or film by a Raster Image Processor and Linotype phototypesetting machinery. Its branch related contacts had made it possible for Budde to remain informed of the latest developments and in the meantime to switch gradually to a new printing process. The interfirm relations were more important for access to experiences and knowledge which contributed to the timing of introducing a new printing process, than for the transfer of specific knowledge necessary to introduce a new printing process. Most of this knowledge came from wholesalers and suppliers. Cooperation in this self-regulating sector, gave Budde the opportunity not only to keep informed about the latest technological developments, but also to keep risks as small as possible. As a consequence Budde was able to choose the most appropriate time to start with new computer aided equipment.

Recapitulation

Threatened by the economic depression in the 1930s Hero decided to launch a new product. The Dutch horticulture branch and agricultural knowledge infrastructure provided the company with general information; their focus on fruit juices contributed to the Hero's idea that this would be a future market. The request of the Dutch government and New Honsel strengthened this even more. Hero was well aware of the market possibilities in the Netherlands of a sprinkling apple juice, but realized that it did not have sufficient knowledge to produce, bottle and distribute a new product. The articles on filtering and distillation were too general and more specific information was needed. To keep ahead of the competition, Hero realized that market introduction should be as soon as possible and a 'proven product', which already had proven itself on the market, would be better than searching for its own production process. Access to general as well as specific knowledge became available by its Swiss mother company directly as well as indirectly. Lenzburg pointed Hero at the Schlör product and it kept Breda informed about developments in the 'sweet most' industry in Switzerland and abroad. Due to the license contract with Schlör – in which the personal transfer of more tacit knowledge was included – Hero was able to deliver Perl. To solve production problems, however, the contacts of Lenzburg with other Swiss knowledge sources was essential to solve production problems. Firms in the beverage industry proved to be an important source for more specific knowledge and information. They provided information how to bottle and market the apple juice. Finally, Hero successfully made use of its own expertise and experience in marketing.

The development of the transistor at Philips shows that to get access to knowledge of the American Electronic companies was important, while knowledge on solid state physics was not available in the Dutch knowledge infrastructure. More general knowledge about the latest developments reached Philips through reports, scientific journals, scientific conferences, and company visits. This general knowledge convinced Philips that it had to go into the solid state physics and into the production of transistors as soon as possible. Philips knowledge base and the enlargement of Philips' internal R&D capacity especially dedicated to transistor technology after the announcement of the transistor effect proved to be effective for the production of point-contact transistors based on the general knowledge from periodicals. Philips' chemical-physical expertise, however, proved to be insufficient to come to producible layer transistors. The possibility to attend Bells' transistor symposium in 1952 to learn the double-doping technique and access to RCA's documents for the alloy junction process were indispensable. The limited self-confidence of Philips just after the War, related to the meagre successes in solid state physics, contributed to the early focus and active and broad search for external knowledge in this field. Philips was more than eager to learn from external sources. Important was that at the end of the 1940s and beginning of the 1950s everyone at Philips was convinced of the future relevance of semiconductors for the electronic industry. While begin 1950s market expectations and the preference for the layer transistor were shared, no consensus existed on the best production method between the Natlab and the product division Electronic Tubes. Not only Bell with the doping technique but also RCA with its alloying technique was seen as an important knowledge source. This resulted in an open attitude to search for the most relevant knowledge among a broad range of companies. But early access to RCA's knowledge was hampered by fear to disturb the relationship with Western Electric and American anti-trust policy.

Co-operation in the self-regulating printing sector gave Budde's director Koudijs, who took most strategic decisions the opportunity to keep informed about the latest technological developments. Reading branch magazines and visits – often with colleague printers – to trade fairs offered Koudijs a general overview of new process technology. Through personal exchange of knowledge between the branch members Koudijs was kept up to date. For knowledge about the financial and organizational consequences of investments in new equipment, such as investments costs, financial risks, competitive position, training of employees and maintenance, reports from and participation in the branch organization KVGO and consultations with colleagues in Club Twelve were indispensable.

Also the supply side was very important, especially for the technological information. Wholesalers and equipment dealers could give access to general knowledge but also offered specific process information to printing companies. They demonstrated new equipment and occasionally gave the opportunity to visit the machine producers. Wholesaler also provided and mediated in training courses for managers and personnel to facilitate printers the switch to computer technologies. Technical assistance and service was given when needed.

The customers demand and ideas about product development was gained in close co-operation with the existing customers. The requirements of the Open University contributed to the decision not to buy one of the first computer-aided photo composing machines. This strategy was possible, because Koudijs' branch contacts offered insights in experiences of other printing companies who already worked with computer aided composing equipment. As a consequence Budde was able to choose the most appropriate time to start with this new technology and to start with it gradually; first only in the Apple computer and a few years later also in the photo composing equipment.

Concluding remarks

All three case studies confirm studies which conclude that to meet radical technological and market changes the formation of expectations and the development of capabilities – in research, development, and production, as well as organization and marketing – are critical. Transfer of knowledge from outside the companies' boundaries contributed to adjustment of the firm's knowledge and expertise base. It also became clear that knowledge flows were important for the development of expectations about future possibilities. These expectations sometimes also guided the knowledge searching process. Important is that all three firms were well aware of their lack of capabilities and knowledge and were open to search for and learn from knowledge outside their firm boundaries.

The cases also illustrate that the knowledge source and kind of acquired knowledge were closely related, with regard to its level of specificity, tacitness as well as the content (technical or market related). Moreover, he importance of the various knowledge sources and the acquired knowledge not only differed between the various cases, but was also not the same for the various phases of the innovation process. This is clearly illustrated by Hero, for which foreign knowledge flows via its parent company were important for the product development, while for production and distribution the beverage industry was indispensable.

Another observation is that for expectation formation other kind of knowledge and knowledge sources were important than for capability development and adjustment. Important in this respect is the distinction between more general and more specific knowledge, which is closely related to codified versus tacit knowledge. General knowledge[81] was most important for expectation formation. It came not only from reading periodicals, attending trade fairs and visiting other companies. Also branch organizations were an important source. Knowledge for capability development was – not surprisingly - most of the time more specific in character. Codified knowledge – mostly in the form of license contracts - from competitors was essential for Philips and Hero to come to product development. While personal contacts and flow of knowledge was necessary for Hero to get access to the tacit elements of the process, Philips R&D and production capabilities in solid state physics eventually were strong enough for internal development. We have to realize, however, that a sharp demarcation between sources who offer general well as more specific information cannot be made. Especially in the case of Budde; most of the time the contacts in the branch and suppliers offered both.

Because next to self-knowledge and internal knowledge building, external knowledge flows are important for firms' innovative capacity, investments in knowledge at a broad range of sources is useful also from a innovation policy perspective.

Endnotes

[1] The case-studies of this paper are soon published in 'Knowledge circulation in innovation networks in the 20th century. Its importance for innovations in small and large companies in the Netherlands', Mary Rose & Paloma Fernandez Perez eds., *Innovation and Networks in Entrepreneurship*, Routledge (forthcoming).

[2] He also mentions aggressive foreign competition. Alfred D. Chandler Jr., "The Competitive Performance of U.S. Industrial Enterprises since the Second World War," *Business History Review* 69 (Spring 1994): 1–72.

[3] Mary Tripsas, "Surviving Radical Technological Change through Dynamic Capability: Evidence form the Typesetter Industry," *Industrial and Corporate Change* 6 (1997): 341–77.

[4] Braun and MacDonald, *Revolution in Miniature*; See also Clayton M. Christensen and J. L. Bower, "Customer Power, Strategic Investment, and the Failure of Leading Firms," *Strategic Management Journal* 17 (1996): 197–218; Donald N. Sull, "The Dynamics of Standing Still: Firestone Tire & Rubber and the Radial Revolution," *Business History Review* 73 (Autumn 1999): 430–64.

Basset, however, points out that large, vertically integrated companies, such as AT&T, 'could put money into research without being concerned about the near-term payback.'

Ross Knox Bassett, *To the Digital Age: Research Labs, Start-up Companies, and the Rise of MOS Technology* (Baltimore, 2002), 278. He compares this with Fairchild Semiconductors which had a more short-term horizon. See for Fairchild and Silicon Valley Christophe Lécuyer, *Making Silicon Valley: Innovation and the Growth of High Tech, 1930–1970* (Cambridge, Mass., 2006).

[5] Henry W. Chesbrough, "Environmental Influences upon Firm Entry into New Sub-markets: Evidence from the Worldwide Hard Disk Drive Industry Conditionally," *Research Policy* 32 (Apr. 2003): 659–78; Harro van Lente, *Promising Technology: The Dynamics of Expectations in Technological Developments* (Delft, 1993).

[6] I. Nonaka & H. Takeuchi, *The Knowledge-Creating Company* (Oxford 1995) Oxford University Press, 3.
[7] T.M. Jorde and D.J. Teece, 'Innovation and cooperation: implication for competition and antitrust', *Journal of Economic Perspectives*, 4/3 (1990) 75-96.
[8] Lauresen, K. & Salter, A. (2006). Open for Innovation: The Role of Opennes in Explaining Innovation Performance among U.K. Manufacturing Firms. *Strategic Management Journal*. 27, 131-150.
[9] G. Hamel, 'Competition for Competence and Inter-partner Learning Within International Strategic Alliances', *Strategic Management Journal* 12 (1991) 83-103.
[10] Schot, TIN19, 1995.
[11] Lipartito, K. (January 2003). Picturephone an the Information Age: The Social Meaning of Failure. *Technology and Culture*. 44 (1) 50-81.
[12] Van Lente, H. (1993). *Promising Technology. The Dynamics of Expectations in Technological Developments*. Delft: Eburon.
[13] Clayton Christensen, *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail* (Boston, 1997); See also Christensen and Bower, "Customer Power," 197–218 and Clayton Christensen, "The Rigid Disk Drive Industry, 1956–90: A History of Commercial and Technological Turbulence," *Business History Review* 67 (Winter 1993): 531–88.
[14] Polaroid, for example, had the capability to produce new digital photo cameras but refused to give up the idea that only the combination of a low camera price and expensive film could be profitable.
Tripsas, "Surviving Radical Technological Change."
[15] Wendy Faulkner & Jacqueline Senker with Léa Velho, *KnowledgeFrontiers. Public Sector Research and Industrial Innovation in Biotechnology, Engineering Ceramics, and Parallel Computing* (Oxford 1995).
[16] Roy Rothwell, 'Successful industrial innovation: critical factors for the 1990s', *R&D Management* 22 (1992) 3, 221-239, 223.
[17] I. Nonaka & H. Takeuchi, *The Knowledge-Creating Company* (Oxford 1995); M. Polanyi, *Personal knowledge – towards a post-critical philosophy* (Chicago 1956); NOG AANVULLEN
[18] Idem, 24-28.
[19] M.C. Parsons and M.B. Rose, 'Communicaties of knowledge: entreprenuership, innovation and networks in the British outdoor trade, 1960-1990', *Business History*, 46/4, October 2004, 609-39
[20] P. Zwaal, *Hero Nederland in beeld. Een bedrijfshistorisch profiel 1914-1994* (Breda 1994).
[21] During this crisis the many small and few bigger fruit- and vegetable canning companies tried to survive in different ways. Some lowered their prices and tried to make price agreements or searched for other forms of co-operation.
[22] J. Bieleman, Geschiedenis van de landbouw in Nederland 1500-1950 (Meppel/Amsterdam 1992), 352-353; NA, Archief Directie van de Landbouw, afd. Tuinbouw, inv. no. 14, Brief van de Bond Westland aan D.S. Huiziinga, Inspecteur van het Landbouwonderwijs, hoofd van den binnenlandschen landbouwvoorlichtingsdienst, d.d. 28-6-1932', in: NA, Archief Directie van de Landbouw, afd. Tuinbouw; 'Memorandum entitled "Hero-Breda" (no date)', in: *BHIC, Hero Company Archives*, no. 189.
[23] GA 's-Gravenhage, inv. no. 1, Notulen van de aandeelhoudersvergadering, d.d. 11-5-1932'.
[24] [A.M. Sprenger], 'Report of the work done on wine- and juice production in 1933, Wageningen 16 Februari 1934', in: *National Archives, Archives of the Direction of Agriculture, departement of Horticulture,* no. 1.
[25] [A.M. Sprenger], 'Report of the work done on wine- and juice production in 1933'
[26] The other two were: Tieleman en Dros and N.V. v/h J. Hoogenstraaten en Co.'s conservenfabrieken, both in Leiden; 'Brief van Hero Breda aan de Conservenfabrik Lenzburg, d.d. 14-7-1931', in: *Brabants Historisch Informatie Centrum (BHIC), Hero company archives*, no. 6.
[27] RAN-B, Archief Hero, inv. no. 6, Brief van Hero aan de Conservenfabrik Lenzburg, d.d. 14 juli 1931; J. Faber, *Kennisverwerving in de Nederlandse industrie 1870-1970* (Amsterdam 2001) 130-133.
[28] RAN-B, Archief Hero, inv.no. 189, (Ontwerp-)verdrag tussen Schlör en Hero, z.d. (maart 1932).
[29] Faber, *Kennisverwerving, 109-110.*

[30] RAN-B, Archief Hero, inv.no. 189, (Ontwerp-)verdrag tussen Schlör en Hero, z.d. (maart 1932).
[31] RAN-B, Archief Hero, inv. no. 151, Brief aan Conservenfabrik Lenzburg, d.d. 21-11-1932'; inv.nr. 189, 'Een door G. Meyer uitgetypte versie van een telefoongesprek tussen hem en J. Schlör, d.d. 28 nov. 1932' & 'Kopie van een brief van W. Holenstein van het filiaal Frauenfeld van de Conservenfabrik Lenzburg, waarschijnlijk aan de directie van de Conservenfabriek Lenzburg, d.d. 28-11-1932'.
[31] 'Een door G. Meyer uitgetypte
[32] RAN-B, Archief Hero, inv.nr. 161, Brief van de directie van Hero aan de directie Conservenfabrik Lenzburg, d.d. 7 mei 1932.
[33] RAN-B, Archief Hero, inv.no. 151, Brief van Henckell aan Jansen, d.d. 18-07-1932.
[34] RAN-B., Archief NV Hero, inv. no. 161, Brief van de directie van Hero aan de directie Conservenfabrik Lenzburg, d.d. 22 april 1932; inv.nr. 189; Brief van Sümak aan Hero, d.d. 20-10-1932 & Kopie van een brief van Gustav Zeiler (betrokken bij de opstelling van de productielijn voor 'perl' in Breda) aan zijn vader, d.d. 24-10-1932.
[35] RAN-B., Archief NV Hero, inv. no. 31, Notulen van de Bestuursraad van Hero, d.d. 22 en 23 febr. 1933.
[36] 'Kopie van een brief van Gustav Zeiler (betrokken bij de opstelling van de productielijn voor 'perl' in Breda) aan zijn vader, d.d. 24-10-1932', in: *RAN-B., Archief NV Hero*, inv. no. 189.
[37] RAN-B., Archief NV Hero, inv. no. 31, Notulen van de Bestuursraad van Hero, d.d. 22 en 23 febr. 1933.
[38] RAN-B., Archief NV Hero, inv. no. 6, Brief van de directie van Hero aan de directie van de Conservenfabrik Lenzburg, d.d. 13-1-1932'.
[39] RAN-B., Archief NV Hero, inv. no. 189, Brief van Hero aan de directie Conservenfabrik Lenzburg, d.d. 01-041932; inv.no. 151, Brief van Henckell aan Jansen, d.d. 18-07-1932.
[40] RAN-B., Archief NV Hero, inv. no. 6., Brief van de directie van Hero aan de directie Conservenfabrik Lenzburg, d.d. 13-11-1931.
[41] Later on Hero made several other fruit and vegetable drinks. In 1938 for example the company started producing tomato juice.
[42] P. Zwaal, *Frisdranken in Nederland. Een twintigste eeuwse produktgeschiedenis* (Rotterdam 1993) 71.
[43] Bronnenbelang was obliged to purchase a substantial amount of bottles at once (40.000) for 9 cents a piece, which were sold for 12,5 cents to hotels, restaurants and shops and for 11 to middlemen.
[44] RAN-B, Archief NV Hero, inv. no. 31, Notulen van de Raad van Bestuur van Hero, d.d. 22/23-2-1933.
[45] P. Zwaal, *Frisdranken in Nederland. Een twintigste eeuwse produktgeschiedenis* (Rotterdam 1993) 71.
[46] The contacts with the supply side changed during the innovation process. As Hero decided to make its first drink out of apples (early 1932) the grapes and tomato producers from South-West Holland - those who approached Hero with the idea to produce fruit juices in the first place - got out of sight. Fruit growers, in the middle and south of the country (Gelderland and Limburg) and Belgium took their place. A network Hero was familiar with because of the production of applesauce.
[47] M. Riordan & L. Hoddeson, *Crystal Fire: The Birth of the Information Age*, New York: W.W. Norton, 1997, pp. 177-8, 181-3; W. Shockley, 'The Theory of P-N Junctions in Semiconductors and P-N Junction Transistors', *Bell System Technical Journal* 28, 1949, 435-89; W. Shockley, *Electrons and Holes in Semiconductors*, New York: Van Nostrand, 1950. The double-doping technique as described by Riordan en Hoddeson: 'Starting with a melt of N-type germanium, they first doped it with a gallium pill to grow a P-type layer on a N-type chrystal. About ten seconds later, they added a second pill containing 100 micrograms of antimony, a fifth-column element located under arsenic in the periodic table. A donor element supplying excess electrons to the crystal lattice, the antimony more than compensated for the electron deficit caused by gallium, converting more than compensated for the electron deficit caused by gallium, converting the melt back to N-type.
Riordan & Hoddeson, *Crystal fire*, 182; H. Choi, 'Between Research and Production: Making Transistors at RCA, 1948-1960', paper presented at the Business History Conference, Le Cruesot, France, 2004; H. Choi, 'The Boundaries of Industrial Research. Making Transistors at RCA, 1948-1960', *Technology and Culture*, 48/4, 2007, 758-82.

[48] J. E. Tilton, *International Diffusion of Technology: The Case of Semidonductors*, Washington: The Brookings Institution, 1971.
[49] I.J. Blanken, *Geschiedenis van Koninklijke Philips Electronics N.V. Een Industriële Wereldfederatie* Deel V (1950-1970) (Zaltbommel 2002) Europese Bibliotheek, 125; Kees Boersma, *Inventing Structures for Industrial Research. A history of the Philips Nat.Lab. 1914-1946* (Amsterdam 2002) Aksant; Marc J. de Vries, *80 Years of Research at the Philips Natuurkundig Laboratorium (1914-1994)* (Eindhoven 2002) 54.
[50] One of the Natlab researchers, J.L. Snoek, concluded after investigating a piece of ferrite material developed by Japanese researchers that its oxygen absorption was related to how the cooling down and sintering process, which inspired him to develop a new method of producing ferrites.
De Vries, *80 Years of Research*, 90-95; Boersma, *Inventing Structures*, 55-57; Blanken, *Geschiedenis van Koninklijke Philips Electronics*, deel V, 121-122, 127.
[51] Van Geel experimented with a grid in a solid state diode.
G. Verbong, De ontwikkeling van de transistor bij Philips. Afstudeerscriptie Technische Hogeschool Eindhoven, mei 1981, 29-30.
[52] Verbong, De ontwikkeling van de transistor, 29-30.
[53] The main reason was not the lack of research experience in this field (although it was minimal compared to American standards) or access to papers or articles, but the lack of focus.
Verbong, De ontwikkeling van de transistor, 31.
[54] The other were prof. H.B.G. Casimir for the physical research and ir. H. Rinia for the apparatus and systems research.
Blanken, *Geschiedenis van Koninklijke Philips Electronics*, deel V, 123.
[55] Verbong, De ontwikkeling van de transistor, 31-32; Ger de Wind, Philips Semiconductors Nijmegen. Een halve eeuw mensen in en om een high tech-bedrijf 1953-2003, Afstudeerscriptie Faculteit Algemene Cultuurwetenschappen, Open Universiteit Nederland, april 2004.
[56] Blanken, *Geschiedenis van Koninklijke Philips Electronics*, deel V, 130; Verbong, De ontwikkeling van de transistor, 33.
[57] The Natlab was confronted with various problems. The organisation had to get out of its – due to the War - isolated position in organisational and scientific respect and had to adjust to the new organisational structure of product divisions. Moreover, it was hampered by a lack of researchers, related to the general engineer and academic shortage after the War, as a result of the German deportation of employees and the education stop in the period 1940-1945, while an increasing number of companies having research facilities also approached the scarce academics. Blanken, *Geschiedenis van Koninklijke Philips Electronics*, deel V, 130-135.
[58] Both groups felt in the main area 'devices'.
[59] Van Overbeeke was part of the Telephony subgroup which fell together with radio, television, microwaves and computers in the 'systems' group. The total material group grew from 21 to 59 in the period 1946-1954. The larges increase was in the subgroup semiconductors (5 to 20). De Vries, *80 Years of Research*, 111-113.
De Vries, *80 Years of Research*, 111-113.
[60] Verbong, De ontwikkeling van de transistor.
[61] Idem, 35 and 63.
[62] Ibidem.
[63] Ibidem.
[64] Michael Riordan & Lillian Hoddeson, *Crystal Fire: The Birth of the Information Age* (New York 1997) W. W. Norton, 177-178, 181-183; W. Shockley, 'The Theory of P-N Junctions in Semiconductors and P-N Junction Transistors', *Bell System Technical Journal* 28 (1949) 435-489; W. Shockley, *Electrons and Holes in Semiconductors* (New York 1950) Van Nostrand. The double-doping technique as described by Riordan en Hoddeson: 'Starting with a melt of N-type germanium, they first doped it with a gallium pill to grow a P-type layer on a N-type chrystal. About ten seconds later, they added a second pill containing 100 micrograms of antimony, a fifth-column element located under arsenic in the periodic table. A donor element supplying excess electrons to the crystal lattice, the antimony more than compensated for the electron deficit caused by gallium, converting more than compensated for the electron deficit caused by gallium, converting the melt back to N-type.

Riordan & Hoddeson, *Crystal fire*, 182; Hyungsub Choi, ‘Between Research and Production: Making Transistors at RCA, 1948-1960’, paper presented at the Business History Conference, Le Cruesot, France, 2004.

[65] Interview with dr. P.W. Haaijman, 21 January 1981 by Verbong, Citation in Verbong, De ontwikkeling van de transistor,38 & 33-34.
Because the Dutch universities were not active in solid state physics at that time the only knowledge source were other companies in this field. Especially the companies in the United States.

[66] Also other companies had approached Bell to get information about the production process.

[67] Tilton, *International Diffusion*, 76. The quotation appeared in ‘The Improbable Years’, *The Transistor: Two Decades of Progress. Electronics,* vol.41 (February 19, 1968) p.81; Verbong, De ontwikkeling van de transistor, 24-25; Choi, ‘Between Research and Production; Riordan & Hoddeson, *Chrystal fire, 179.*

[68] This meant that Philips had to pay 5% royalty for the transistors, 1) sold or produced in countries with Western patents, being part of appliances not falling under the scope of the main agreement, 2) sold as single devices in the US and 3) sold separately in other countries for other purposes than transmitters, receivers for sound, facsimile and television. The license agreement opened the way to the Transistor Technology Symposium.

[69] Verbong, De ontwikkeling van de transistor, 39-40.

[70] Riordan & Hoddeson, *Chrystal fire,*197.

[71] Citations in Verbong, De ontwikkeling van de transistor, 39.

[72] To spread the knowledge over the other Philips' departments and to stimulate the development of transistor applications, the so-called Transistor Application Group (TAG) was established. Verbong, De ontwikkeling van de transistor.

[73] Philips' refusal of the offer from the Germanium Products Corporation (a part of the Radio Development Research Corporation (RD&RC)), the largest producer of layer transistors at that moment, to get access to its knowledge for mass producing these transistors, illustrates that the Natlab and Nijmegen agreed that this process would not be preferable. Verbong, De ontwikkeling van de transistor, 49.

[74] Ibidem.

[75] Choi, ‘Between Research and Production; Riordan & Hoddeson, *Chrystal fire,* 199-200; Tilton, *International Diffusion*, 17.

[76] Choi, ‘Between Research and Production, 21.

[77] Parsons & Rose, ‘Communicaties of knowledge**'.**

[78] Interview with Henk Gianotten former marketing manager at Tetterode by Frank Veraart, August 19th, 2005, Utrecht; ‘PostScript’, in *Macintosh Magazine*, (1990), nr. 1, p. 64-85; ‘Pagina Beschrijvingstalen’, in *Het Appleblad*, February 1990, p. 26-30

[79] Estimate given by Jan Koudijs; currency rate January 1990: € 1,00 = $ 1,20; Statistics Netherlands (CBS), Voorburg Heerlen 2005.

[80] Interview with Jan Koudijs, July 6th, 2005, Utrecht.

[81] General knowledge resembles what is also labeled as information.