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COLLABORATIVE LEADERSHIP AND INNOVATION

MANAGEMENT, STRATEGY AND CREATIVITY

Elis Carlström

ROUTLEDGE

Collaborative Leadership and Innovation

Original ideas start in a person's mind, but the environment where they operate is crucial for the capture and development of these ideas. Equally important is the interaction with others in developing and evaluating ideas, as a brilliant idea influences the world only if it is put into use.

This book hopes to inspire the team leader, innovation manager, or research group leader. It deals with the delicate balance of managing and controlling intellectual property in a collaborative environment. Insights on how new inventions can be evaluated are offered. Following the whole cycle of innovation from a creative idea to where a product or service can be put on the market, examples illustrate how an innovative environment can be created and maintained. Strategies and solutions based on the science of team development are presented and leadership models for the different phases of group development are provided.

The book will be of interest not only to researchers, academics, product developers, entrepreneurs, and advanced students in the fields of technology and innovation management and entrepreneurship and small business management but also for leadership.

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Preface

After studying chemical technology, I started working at the Swedish Ceramic Institute in the late 1970s. I worked with applied research in the field of advanced ceramics that was developing explosively at that time. The idea was that traditional car engines would soon be replaced by very efficient ceramic turbine engines using the new strong and high-temperature resistant ceramics.

This never happened, but high-strength ceramics made their way as important components into many new applications in automotive, electronics, and other industrial products and in biological applications as bone replacements and dental materials. At our institute, we were part of a first wave of using a more science-based approach to improve the forming methods for the new ceramic materials.

I moved gradually from being a researcher to becoming a project manager and a research manager. We took part in European Union (EU)-funded research projects, with both industries and research partners, and I experienced how the funding schemes developed over several EU framework programmes. Our research was noticed internationally, and I had the chance to take part in a research collaboration when Rutgers University in the USA built their Center for Ceramic Research in collaboration with industry. I was invited as one of the few overseas research partners in the large Japanese Synergy Ceramics research programme. This programme was designed to do cutting-edge innovations, and the participants were both researchers from universities and institutes and major industrial companies in Japan.

My responsibilities gradually changed from doing my own research to managing projects and research programmes. I became interested in learning about developing ways of supporting other researchers and research management. I also started writing about my experiences, and this book has been slowly written over a period of years.

In Sweden, the research institutes were small and scattered and there was a gradual process of merging the institutes. The institutes dealing with materials and production methods were merged into a group called Swerea in 2004, and in 2017, I became the Chief Technology Officer of this institute group. Today, the Swerea group has merged into RISE – Research Institutes of Sweden – a larger group of Swedish research institutes. In this gradual process, I had the chance to work with a much wider area of technology and industrial sectors. One of my roles was in developing the work with intellectual property and research collaboration agreements for Swerea and later help with building a technology transfer office for RISE.

Currently, my work is with innovation and technology transfer at Chalmers Industriteknik, a research and development organisation with emphasis on innovation for a sustainable society, closely related to Chalmers University in Göteborg, Sweden.

During the years, I have had a chance to work with many truly inspiring research colleagues. Some of them are mentioned explicitly in examples in this book, but I would like to thank everybody whom I have worked with for their inspiration, research collaboration, and many fruitful discussions. My wife Gunilla Petersson Bergström has also contributed significantly with her psychology expertise. Her support has been invaluable for me when I worked as an active leader. She has also given sound advice during the process of writing this book.

1 Introduction

Three levels of innovation

This book is about creativity and innovation on three levels. It describes how you can support persons around you to become more creative and to develop ideas into innovations. The concept of psychological safety is introduced, and it is shown how important it is to feel safe enough to dare to try new things or voice a differing opinion.

On the second level, it deals with how leadership can influence creativity and innovation and enhance or destroy a creative climate. In this context, it is described how groups develop and how it is possible to provide leadership tailored to the stage of group development. A leadership tailored to the group will increase the safety in the group and enhance creativity.

The third level describes the collaboration across organisations that often is necessary to realise innovations. This leads to a discussion about how to work strategically with finding collaboration partners, making collaboration agreements, and handling intellectual property. At this level, society plays a major role in supporting innovation in general. But society also plays a more recent role in trying to steer innovation into tackling major societal challenges and fulfilling sustainable human development goals.

Why is creativity and new ideas worth pursuing?

My major reason to go for creativity and new ideas is that it's fun. Life becomes more exciting and interesting if you can be creative and work with developing new ideas. I think we need to be creative to enjoy life. Many of us do creative activities in our spare time, but we also should find ways to also be creative at work. Work is a large part of our lives, and we have often put a lot of effort on education and training to do what we do at work well. We also need to be creative in that part of our life to feel satisfied and useful.

You cannot be creative unless you feel at ease and enjoy yourself. This is something that is backed up by hard research facts. Because of this, it is important to create a climate that fosters creativity. The climate at a workplace is strongly influenced by leadership. Non-functional leadership creates fear of failing, and this stifles creativity. The co-workers will tend to play it safe instead

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of testing new ideas. A well-functioning leadership creates the psychological safety needed for creativity. But the manager or team leader does not have to be the person creating all the ideas. If the thinking of the whole group can be used, the creative force will be so much stronger than the creative force of one person. The team leader or group manager's best tool for this is listening. Listening to the co-workers in your workplace, in your science lab, in your development workshop is a powerful tool that will release creativity.

There are many good books that give inspiration and explain how creativity works on an individual level. This book is not about how you can become more creative yourself. It is about how you can support others to become more creative. It is about the creative climate you can support with your own leadership, and it is about speeding up creativity by collaboration between organisations. This book is not only about the climate that is needed to support and develop the creativity of all the individuals in the group but also about exploiting creative ideas and making them into something that will create an impact.

From creativity to innovation

But being creative is not enough. New ideas need to be developed into products or processes. New ideas need to be implemented in the real world to have an impact. This book will describe mechanisms that can help you go from invention to innovation. It deals with how organisations can value their unique ideas and use the possibilities to protect them or get credit for them.

Collaboration across organisations

Many ideas cannot be realised within a single organisation. The collaboration between universities, research institutes, and enterprises is a crucial part of modern development. This collaboration across organisations is not often apparent when we see new products on the market. But modern products are often a complex mixture of technologies that need a mixture of competences and capabilities.

How can we handle this collaboration with several partners and that are needed to exploit creative ideas into innovations? In such a collaboration, each organisation needs to protect its own knowledge and technology and still collaborate intimately with other enterprises. How can we balance the need of the university researcher to publish their research, with the need of companies to guard their trade secrets? This book will discuss such questions and help find strategies to deal with such problems.

Why should we develop ourselves?

Is it necessary to develop within your own business or organisation? Can't you just buy new technology and new ideas? Do you have to put a lot of money and energy in doing development?

In the enterprise world, it is common to think that you can let others do the development and then buy the new technology when it is ready. It is of course possible to buy new technology from another company or from an inventor, but this puts even higher demands on managing creativity.

Projects where you buy inventions without contact with the inventor often fail. If they don't fail, they are often delayed or exceed the budget many times over. The inventor has lots of knowledge, and often, parts of this knowledge are not transferred by drawings, patents, or prototypes. For this reason, it's not enough to buy the invention; you must cooperate with the inventor after the purchase. Then you have an additional problem not just of leading your own development department but also of leading external inventors. Inventors often became inventors because they wanted to work independently, which can make the collaboration very complicated.

The person or organisation that has developed a product nearly always has an advantage. A patent can be part of such an advantage, another part can be the know-how that you can't patent. These types of advantages give a competitive edge. Even if you in the end choose to buy new technology or new ideas, you have a better position if you have undertaken you own development work.

If you look at experiences from the history of technological changes, you can find further arguments for doing your own development. Where new technology has taken over, this has often resulted in that market leaders have lost their position. The Swiss watch industry lost market shares from 80% to 20% when electronic watches replaced the mechanical watches. The large manufacturers of mechanical typewriters lost their position when the electronic typewriters took over. Many manufacturers of electric typewriters had difficulties in keeping up with the development as computers took over. The leading manufacturers that made mobile phones lost their market positions as the smart phone emerged.

Research on how market leading companies have handled new technology describes these patterns. The companies that were fastest to make a strong effort on the new technology were the ones that survived the best. The companies that waited for the technology to mature lost tempo and were often left behind. The ones that made large efforts early sometimes chose the wrong path, but they were often able to adapt their efforts(Andersson and Tushman 1997; Tushman and Murmann 2003).

Today, we are facing a climate crisis. This challenges enterprises to rapidly move to new types of technology. Automotive manufacturers must develop new electric drivelines and learn how to handle battery technology. Airplane manufacturers face even bigger challenges and will probably need to move to hydrogen technology for long-haul flight and to battery-powered engines for commuter flight. Oil and gas companies will have to shift to hydrogen technology and biogas or become obsolete. Manufacturers of plastic products are challenged to use bio-based materials in their products. Farmers will have to find ways to rely less on imported feedstuff for animals and to reduce the reliance on energy-intensive chemical fertilisers. The current need for innovation and creativity is enormous.

There are many arguments that show how important it is to have your own development. But don't underestimate the gratification of having developed something within you own organisation with your co-workers. The enjoyment of having developed something is important for me as a human being on a deeper level.

How do you do this? How do you lead such activities successfully? There is no simple formula, but this book hopes to give you some hints based on science and illustrated by my own and other people's examples.

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2 How to make your team creative

The creative environment

The traditional picture we have of creativity is that inventions and discoveries are made by special people born with special talents. We have been fed with stories about genial inventors who from childhood surprised their environment with their fantastic inventions. We hear stories about great scientists with huge intelligence, predisposed for something big.

But if we look more closely, we will find that the picture of the great inventions needs to be re-examined. Breakthroughs are often the result of many people's contributions. Each of these contributions is not as dramatic as the impressive end result. We seldom hear about all the people with genial ideas who never had a chance to develop them. People who lack resources, lacked somebody who believed in them, or did not make their inventions at a moment in time when it was needed or could be realised.

The true story is that all people are creative. In the right environment, this creativity will thrive. In an adverse environment, the ideas never get a chance to develop, and they will be neglected and forgotten. In most practical situations as in a company or an organisation, there is no possibility to employ this unique inventive genius. You will have to do with the persons you already have available. The question then becomes: What can I do to use the creative talents of the people who already are present in my organisation? How can I create a climate that helps them thrive, develop, and be of use in the organisation?

You must be at ease and have fun to be creative. My own best ideas surface when I am relaxed, at ease, and in harmony. When I start thinking new thoughts, I enjoy myself. This becomes a fun and rewarding activity. I am sure that most people can have similar experiences. This contrasts with the common picture that starvation and need is the driving force for creativity. If we look at the facts, we will, for example, find that great artists were most productive when they did not have to worry about money and survival.

If you have ground-breaking ideas, it is not always easy to find supporters. New ideas disrupt and challenge the established thinking and established structures. And you need supporters because you need the time and resources to develop these ideas. The impressionist painters were banned from regular

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exhibitions since their work was new and challenged the old ideas of painting. They had a difficult time to support themselves, had to arrange their own exhibitions, and suffered severe criticism. Now their works are regarded as some of the art history's finest works.

Creativity often challenges established ideas and does not automatically receive support or economic resources. This has often led to those creative persons being forced to either give up their ideas or live near starvation. When their story is told, it is easy to romanticise the misery and describe it as essential for creativity. But the creativity often took place despite the hard times, not because of it. To go back to painters, van Gogh hardly sold a painting during his lifetime. He lived on the financial support from his brother who was an art dealer and understood the value of art. Without that economic security, we probably would have lost many of his great works.

In history, we have had safe havens where creativity has been able to flourish. Convents were early such safe places. In time, universities took over part of this role. Cutting-edge ideas are seldom the source of a steady income in the beginning. Places where there is extra space to experiment have always been important. The extra space has been created in many ways. Some experiments have been part of the organised research at the university. Other experiments have been made outside the curriculum and done by students who had more fun skipping the curriculum and pursuing their own interests.

Some of these experiments were crucial for the computer industry. People who neglected their studies and started to build and programme their own small computers were essential for companies like Apple and Microsoft and for the entire Internet.

Patronage has always played an important role in art history. Much of the historic art and music was created by artists and composers who were financed by nobility or other rich financiers. We would have been deprived of much enjoyment had these patrons not existed. Today, scholarships, business angels, and venture capital have taken over parts of these roles.

Creative ideas always challenge what really exists and has been accepted. That is why it takes courage to be creative. We often self-censure many of our new ideas and stifle our own creativity. It is easier to be courageous and stick to your ideas if you are listened to and supported. One of the most important elements in a creative environment is personal support. With personal support, I mean that there should be persons who are willing to listen, give response, and offer encouragement. In a creative environment, you dare to risk being ridiculous and make a fool of yourself. In a creative environment, you are listened to when you have new ideas. We need somebody who supports us and renews our courage when we feel insignificant and scared of making mistakes.

There are many historic examples of creative environments. In ancient Greece and later in Rome, creative environments produced knowledge that still affect us today. That all painters wanted to go to Paris for long periods of history was not a coincidence. The local community of painters in Paris could support and encourage new developments. In Silicon Valley, a string of new companies have launched successful information technology (IT) products that have changed everyday life for a majority of people.

Sweden has become a popular place for music recording. The brightest star of this success is probably Max Martin. He has written music for many of the current best-selling artists. He has written and/or produced 25 Billboard Hot 100 number-one singles (as this was written in 2021). Max Martin is the tip of the iceberg of a music industry that has grown to large proportions. The development of the Swedish music industry did not start with him. The creative environment that this started from is the public school system that provided music education as an extracurricular activity. The system provided a safe haven with lots of training, access to instruments and recording equipment, and chances to perform in front of live audiences.

This was an activity supported by public funding. Possibilities were created for large numbers of young people to experiment and learn music. From this wide array of people emerged creative successful groups of artists. Of course, most of the artists and groups failed to make a music career. There were plenty of people who lacked the talent or the persistence. Many good talents never reached a bigger audience. But enough artists and groups were successful, and they inspired and supported others. This chance to experience music was important in many ways also for the persons who did not become musicians. Economically, it created a music industry that paid many times for the initial investment.

There is a parallel with Motown Records funded by Berry Gordy. He teamed up with Smokey Robinson and together they created the Hitsville studio where a very large number of hit records were produced and several singers, groups, and music writers developed. Artists such as Michael Jackson, Diana Ross, and Stevie Wonder developed in their studio. Motown achieved 79 records in the top ten of the Billboard Hot 100 between 1960 and 1969. An important factor in the success was the music schools run by Ford Motor Company in Detroit. This meant that Motown Records had access to large numbers of trained musicians. Motown Records recruited primarily jazz musicians who had superior music skills, and they created a supportive environment with a nearly endless stream of hit records and new artists.

Norbert Wiener in his classic book "Invention – The care and feeding of ideas" (Wiener 1994) points out how important climate is for innovation. The intellectual climate during a specific time period favours new innovations in certain fields.

But innovations are not only dependant on intellectual climate but also dependant on individual persons. There are historic examples of how a certain innovation would have been useful and attainable based on the knowledge at a certain time and place. Still this particular innovation was not accomplished. Wiener exemplifies the importance of individual persons with the innovation to let the position of a number play a role to the meaning of the number. This has been a decisive innovation for our civilisation and makes it possible to write and process large numbers in a practical manner.

When we write the number 125, it is the positions that tell us that 1 designated 100th, 2 10th, and 5 single numbers. The Maya people invented this principle but used 20 as a base instead of 10. Similar inventions have been made several times during history.

In ancient Greece as well as ancient Rome, this principle would have been very useful. Despite this, neither the Greeks nor the Romans used this principle for writing numbers. That they were close to this innovation can be seen when they used a similar principle for calculation with an abacus where a certain row of stones were given a higher value. But despite being so close, this principle was never used in written notation of numbers. Innovations and creativity take place in a dynamic interplay between creative individuals and the climate these individuals live and work in.

We are living in our own world now and we must resort to our own surrounding culture. We can to a certain extent choose the persons we interact with, and we can influence the closest surrounding culture. If we can enhance creativity by influencing our immediate environment, it becomes interesting to see how we can do this effectively.

Four pillars of a creative environment

It is possible to enhance the creativity of any company, organisation, or group. It requires a small surplus of resources but nothing big and fancy. The demands are more on a personal level. At least one person needs to be willing to start a work of change. That person needs to look upon her or his role as a leader (a formal or an informal leader) with new eyes. Appointing a person for this job is often more effective but not absolutely necessary. Appointing a formal leader declares that there is formal backing from the established structure. This makes the task somewhat easier.

Changing an environment of culture in a group or an organisation is no simple task. It requires time and persistence. But it also requires a sense of direction. There is a simple foundation you can start building from that I have tried to summarise as the four pillars of a creative environment.

The four pillars of this being

- Expecting innovation
- Listening
- Encouragement
- Protection

Expecting innovation

For a group to produce a new type of process, a new product, or a new service, there needs to be an expectation of this. Somebody must declare that we expect innovations. There is a difference between expecting innovations and expecting small improvements or expecting new research. Small improvements are necessary but usually also have small stepwise results.

Several small improvements do not automatically lead to large changes. The small improvements are often limited since they are made within the current boundaries.

Voicing the expectation is important: "I expect you to develop new products", "I expect you to surprise me with new innovative solutions". A positive expectation is important. If I communicate that "I trust that you will succeed", it will make innovating easier. If I, on the other hand, communicate a threat or desperation as in "We have to succeed with this new product or we will be out of jobs", the innovative climate is destroyed.

In industry, there was a period when large companies built large central research departments. Many of these departments were effective, but it was also common with research departments that mostly generated new research in the sense of new knowledge. While this might be useful, new knowledge does not automatically lead to new products or processes or something that can be used and exploited. Some of these central research departments were dissolved since they were deemed ineffective. The development was transferred to local departments. While this transferred resources closer to the actual requirements of the organisation, the local development departments were often bugged down with current short-range problems. This is important, but it often leads to solutions where you work around problems instead of finding solutions that solve problems in the long range.

By moving development to local production units, the expectation criterion was fulfilled. But, at the same time, this shift to local production units did not provide the needed protection of the development activities that also is necessary. Creating a safe non-threatening environment is crucial and strongly supported by research as we will see later in this chapter. You must feel at ease to be able to be creative. Stress, harsh criticism, and fear shut down the creative process.

In 2005, the Swerea group of institutes was formed in Sweden. It comprised several institutes from the materials and production field. When the group was started, one very innovative person asked what the procedure for this new group of institutes was for handling patents. He was brusquely told that patents were nothing the Swerea institutes should concern themselves with. Since there was no interest from management and no expectation, there were very few inventions reported at that time. Later, I had the opportunity to take part in building a system for handling inventions in one of the Swerea institutes and later for the whole group. When we started informing our researchers about the possibilities of patents and our new system, the number of reported inventions rapidly increased.

Listening

To listen is one of the most powerful tools for change and innovation. As a young research engineer, I learned early how powerful it was to listen. My first project manager at the Swedish Ceramic Institute was Leif Hermansson who later moved on to become research manager at ABB Cerama, entrepreneur, and founder of the dental ceramic company Doxa. We talked about everything, and he always listened with respect to my ideas, and I listened to his ideas and thoughts about life. When I had a technical problem, it was often enough for me to go to Leif Hermansson and explain the problem. While I was explaining the problem, I often found the solution. That he listened attentively made it possible for me to structure my thought well enough to find the solution.

Later, I have learned that the most important thing I can do as a supervisor for creative work is to listen. The person I am supervising needs to talk a lot, and it might seem like the thoughts are going round in the same track. But if I have enough patience and listen attentively in a positive manner, it is an enormous support for the creative work. In the end, the person will find the thought with the solution.

Even if I have a lot of knowledge in the field, it is important not to let that take over. It is important to teach what you know, but you must not forget to listen. You need to remember to give the person a chance to make their own mistakes and to absorb the knowledge and make it their own. Facts that we just learn to repeat mechanically are of very little use to us when we try to be creative.

The principle is very simple. Still the practice can be very hard. It is difficult to give the undivided attention that is necessary. I personally don't always have the endurance that is necessary. Sometimes I get stressed and don't give enough attention and the method does not work. But what I can do as a group manager is to remember that I am not alone and that if we can create a supportive atmosphere and if we have the patience to listen to each other in the group, we will gain a lot of momentum.

To listen might seem like a trivial activity but is difficult (Weissglass 1990). Most of us have a hard time listening without interrupting. To hear somebody talk about their ideas makes us want to talk about our own ideas. Because of this, it is easy to interrupt and forget to listen. We feel like we just must tell somebody about our own ideas.

Another common reaction is to just turn silent. But being silent is not the same thing as listening. The person who talks immediately notices that the other person doesn't listen. Asking questions can be important. Asking questions not for your own sake but to help the other person keep talking and keep focusing on the problem. Another common problem is a when a conversation turns into a discussion (in the negative sense of the word). In a discussion, the participants often stop listening to each other. They use the time when the other person talks to think about what they want to say next. The more the discussion progresses, the longer the participants slide away from each other.

Since most of us have difficulties in listening with attention for long time, it works best if you take turns talking and listening. If somebody listens to you attentively and with respect, it is much easier to listen back with the same intensity.

When Albert Einstein published his dissertation about the special theory of relativity, he breaks a common tradition of how a scientific dissertation should look. In his book, there are no references to any other scientific works. It does not have any acknowledgements to his colleagues, friends, or close relatives. Instead, he thanks one person by the name of Michael Besso. Einstein thanks Besso that he *listened* to him when he talked about his theory of relativity. You can interpret this as Einstein being very self-centred and wanting to stress that the new ideas were his alone. You can also interpret this as Einstein being a male chauvinist and not wanting to give his wife (also a physicist) any credit. Both these interpretations are probably partly true, but you can also see it as he wanted to point out the fact that Michel Besso's listening had been terribly important and helped him profoundly when he formulated his thoughts and theory.

Encourage

Personal encouragement is a cornerstone of all creative work. To be creative means to fail, try something new, and fail again. If you want to succeed, you have to be persistent and not give up in face of the failures. This is the reason why you need encouragement. You need somebody who notices every little progress and nods encouragingly. You need somebody to share your enthusiasm every time you succeed even if it was a small step towards the final goal.

You also need encouragement when you fail. Somebody needs to tell you that you have a second chance. Somebody needs to remind you that you are a proficient developer even when you feel like a failure. You need somebody who appreciates you as a person and not only for your accomplishments.

Again, I will go back to Leif Hermansson, my first project manager. He showed me that he liked me. That meant that it was so much easier to keep on struggling. The first projects I worked on had some scientific results but not the materials that had any interesting applications that we were aiming for. That is why it was so important not to give up but to keep trying.

In the next project, I spent nearly a year trying to fabricate a certain ceramic material. We knew that a large US enterprise had succeeded but we did not know how they had done it. Again, it meant keep on trying despite failure and in this case finally succeeding.

An important thing you can do as a leader is to show that failure doesn't affect your career. That sort of practical example boosts morale and unites the team. There are large US companies where this is made a formal system for development work. In a country where job security generally is not great, this is an important gesture.

But it is important not to confuse encouragement with rewards. There is a lot in the literature about different reward systems for invention and innovations. Many consultants urge companies to arrange competitions and award prices for innovations. I think these systems need to be carefully examined and are often best avoided. The awards often lead to unhealthy competition and discord rather than strengthen team spirit and cooperation. It is also too easy as a leader or manager to hide behind this formal system instead of giving personal encouragement.

The consultants that set up and favour these systems are often ignorant of the research in this area. There are many studies about the effectiveness of different reward and bonus systems. Alfie Kohn summaries the scientific literature about bonus systems in an article in Harvard Business Review (Kohn 1993). The 25 plus studies done under three decades painted a consistent picture. People who are rewarded for performing a specific task do not perform it better than people who are given no reward. In fact, the more complicated the task is, the more cognitive or creative thinking the task requires, the less positive the effect of rewards.

Kohn refers to a meta-study by Guzo that reviewed 330 comparisons from 98 different studies made in the mid-1980s. The statistical analysis showed that financial rewards had no statistically significant effect. Training and goal setting programmes on the contrary had a significant effect on productivity that the economic rewards lacked.

Why doesn't it work to use rewards to improve productivity? It is easier to understand if you look at punishments. Most people agree that punishment in a work environment does not make people function better. If you want somebody to think independently and become enthusiastic about a task, you would probably agree that punishment is not an efficient method. But if you miss out on the reward, it is regarded as a punishment, and because of this, the rewards work as a punishment or a threat of punishment.

More severe is that rewards can stifle risk-taking and exploring ideas that are not in line with what is already known. In this way, rewards can have catastrophic effects instead of encouraging creativity. In the best case, there is no effect, and in the worst case, it undermines the inherent motivation.

Hygiene factors and motivating factors

Fredrick Herzberg (Herzberg 2003) has demonstrated why it does not work to motivate employees with rewards by studies as early as the 1950s and 1960s. These studies showed that low pay, bad management, and bad work environment caused discontent and lowered motivation. But at the same time, it was not possible to increase motivation (above the mean level) by improving these factors. The inherent motivation is created by interesting jobs and the possibility to grow and develop.

Herzberg calls factors that can lower motivation but not improve it as hygiene factors. Hygiene factors can destroy motivation but not improve it considerably. You can compare this to going to a restaurant. You expect them to have a clean kitchen and prepare food in a sanitary manner. If the restaurant doesn't fulfil this expectation, you may never visit them again. At the same time, you would never choose a particular restaurant just because it has higher hygiene standard than other restaurants.

Table 2.1 Hygiene and motivating factors according to Herzberg

Hygiene factors	*Motivating factors*
Salary	Achievement
Administration	Recognition
Status	Work in itself
Safety	Responsibility

Salary turns out to be a hygiene factor. A bad salary might destroy motivation, but a pay raise does not automatically increase motivation (see Table 2.1). Herzberg made his studies with relatively basic jobs that did not demand a high education or high cognitive skills. For creative jobs, we can assume that similar effects are even stronger.

Protect

To protect is an important task for a person leading creative work. The creative work never seems as important (on superficial plane) as the daily work. It often takes place without the same hard deadlines and because of that it is easier to use resources for more pressing matters. There is always somebody who wants to close this particular part and use the resources for something else. For a company that is noted on the stock market, it is an easy but short-sighted way to increase profit by closing the development department. This increases profits in the short range but destroys the long-range possibilities for the company. For this reason, there is a need for somebody who protects and reminds why we need creative activity and secures the needed resources.

The important thing is not the level of resources. You can perform innovative work with several persons full-time or with part of one person. You do it in a well-equipped lab or a small corner of a workshop. But if somebody constantly questions the activities or time after time decreases the resources, there is a great risk that creativity will disappear out the back door.

When a large Swedish chemical company reviewed their development projects, they found out that none of the projects had failed because of lack of resources. But several projects had failed because there was no key person who wanted to devote themselves to the project. No one was there to speak for the project and defend it against any "attacks".

If you look at the history of many major successful industrial development projects, you find that the projects nearly always have been threatened by closure during some phase of the project. Astra Zeneca had a huge commercial success with the ulcer medicine Losec. This medicine was followed by the improved version Nexium, which was another success. The development of Losec was threatened by shutdown several times during the duration of the development project. It was only by the enthusiastic work of developers who did not give up that the project lived on long enough to take it to the next phase where it was again supported by Astra.

Harry Frank, a former CEO of ABB Corporate Research, has often stressed the importance of protecting innovative activities. When confronted with a new idea, he would always ask the question "What does this new idea threaten?" and "Who does this idea threaten? Then he would decide to inform these persons as little and late as possible to keep them away from the project.

"Skunkworks" is an American expression that was coined during the development of the U2 spy plane. It means that you move out a development activity to a small shed somewhere hiding it from the rest of the company to protect the developers from other distractions. Watson and Crick solved the puzzle of the structure of DNA in a small shed in Cambridge University. At least as the story is told by James Watson (Watson 1968). Harry Frank at ABB claimed that nearly all radical innovations within ABB were developed in this way during his time.

For several years, I worked as a manager of a research and development programme with that included several collaborative projects together with industrial partners. The industry participants did put demands on me and my co-workers. Since the goal of the projects was industrial use, this was a natural part of the work. Sometimes the demands were reasonable and well thought through, but sometimes the suggestions were not very useful. It is easy for the industrial participants to want solutions to the problems that are foremost in their mind even if they are not well suited for the project. A research project is seldom a good place to solve very short-term problems even if input from industry is very valuable. Sometimes the suggestions were important but demanded much larger resources than were at hand. My job as programme manager was to defend these projects and to argue against unrealistic demands.

Tetra Pak as an example

Ruben Rausing started as CEO for the Swedish company Åkerlund and Rausing in the 1950s. This was a company that produced packaging for food. He was inspired by US supermarkets and realised that pre-packed foods would soon start to grow also in Sweden.

Åkerlund and Rausing had already introduced packaging for flour. Pre-packaged flour got rid of the time-consuming work to sell flour by the kilo in the shops. It also made it possible for the companies milling flour to advertise for their brand of flour by printing a brand name on the flour carton.

The success with the flour-packaging made Rausing interested to continue to develop his concept. He started to look at a new packing for milk since this was the food that was sold in the largest quantities in Sweden at the time. Rausing gave his lab the concrete task of developing a paper-based packing for milk.

Eric Wallenberg who had only been employed for six months and had just been put in charge of the lab got the brilliant idea of creating a packaging for milk by folding a tetrahedron of paper. A tetrahedron was a way to reduce the amount of packaging material for a certain volume (Larsson Segerlind and Andersson 1998).

A further innovation that was done was to fill the milk continuously in a cardboard tube that was folded, glued, and cut at regular intervals to tetrahedrons. In this way, the time-consuming and expensive individual filling of the cartons was avoided.

The long successful development work that Ruben Rausing initiated in this way resulted in time in the new packaging called Tetra Pak. The tetrahedron required less cardboard per volume than other shapes. However, it proved not so practical for many applications. Later products used right angles but kept the cardboard and the filling method. Tetra Pack was the first in a row of packaging that would be the foundation of a major Swedish industry that found customers all over the world. One person built and controlled a major industry.

Ruben Rausing claimed himself the inventorship of the innovative solutions. He never did the inventing himself. But nevertheless, he played a very important role as a leader for the creative work. This role was crucial for the success and is worth noting.

What Rausing did that was crucial is that he furnished expectation. He set up high goals and expected his co-workers to solve the problem in a creative way. He immediately took to new ideas and always listened to them. When somebody objected and said that "This cannot be done", he often asked, "Have you tried"? Once he realised the worth of a new idea, he kept at it and protected the idea and furnished the necessary resources to test it. So he provided the four pillars of expectation, listening, encouragement, and protection.

The example Procera

Matts Andersson started as a dentist in the Folktandvården in Östersund. Folktandvården (the Public Dental Service) is part of the public healthcare system in Sweden. He had many old patients with bad teeth and thought much about better ways to help them. He often had to extract the last teeth for an old person and had to replace them with a complete set of dentures. People who received dentures late in life often had problems with them. They found it hard to speak clearly and could not eat the foods they were accustomed to.

When a tooth is so decayed that there is just a small remaining part that cannot be filled, you can put an artificial crown on what is left of the tooth. The common way of doing this was to make a coping in gold that fits on what is left of the tooth. On top of the coping, you add a tooth in porcelain (a crown). But copings in gold are expensive, and for certain patients they cause inflammations. On a front tooth, you can see the gold and there is often a discoloration of the gum next to the tooth.

Matts Andersson invented a way to make copings first in titanium and later in aluminium oxide. (Andersson 1996) The Procera method, that Matts Andersson invented, starts with the dentist making an impression of what is left of the tooth that needs a new crown. A dental technician transfers the impression to a gypsum model of the remainder of the tooth. This model is put in a computer scanner. The scanned 3D model is transferred via Internet to a ceramic factory that produces a coping that fits on what is left of the tooth. The coping is made from a strong ceramic (alumina or zirconia) and sent back to the dental technician. A porcelain crown is built in porcelain on the coping. The porcelain colour and shape are matched to the existing teeth around it. This provides a cheaper and more aesthetic crown replacement than what could be achieved using a gold coping.

Matts Andersson started a development company that later was bought by the Nobel group; he continued to work in the company named Nobel Biocare AB, and the method was launched under the name Procera. Nobel Biocare AB started out as a pioneer with titanium implants. Implants are used when an entire tooth is missing. The Procera method quickly grew and as a second business area beside the implants. It started very quickly to generate a large profitable turnover in the beginning of the 2000s. Matts Andersson worked both as an entrepreneur and leader of a development team where many persons have contributed with innovations.

When Nobel Biocare was bought by a Swiss company and development was moved to Switzerland, Matts Andersson struck out on his own again as a serial successful entrepreneur. Today the market is dominated by the ceramic copings because of the better aesthetics, and the Procera method is one of several methods of fabricating them.

I had the opportunity to work together with Matts Andersson in the late 1990s and early 2000s and could observe how he worked. What was noticeable was his enthusiasm and faith in people. He always has an encouraging word and is always enthusiastic about all progress. When we encountered problems, he was the first to say that we should and could solve them. When you work with him, you feel that he trusts that difficult problems can be solved. If you have a problem, he listens well. He also has been able to protect his development project and secure higher management support and necessary resources.

He often spent time explaining the bigger picture to everybody involved in his projects. Working with him, you learnt what the overall development strategy was and how your small piece fitted into the bigger picture.

One of his constant goals was to keep a high tempo. To quickly move on to the next experiment instead of losing yourself in failures. In this way, he managed to keep ahead of large competitors in this area. He worked with a combination of protecting important inventions by patents and working openly relying on speed in innovation rather than protection. This openness made it possible to receive impulses and inputs from others and made it easier to keep the level of innovation high.

Psychological safety

What does research have to say about creative teams? It is a very difficult subject to study. How does one measure creativity correctly? It is so much easier to measure productivity in a plant than creativity in a research and development lab. There have been suggestions to measure "inventivity" as number of patents/dollars (Gilman 1992). Patenting is also used as one of the performance indicators when the innovative climate in countries is compared. However, patenting varies independent of real innovation. In the telecom and automotive industry, patenting is much more common than in the construction, software, or process industries. Two companies in the same type of industry often have very different patenting strategies. So the difficulties of such methods are obvious. Other questions that arise are: Can you study a team without influencing it as an observer? How do you create a control experiment and even more difficult a double-blind experiment? The pharmaceutical industry has long worked with problems like the placebo effect when testing new drugs.

One of the factors that has been studied rigorously is psychological safety. The term was created by Amy Edmundson, and the concept has been studied both by her research team and by other researchers. She found out that psychological safety is an important factor and that lack of psychological safety hampers creativity(Edmondson and Lei 2014; Edmondson 2019).

What is meant by psychological safety in this context? It means that, for example, you are not afraid of what might happen if you try something that fails. It means that you will not be attacked or must be afraid of being attacked for raising questions or pointing at problems.

Amy Edmundson has constructed questionnaires that can be used to measure the psychological safety in a group. It measures the experienced safety, and this is what influences the team members. You might be protected from being fired from your job by law or by a contract. That doesn't help if you feel afraid of losing your job. This feeling will anyway interfere with your creativity. But psychological safety does not mean that you drop all criticism. You want a climate where you can discuss and question ideas without the person behind the idea feeling attacked.

Several studies indicate that psychological safety is important for creativity. My own experience of working in an organisation that had deep financial difficulties were that the fear of losing your job and uncertainty about the future were major setbacks in an organisation that otherwise excelled in creativity. My personal experience is strongly backed by the research that Amy Edmundson and other researchers have conducted.

The four pillars that I have mentioned earlier in this chapter are designed to improve the psychological safety. Expectation provides a clear goal that makes people understand where we are heading. Uncertainty about that makes you feel unsafe. Someone who listens shows that you are important and that your thoughts are valuable. This also improves safety when you thread on new ground into the unknown. Encouragement is the opposite of discouragement. And protection is something that keeps you safe.

Curling as an example of safety in a creative team

Curling can be a nerve wrecking sport. A sport that requires creativity and adapting the tactics to the changing situation during the game. The Swedish Curling Team – Team Norberg – won an Olympic gold medal in Turin in 2006. They were the first team to defend the title, and they won a second OS gold medal in Vancouver in 2016. Additionally, Team Norberg won three World Championship gold medals and seven European Championship gold medals. But the way to these victories was filled with hard struggle (Lundholm 2020).

The newly formed Team Norberg with the skip Anette Norberg had won a Word Championship silver and then a European Championship gold medal. But the team nevertheless was not selected for the 2002 Olympics in Salt Lake City. Anette Norberg and her team were very disappointed, but the team decided that they wanted to win the next Olympics instead and made a strategic plan for this.

But the skip Anette Norberg and a team member Eva Lund soon ran into a difficult conflict, and this interfered with the whole team. The conflict made the team perform badly in the World Championship in 2004. They lost an early game and Anette Norberg blamed Eva Lund in public. Anette Lund thought that she was just citing facts, but Eva Lund was severely hurt and wanted to leave the team after this public criticism.

The team then embarked on way to build a renewed safety in the team. The coach started systematically to help build trust in the team. For example, Eva Lund explained that she wanted eye contact during playing to feel safe. If she lost eye contact, she felt that she was being criticised and this interfered with her play. For Anette Norberg, her safety depended on that she felt that the team was focused. Her safety was interfered with if the members chit-chatted, laughed, and did not seem to have focus during training. They worked with this systematically to improve the safety of the team. They also tried to systematically build personal relations also outside of the curling rink. The team came together forming a strong bond and improved their play. They started winning all competitions they entered before the Turin OS, won the gold medal in Turin, and four years later defended the gold medal in Vancouver, Canada.

This example highlights the importance of psychological safety. It shows that with the feeling of safety people can excel even under extreme pressure and competition. It also shows that it is not always obvious what makes a person feel safe or unsafe. You must ask them and really listen to their answers. Then you must work systematically to give the person what he or she needs to feel safer, and you must be persistent at it. You can destroy the safety much more quickly than you can build up safety.

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3 Follow up ideas

Evaluate ideas

Being excellent at creating new ideas does not automatically mean being excellent at evaluating the ideas. Adam Grant professor in organisational psychology at Wharton Business School has described this in his book Originals (Grant 2017). He shows how great composers seldom can rate their most important works highly. The online eyewear outfit, Warby Parker, became a monster success. Adam Grant describes how he declined to invest when he was given a chance after misjudging the potential completely.

In Originals, he also describes how experienced and successful investors were completely taken by the Segway idea. The CEOs of both Apple and Amazon believed that the Segway had a great future. The Segway was an electrically powered two-wheel self-balancing vehicle for personal transport for shorter distances. Segway was successful for a short while but did never live up to the original expectations. Today production has closed, and battery-powered bicycles seem to have taken the niche that many experienced investors believed that the Segway would take.

The creative process can be divided into two parts. One part is where you are thinking freely and without censoring of your thought. The other part is about evaluating the creative ideas. In the second phase, you must look at potential problems and throw away ideas that fail when you look at them more closely. When you evaluate new inventions, you have a much better chance if you have experience with the market and the particular technology. Being a smart entrepreneur in one area does not automatically make you a good judge of all types of inventions.

Being the CEO of Apple or Amazon does not necessarily give you experience about vehicles and transportation. We can find that you generally need experience in the field if you want to evaluate an idea. But being the originator of an idea also makes you blind. You easily fall in love with your own idea, and it is difficult to get the perspective that you need to evaluate the idea.

If you try to evaluate ideas at the same time as you create them, you will probably censor yourself and inhibit your creative ability. Something similar will happen if you discuss in a group. If you start by directly criticising each

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other's ideas, the participant in the group will tend to be self-conscious. This will make them censor themselves, and at least some of the group members will tend to be very silent.

To be creative is not just about creating something new. It is very easy to create lots of new things if the new is a nonsensical chaos. When we let go of our fears and inhibitions, we can create lots of new ideas. But many of these ideas are not useful at all. Therefore, we always need a second step where we evaluate ideas. But it often needs to be done in a separate step. If we try to do it at the same time as we create ideas, it often stops creativity.

In this second step, you need to weed out the ideas that are not useful for us presently and all ideas that are just "noise". It is easy to believe that this evaluation and screening of ideas is just about economy. Economy might be a useful criterion, but it is far from being the only reason to skip an idea.

The film director Ingemar Bergman had a saying where he talked about: "Kill your darlings!" What he meant by that is it is easy to become overly fond of some ideas. Such an idea might be exciting, aesthetic, or interesting. But you anyway might have to delete the idea because it does not work in the context where you are trying to fit it in. Researchers often get enamoured by their first positive result. Some researchers spend a large part of their research career trying to fit a model, that was an early success, to new areas where it doesn't work at all. They do this instead of trying to find a new way to look at new problems.

There are many technical innovations that are new, creative, and fascinating but that are not possible to use in an industrial context. In the industrial context, there are economic considerations that must be taken. So there needs to be a business idea connected to the technical innovation. There are also ideas that are so difficult to realise in practice that industrial demands of getting things right every time cannot be fulfilled. Therefore, we often talk about innovations as separate from inventions. An invention does not become an innovation until it results in a useful product or process that can be sold or implemented in some other way.

Approximately at the same time as James Watt invented the first steam engine, several other types of engines that were driven by heat were invented. The steam engine was the first engine that got a more general use because it was so easy to manufacture. With the technology that was available at that time, it was very difficult to produce machine parts with very small tolerances, that is, with a perfect fit. It is reported that you could stick a coin in between the cylinder and the piston in the first steam engine. But a steam engine can work even with large leaks. A petrol or diesel engine would never have functioned with this poor precision in machining. In an internal combustion type of engine, you need to have a tight fit between the cylinder and the piston, or the motor will stop. These types of engines have higher demands on the manufacturing precision than a steam engine has.

Today, we do not have problem in manufacturing the machine parts that we use in petrol or diesel engines. But the Sterling engine was even more difficult. This engine was invented in 1833 by the Scottish priest Robert

Sterling. The Sterling engine sets such high demands on precision that it still today is difficult to manufacture cheaply. It can still be motivated in very special applications where the special advantages can motivate the costly demands for manufacturing.

Another example is the first integrated circuit manufactured by Intel in the USA that later became famous for its microprocessors. Intel developed the silicon chip that is the "brain" of the integrated circuit. The "skull" of the chip's brain is a ceramic shell that protects the sensitive circuit. It also provides electrical insulation and at the same time dissipates the heat produced by the chip. This part was manufactured by Kyocera. Kyocera is a Japanese ceramic company that had moved into electronic applications by making parts for the CRT (cathode ray tube) in television sets. They dominated this market because they could produce ceramic parts with high precision something that also was crucial for the integrated circuits.

The conclusion is that we cannot evaluate innovative ideas in themselves. They need to be put in a societal context where we account for the manufacturing possibilities, the resources of the producing company, and potential customers, and so on. Even a very simple invention like the wheel required reasonably even roads to be able to be used.

Metro Newspaper

Monica Lindstedt had a background of running a paper in a small town in Sweden and turning loss to profit (Johnsson 2018). She then became the CEO for a part of a large publishing house. Together with two other persons, she started to develop ideas for a new morning paper in Stockholm. At that time, Swedish morning papers were large unwieldy papers that people tried to read on the subway without knocking out the fellow of the seat beside them. The evening papers were in the tabloid format, but for historical reasons and heavy investments in printing presses, the morning papers were not.

The main income at that time for newspapers were the advertisements. The subscriptions were just a minor part. She figured that if she could deliver a free paper with a tabloid format in the morning to people travelling on the subway in Stockholm, it would be very popular. Popular enough so that the income from advertisements would be more than enough to finance the paper. Eventually, she got a contact at the Stockholm subway to approve of the idea. The subway thought it would be a nice free-of-charge service to their customers. They were willing to allow placing newspaper stands on the subway where people could grab a free copy on their way to the train. The news in her new paper would be mostly supplied by news agencies. Their short type of news stories would fit well for people who had a few minutes of reading on the subway stop where they were getting off.

She had a new creative idea and a sound business case to back it up. Now she needed financing. So she went to a large bank that she had lots of confidence in. Their response was: "You need to show an example of that this idea has worked already". She tried to say: "This is a new creative idea; nobody has done this before". But to no avail, no bank was willing to take the risk of funding her and her friend's project. Then some other friends persuaded her to approach the Swedish business leader and media pioneer Jan Stenbeck. He already owned a TV station, a telecom company, and several other large enterprises.

Jan Stenbeck wanted to own a morning paper. He had given his associates the task of drafting a business idea for a morning paper. They presented one idea after the other, but all the ideas had bad economy and Stenbeck found them useless. When Monica Lindstedt presented her idea, he immediately understood that this was doable. So he funded the creation of the successful free morning paper Metro, which was launched in 1995. It was very successful for a period before people started looking at their smart phones in the subway instead of reading a paper.

Ericsson example

The history of the Swedish telecom company Ericsson is described by Lasse Åsgård and Christer Ellgren in their book "Ericsson" (Åsgård and Ellgren 2000). It details several examples of how difficult it is to determine the value of an innovation. Ericsson started as a telephone company in the 19th century. Telephones spread rapidly in Sweden, and in 1885, there were more telephones in Stockholm than in London or Paris. At that time, Sweden was generally a backward country regarding technology.

Ericsson took up the competition with Bell Company in Sweden and then in Norway. At first, he copied and then improved the Bell telephone. Because of the high prices for Bell network, several competing telephone networks were started and Ericsson was one of the operators. The founder Lars Magnus Ericsson thought in the beginning that when all the rich merchants had got telephones there would be no more market. But telephones slowly kept spreading through the rest of the population.

With time, Ericsson started making switchboards for telephone stations. In the 1960s, the automated electromechanical switches for telephone stations were a big seller. But electromechanical relays were slow and prone to failure; so in the 1970s, Ericsson developed a system with electronic switches that were faster, were more reliable, and could be given more automatic functions. The electronic system brand named AXE eventually took over the market completely. Despite their deep technology and intimate market knowledge, Ericsson completely failed to understand what was happening. The prognosis for the electromechanical systems overrated the sales volumes again and again, while the prognosis for the electronic systems overrated and then underrated the success of this system.

Even when it was obvious that the sales volumes of the electromechanical systems were failing and taken over by the electronic system, there was still a tendency to think of the decreasing volumes as something temporary. There was a hope that sales would pick up or at least stabilise (see Table 3.1).

Table 3.1 Comparison of projected sales volumes with actual volumes from 1974 to 1978 for Ericsson's electro mechanic and electronic telephone stations

Year	*Electro mechanic*		*Electronic*	
	Prognosis	*Actual*	*Prognosis*	*Actual*
1974	Constant	Constant		Slow increase
1975	Constant	Strong decrease		Slow increase
1976	Constant	Strong decrease		Slow increase
1977	Slow decrease	Strong decrease	Slow increase	Constant
1978	Constant	Strong decrease	Slow increase	Strong increase

As personal computers (PCs) surfaced, Ericsson developed their own PC Ericsson One. Despite heavy advertising, the Ericsson PC miserably failed on the market. One of the leading electronics companies at that time failed to develop a PC that could sell.

When computer technology matured, Ericsson put lots of development efforts into the next generation of AXE switchboards that were to integrate telephone lines and computer lines. The development was delayed. It was difficult to get the technology to function, and the technology was outdated before it was launched on the market. The Internet Protocol (IP) and the possibility to send voice over IP (VOIP) made next generation AXE obsolete.

At the same time and with a much smaller development budget, Ericsson started building mobile phones and a mobile net. The Swedish national company Televerket (later privatised as Telia) had put down an order for a Nordic mobile network system. The standard was named Nordic Mobile Telephone (NMT), and Ericsson built the base stations and phones for the system. This was not big business since Ericsson only sold a couple of hundred phones per year in the beginning. The phones were expensive, heavy, and more luggable that truly mobile. So without the order from the national telephone company, Ericsson probably would not have ventured into mobile phones at this time.

But as the Global System for Mobile Communication (GSM) standard was adopted, Ericsson had just the right experience to be at the forefront of this international system. All due to that the Swedish government through Televerket had ordered a mobile network from Ericsson. Another factor was the military side of Ericsson that had supplied the Swedish armed forces with radio communications that jumped between frequencies as a way of avoiding being listened to by the enemy. This technology was also an important basis for the GSM system.

Eventually, the Ericsson phones were sold off due to the competition from smart phones. Ericsson has managed to keep their position as a base station and network builder with the new standard 3G, 4G, and the emerging 5G.

This shows that it is very difficult to predict the success of new products and very difficult to predict the speed of technological development. This is true even if you have very high expertise both in technology and marketing.

Developing an invention into a product

Whether a creative idea or an invention can be realised and exploited depends on many factors. There is often a need for investment that the inventor or the inventing company is not able to make on their own. So the need to be able to convince an external investor that this is a viable idea like in the story of the Metro paper above. But there are many other hurdles that must be overcome. Inventions that come from research at a university often requires extensive development to convert them into a product. The typical university researcher usually has a very deep knowledge in his own field. But to take the step from an invention to a functioning product can require knowledge in other fields that are not apparent.

If you are a researcher in microelectronics and invent a new sensor based on an electronic chip, you might think that it will be easy to exploit this invention. Chips can be produced by a silicon foundry, so production is already secured. If you have the design of the chip ready, it can be produced to a cost that probably is quite easy to calculate if you know the number of chips you want to manufacture. But it might be quite difficult to sell the chip as a sensor. You might have superior measurements that you can demonstrate in the lab. But this does not help unless you are able to package the chip in a way that protects it properly from the environment. As part of the packaging, the chip needs to be fed with current and signals from the chip must be able to be conducted to some other part of the electronic. This might not be too difficult in a clean and temperate environment, but if the sensor should work outside, in an industry process or just near a process that emits heat, it might be quite difficult. If you invent electronics that is part of a mobile phone, it will be handled roughly but it does not have to last forever, and if it fails, you can always replace it. People change their phones a lot, and they are used to some problems and will probably blame themselves for malfunction. But electronics that is part of a heavy vehicle must last for many years, and if they fail, it is very expensive for the supplier of the failing component. This means that understanding the demands of the application is crucial for developing an invention into a product. It is also important to understand how a product can be produced and the possible problems that can occur in manufacturing as the following example will show.

EffPower Bipolar Battery

Erik Sundberg and Ove Nilsson invented the bipolar lead-acid battery and filed the first patent application in 1991. In a normal lead-acid battery, such as the start battery in a traditional petrol car, you have two electrodes – one positive and one negative. The positive consists of lead and the negative of lead oxide. Between them is a liquid electrolyte of mainly sulphuric acid. In the bipolar battery, there is a plate where one side is positive and the other negative. The plate is a porous ceramic impregnated by lead that is metallic lead on one side and lead oxide on the other side. This bipolar battery is much more weight efficient, and it can be discharged and charged much faster that a normal lead-acid battery.

A development company called EffPower AB was formed to exploit this battery. This was at a time when lithium-ion batteries were starting to be used in cars but were still very expensive and the common understanding was that it would not be possible to use lithium-ion batteries in heavy vehicles. Today this is no longer true, and we have heavy trucks with lithium-ion batteries. But at the time, the bipolar battery was a strong contender. It was potentially cheaper and still much more efficient than traditional batteries; it seemed to have a place especially for heavy vehicles that required larger batteries.

The only problem was to develop a reliable method to produce the porous ceramic plates for the batteries. This was thought to be a simple problem since the plates were made of a well-known ceramic material. So the prototype production was started. The prototype production was done by a small company that already produced porous materials for ceramic filters. But ceramics are brittle materials, and they are sensitive to defects. In the bipolar battery, the ceramic was put under large stresses. This meant that there was a huge development work ahead. The production in the small company was not set up to produce defect-free materials, and they had to produce component where one defect could ruin the entire battery. The development was stopped in 2012 just before larger production was planned to start. The production problems were too difficult to handle, and time was running out for the bipolar batteries as lithium-ion batteries were getting better and cheaper by the day.

When the strong advanced ceramics were invented in the end of the 1970s and beginning of the 1980s, several small companies were started to exploit the new materials. Most of these companies had a short lifetime since the problems they faced required development efforts that were beyond their capacity. Several traditional ceramics companies also started work with advanced ceramics. These efforts failed in most cases. To produce an advanced ceramic requires a very clean environment and a very high precision that was difficult to find in the traditional ceramic industry. The potential customers were also found in other parts of industry than what the traditional ceramics companies were used to supply to. If we look at the chemical industry, we find similar failures. Large producers of bulk chemicals that try to enter a market of special chemicals have a high failure rate. Today there are still several small, advanced ceramics companies around, but most of the advanced ceramic industry is dominated by a few large enterprises that have acquired the smaller companies.

Developing ideas in practice

How can you transform a creative idea into a practical product or process? In most cases, you need to test the idea. The team then becomes a crucial asset. Especially if you have a team consisting of people with a variety of knowledge and experience. Ideas can be tested by discussing them in a group. It is a good idea to discuss and scrutinise the idea before putting a lot of effort into realising it.

If you want to evaluate the ideas before you put a lot of resources into developing it, you should look at the entire chain. Where do you get raw materials with the right properties? How do you manufacture components? How do you assemble components into a product? How do you sell and service the product? Can you upgrade, remanufacture, or reclaim the material from used products? For many of these steps, you need to estimate the costs. Often, it will not be possible to do exact calculations but even ballpark figures can show if the ideas are not worth pursuing in its present form.

In some cases, you can examine the idea theoretically. A product that generates energy out of nothing is probably not worth pursuing. Even so, an idea that seems impossible at first glance might very well be a functioning idea.

Building prototypes

Building prototypes is a crucial competence when you are developing inventions into products. A prototype can mean many things and they can function on several levels. If you have an invention, you can design a product right out of the invention. This will often mean that you do a lot of calculations and design work. When the product is designed, you start producing it. If there is some inherent flaw in the design or calculations, much of this effort will have to be done over again.

The alternative approach is to build a series of prototypes. You can build a prototype that only shows the design of the product. It is much easier to hold a real object in your hands to see how it will look in practice. This can be easily done by using 3D CAD and 3D printers. But what I am talking about in this case is building functional prototypes. A functional prototype executes at least one of the functions of the product or process that you want to design. By realising this function in practice, you can verify that it works the way you want it to work.

If you design a car, you want a low air resistance. You don't want to lose a lot of energy by getting a very turbulent flow around the car. At high speed, you don't want air to lift the car so that it loses its grip on the road. This could be simulated in an aerodynamic calculation. But if that was not available, you might build a small model of the car you are designing, blow high speed air against the model, and observe airflow and behaviour of the model. In this case, there are methods of simulation that can be used so you could test your proposed car model digitally. But if you are developing a completely new product, the simulations might not be available or will take too long time to set up. So building a prototype that can be tested is often an efficient way.

If you are designing a software application, you can build a prototype that has some of the functionality of the final programme. This makes it possible to test this functionality without finishing the entire programme.

Building prototypes can be about building things with egg cartons, LEGO bricks, strings, and glue or it might be using 3D CAD programme and printing with a 3D printer. But building of prototypes is often a company culture more than technical solutions.

When the first legislation that required new cars to have exhaust catalysts was passed in California in the 1970s, the time to implement this was very short. Various designs that were used in the chemical industry had been tested. These catalysts used containers that were packed with ceramic rings as catalyst support. The rings were covered with thin layers of the active platinum catalyst. The vibrations in a car quickly ground down ceramic rings to dust and the passage of exhaust gases was blocked.

A developer at the Corning company realised that a whole ceramic body with small channels could resist the vibrations. The channels had to be straight to avoid resistance to the flow of the exhaust gas. They also had to be small to create a large surface with intimate contact between the exhaust gases and the walls of the catalyst support. It was possible to create such a ceramic body by extrusion, which is an efficient and cheap forming method for ceramics. Bricks are, for example, formed with extrusion.

By going to the workshop at Corning and having them make a prototype tool for extrusion, it was possible to persuade management that the idea was worth trying. The special type of extrusion tool was already patented by the UK chemical company ICI but was licensed to Corning. The method worked but the time was very short. The last material problems were solved even while the workshop for manufacturing was built. The result was an exhaust catalyst that dominated the market for several years. Without the quick prototype to persuade management, this product that completely dominated the market would not have been realised.

Machining railway welds

When you lay the tracks for a railway line, the rails must be welded together at intervals. After welding, which is done using a termite mixture, the weld must be ground to make a smooth passage over the weld possible. Traditionally, this has been done using a very heavy handheld grinding machine. This is heavy and slow work. To solve this problem, an automatic grinder was invented. The grinder was sitting mounted on a cart that rode on the rails. It had an automatic system to steer the grinding to create an even surface at the weld. The design process was complex and time consuming. It was done with several smart features and finally led to a new equipment. But when this equipment was started for the first time, there were terrible vibrations. The whole grinding rig threatened to vibrate apart.

Most of the extensive design work proved to be useless. The alternative approach would have been to make a simple prototype. To test grinding in a rig and to build in more functions as soon as the basic functions were proven to work. The vibrations had probably been discovered early with this approach and could maybe have been designed away by making initial adjustments before the entire product was designed.

The pellets burner

Wood pellets is renewable fuel that you can use to heat your house with. Compared to an oil burner, it is slightly more complicated to feed pellets instead of pumping liquid oil. Wood does not burn directly; it has to be heated enough to give off fumes and these fumes are combustible. An inventor came to me with an idea for a new type of pellets burner when I was working at a ceramic institute. He had tried the idea of burning pellets by using a steel can that he tried in his back yard. When he tried it, he got so much heat so that the steel melted down. Then he went to a professor in the local university to get help to calculate the thermal profile of his invention. He got the reply that this is possible to calculate, but it was a large job, and even then, the results were not completely reliable.

Somehow, I got the question if our institute could build something with ceramics. This was a challenging problem, both because of the shape of the ceramic part that he needed and because of the materials requirements that the ceramic material had to fulfil. It was shaped like a sphere with several holes around the circumference of the sphere. In the bottom and the top, there were larger holes. The pellets were placed on the outside of the sphere, and the fumes entered through the holes and the flames formed on the inside of the sphere. Air entered through the bottom hole, and smoke departed through the top hole. One of my colleagues figured out a workable forming process for this geometry. The other problem that needed solving was to choose a proper ceramic material. Many ceramic materials are sensitive to thermal shock. They can crack by rapid heating. But you can find material with low thermal expansion such as the ceramic that is common in stove tops. But the second problem is that wood contains lots of sodium that forms a salt melt during burning. Many ceramics are insensitive to corrosion but the common exception to this are salt melts. Most ceramics corrode heavily in contact with salt melts. In this case, a typical supplier of ceramics could not have delivered components that would fit the demands of this invention. But as we were a ceramic research institute specialising in forming technology and that happened to have a ceramic that was resistant to salt melts available, we could solve the problems and make a functioning prototype. The pellets burner prototype functioned and could deliver a very high amount of heat.

New trams for Göteborg

In November 2021, the public transport authority in Göteborg took 48 trams out of service. This was a heavy blow to the public transportation in Göteborg that relies heavily on trams. The trams that were decommissioned had served for 56 years and were running on overtime. According to the plans, they should have been replaced already in 2010. The reason that they were not replaced was that the new trams that were ordered for 2010 were a total failure and could only be used for a brief time. A new generation of reliable trams were on the way, but the delivery was slowed down by the pandemic in 2020 and the old trams had to be taken out of service before the most recent were delivered.

How was it possible to buy many trams that only could be used for a short time? Trams normally last for a long time compared to buses that have a much shorter life cycle. Unlike buses, trams are developed for a special nonstandardised traffic system. If you buy a tram, you must be able to specify many features of the tram, and it is then designed and manufactured to specification.

Göteborg is the second largest city in Sweden, and it is the home of the Volvo Companies that makes passenger cars, trucks, buses, and heavy construction equipment. This means that there is a large competence regarding vehicles in the Göteborg area at the local Chalmers technical university, at consulting, and at subcontracting companies. There are also research institutes in the area that do vehicle and manufacturing research.

It is also common knowledge that the climate in Göteborg is terrible to any vehicle. In the winter, it seldom stays cool; it snows one day and rains the next. To deal with the snow on the roads, salt is used frequently. Road salt and snow form a corrosive slurry. Owners of private cars are aware that the cars rust much more easily in Göteborg than in other parts of the country.

When the public transport authority of Göteborg ordered new trams to replace the old ones, they did not use this local competence. It seems that they even forgot to use the competence of their own workshop according to the local newspaper Göteborgs-Posten. The specifications of the new trams had lots of problems. What was most problematic was that the trams started to rust. This problem was so bad that the trams had to be taken out of service after a short time, and further orders were cancelled. The slow and tedious process of buying new trams from another supplier had to be started all over again. These are the trams that will be delivered during 2022.

Here is an example that we can learn from. We are dealing with old established technology that is used to develop a new product. Specification of the product and understanding the requirement are crucial. To do this, you have to listen to all categories of people who will have contact with the product. This means both the passengers and the tram drivers but also the people who clean the trams and service the trams. Since the trams are a part of a larger traffic system, their design is also important for people who are involved with selling the travel and planning timetables and probably some other categories as well. The scientific literature has many examples of methods that can be used to involve stakeholders in product development some of which have been reviewed by Kaulio (1998), but studies have also shown that such methods are sadly seldom used in industrial product development.

But the trams do have to be manufactured as well as designed. The manufacturing should produce trams of good quality and reliability. The reliability of a tram is more important than the reliability of a bus since a broken tram will block the rails. So how can you ensure that all trams have the same quality as the first one manufactured? The car industry in Göteborg and indeed the whole European automotive industry faced this challenge in the 1990s. At about that time, the European car industry realised that Japanese cars had better quality and were more reliable than the more expensive European cars. They also realised that the secret to this was the processes for quality management that Japan had adapted. Today, the concept of lean production and Six Sigma quality are generally accepted. This way of producing products right the first time was inspired by the US statistician W. Edward Deming. His teachings were adsorbed and mixed with other elements of Japanese culture. Today, most automotive cars companies have their own version of the Toyota Production System that ensures high quality and efficient work by constant improvements (Ohno 1988).

A proficient production engineer would be able to assess the quality of a workshop very quickly. And it would not have been difficult to find out if the quality of the workshop that was supposed to build trams for Göteborg was inferior. If that had been the case, they would probably have been able to avoid buying trams that started to rust straight away.

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4 Leading creative teams

The role of the creative mentor or supervisor

You cannot "teach" creativity in the same way as you can teach other subjects. What you can do is to learn how to create an atmosphere that supports creativity. This means an atmosphere that supports and encourages new creations. Part of the creative climate is to provide mentoring. Every creative person needs one or several mentors. It is good if your mentor has a lot of knowledge in the field where you want to be creative. This often means choosing an older person with lots of knowledge and hopefully enough time. But the person with the knowledge you need might as well be younger than yourself. If I wanted to be an influencer on the Internet, I would probably choose a mentor much younger than myself. You can also mentor each other. A professor in polymer technology once told me that when he did his PhD, he got very little support from his professor who was supposed to be his supervisor. "We were two PhD students who supervised each other" he said, when we discussed bad supervision at the university. He apparently learned enough to eventually become a tenured professor.

PhD education in the university is probably a place where the mentoring or supervising of creative work has a long and formal tradition. In a university, every PhD student has at least one supervisor. The PhD student is learning to become an independent researcher and is supported by a supervisor. At the end of the studies, an examiner will lead the examination process. This process should determine if the student has been able to produce a PhD thesis that will stand up to the demands of the university. All research must create new knowledge based on earlier knowledge. And creating new knowledge must involve an element of creativity. The examination process usually involves an examination committee and often a public thesis examination with an external examiner. The actual process differs between countries, but the general content of PhD education of students to become proficient researchers is the same.

Depending on the type of subject, the research questions will be constructed by the PhD student or defined by the supervisor. The latter is common in mathematics where it is up to the supervisor to furnish a

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research problem that is difficult but not too difficult for the student. In applied research, the research problem is usually part of a project with a specific goal and sometimes a piece in the research work of a large research group. In physics or chemistry, the research is sometimes centred on a specific experimental equipment such as an accelerator or a specific analysis equipment. In biology, it might be centred on an experimental area in nature. In a humanistic subject such as a language or history, it is usually up to the PhD student to define her or his own research area and research questions.

But regardless of how the research question originates, the aim is to help the PhD student develop and mature into an independent proficient researcher. The goal is also to become a part of a research group or an international network of researchers and to learn how to train yourself as a new researcher. To do useful research is to create new knowledge and this will require being creative.

The supervisor's role in this is to support the PhD student. The student will specialise in a specific subject, and as a supervisor, you must help the student become a better expert than the supervisor in just this subject. The supervisor needs to be an external source that helps scrutinise the work and point out eventual problems and omissions. In many research areas, the thesis is put together from several publications in scientific magazines. Each such publication is also examined in a review process where external experts examine the publication and help correct it before it is published.

The role that you have as a supervisor is very similar to the role you have as a leader of product development in industry or as a mentor to an inventor. The actual product or process that is being developed might in similar ways be fixed or have more flexibility. A new product in a line of products will have to be designed within certain limits. But an inventor might invent something new completely outside of the box and start a new business based on this.

In a university setting, it is common to hear students complain that their supervisors have too little time for them. All too often, this is true. Professors and experienced researchers often are bogged down with administrative tasks, applying for new funds, or doing something else that does not have to do directly with research. A successful professor often ends up with too many PhD students so each of them gets a minute amount of time.

But to transfer from a normal education to training as a researcher can be very difficult. To go to industry and work with product development is also a big step and a new role. Traditional education is too often all about learning to give standard answers by solving standard problems. That there are several ways of solving a problem and that there might not be a single answer or no answer at all are things you may never realise in normal education or job training. The new PhD student often feels like being left out in the cold without guidance even with perfect supervision. Schools are slowly becoming better at giving students training in project work and more open-ended problem solving, but there is still a major transition that must take place when you go from education to creative work.

The problem is not just about more time for supervision. Enough time is a necessary but not enough. How you spend the time as a supervisor is very important. This applies both to the supervisor of a PhD student and to the supervisor of a development engineer. It is the quality of the time you spend that is most important.

The major transition that students will have to become researchers or developers will make them go through a series of crises. They can be smaller or larger crisis. But the individual will often start to question themselves and they will need encouragement to survive the crisis. But surviving a crisis is so much easier if somebody from the outside believes in you and stays patient. The person who survives a crisis will emerge with a new type of maturity. As we will show later in this chapter, a group also has to go through crisis or stages of development to become fully functional.

Leading a research, development, or innovation team

What can you do as a leader of a development group or a research group apart from the individual mentoring and support? There are several things you can do on a group level. Apart from supplying knowledge, I would point to four things:

- Expectation
- Encouragement
- Resources
- Structure

Expect creativity

Expectation is an important ingredient in a creative environment. If you expect usable inventions or new development from a group, they will deliver those with time. If you just expect knowledge, then inventions become a by-product and might not be given enough attention. Knowledge might be generated by doing more observations in the same manner as previous researchers, but real new knowledge also requires new creative thinking. New ideas need attention and some work to develop beyond the initial stage of a wild idea. As a researcher, it might feel safer to work with established methods for measuring and make small improvement rather than develop something completely new. As a product engineer, it is safer to make small improvement for the next product instead of radical changes that involve a higher risk.

To clearly expect creativity and give it the necessary priority is necessary. Otherwise, new ideas will drown in all other day-to-day things that have to be considered. New ideas have an attraction in themselves, but then, they also create many new problems that must be solved before they can be realised.

In every period, there is often a key issue. If you lift that key issue into the light and declare it, you help focus on thinking and resources. Other important issues will often be solved by focusing on the key issue. Without a key issue, you risk division and a feeling of powerlessness as problems amass.

Encouragement and support

Everyone who wants to break new ground needs encouragement and support. You need to try several times before you solve a new problem. If you don't fail trying, you are probably not trying to do something new. The fact is that a skilful inventor or a skilful researcher fails as often as the less skilful. The difference is that the bad inventor refuses to see that the attempt has failed. Then he or she gets depressed by the failure. The good inventor quickly realises when an attempt has failed. Instead of feeling bad about the failure, he or she focuses on what could be tried out instead.

To be able to stand the failure, you need encouragement and support. Specially in the beginning before you have understood that failure is normal and that everybody fails. You can always give a person support and encouragement. You don't even have to be creative yourself to be supportive. What is even more important is that by setting a good example you can create a supportive atmosphere in the whole team.

But being supportive does not mean to only give praise or encouraging words. It means being a good listener. To listen to irritation, discouragement, and feelings of powerlessness helps the person get rid of the feelings and get back on track. It can be difficult to listen without be dragged into the feelings. It will be difficult but if you can listen in a relaxed manner, the person will find a way for themselves out of these feelings. If you really listen without losing your own courage, the discouragement will soon transform into renewed optimism.

Confidence is contagious, and if you show confidence, the group starts to show confidence towards each other.

Resources in the right place

The single developer or researcher is not always good at obtaining the necessary resources. If you lead a development group, it is easier to get a perspective from the outside and judge what is important. A person who cries out for more resources before the job is even started might need to be asked to show some progress first, while the person who works hard and gets results might move faster by being given better equipment or more persons who help.

One of the ways by which people mature in creative jobs is by learning how to work together. A good way of doing this is by teaching and mentoring others. If we look back in time to great artists like Michelangelo or Leonardo da Vinci, we find that they had several apprentices who helped create part of paintings or sculptures. PhD students who learn to become a productive part of a research team can create much more by collaboration than on their own. Great development teams work together inside and across organisations. For

PhD students, there is a formal way of training by supervising master's thesis and project works. The training not only helps the PhD student to mature but also provides more resources to the research job.

Structure and beauty

It is a bit exaggerated, but we can say that most people are either compulsively sloppy or compulsively pedantic. In the best case, we swing between these two extremes. As a supervisor for a creative group, it is important to create an order that makes work efficient but at the same time not such a strict environment that there is no chance of trying out ideas that do not fit in the structure.

All too often, we are brought up to be neat, be tidy, and keep things clean without ever getting an explanation why. If you don't clean or keep things in order, you are told that you are bad or disobedient but that doesn't explain anything. To keep clean is about creating a safe environment. In a dirty environment, we risk disease, poisoning, or simply to slip, fall, and hurt ourselves. In an environment with bad order, it is difficult to work in a fast and efficient way. We must use a large amount of time to look for material, tools, or paper. In the lab, we risk contamination of samples, false result, or unstable measurements.

But keeping our environment clean is not enough to support creativity. We need a beautiful and inspiring environment. A clean environment reminds us that we feel good and are harmonic. An environment that thrives of creativity reminds us that we are creative. The beautiful environment does not have to be about buying expensive art to hang on the walls. It can be about allowing every person to contribute with their creativity in the form of artwork, photos, or drawings. It can be patents documents or commendations, but it can also be beautiful shells or rocks gathered on the beach (Jackins 1991).

It is easy to lose the structure when you are developing new things. It is easier to keep structure when you are doing systematic studies where you catalogue or measure something. But structure is just as important when you want to achieve something new. To ask for written reports is an excellent way to create structure. "Write a short report about what you have done this month". In many laboratories, people use lab notebooks where they jot down ideas, experiments, and results. The hardcover form gives the book extra status and can be a useful way of creating structure. Since you use a hardcover book and date each page, the books used to be especially important when US patents were awarded to "first to invent" instead of the international norm "first to file". With the "America Invents Act", US patents also follow the norm "first to file", but dated notes can still be legally important, for example, when a product is shown to be harmful when introduced on the market.

Today, the hardcover notebooks are slowly being replaced by electronic lab notebooks. With these, it is easy to include photos, calculations, graphs, and tables as well as written text. Everything you save can be given a timestamp and you can follow edits and corrections back in time.

Another simple way of systemising experiment or trials is to create a form. The form reminds you to input all the data about the experiment that you will later want to know. In this way, it is easier to get at complete documentation and you do not risk losing important data that you need to create structure. Creating forms can done using a variety of software depending on your type of creative work.

In some types of research, it is important to build databases that can be reused by other researchers. Openly storing primary data is also important to be able to check the quality of research. For example, in climate research there is a vast amount of data generated and there is a need to be able to reuse this data for different types of analyses. FAIR data are data that meet the principles of findability, accessibility, interoperability, and reusability. These principles can be used to create databases of lasting value (Wilkinson et al. 2016).

How a team develops over time

The research psychologist Susan Wheelan has described how teams develop over time in different stages. Each stage requires a specific type of leadership. She has summarised this in the book "Creating effective teams" (Wheelan, Åkerlund, and Jacobsson 2020). This book is a practical guide both for the team members and team leaders. The knowledge of team development is based on extensive research both by Wheelan and by other researchers. A more thorough description of that research can be found in her other books, for example, in "Group Processes" (Wheelan 2005).

First stage: Dependency and inclusion

When a group is first formed, the members depend heavily on the leader. The members are also very concerned about safety and inclusion in the group. The group is eager to follow the leader of the group and often waits for the leader to take decisions. Since the members often are preoccupied with being accepted by the group, more than focused on the work at hand, the group is not very efficient. The group members are reluctant to express their own views. Questions from the leader are often answered by silence.

Second stage: Freeing themselves from dependency and conflict

If the group continues to develop, they start to free themselves from this dependence of the leader. They tend to fight among themselves about the goals and the functioning of the group. Some individuals might also try to challenge the leader or compete with the leader. This is easy to regard as a problem, but it is a stage of group development. The group needs to unite around goals, values, and procedures, and this creates conflict. Conflict is necessary for the group members to establish a climate where they can safely disagree with each other.

Some groups get stuck in this development stage of conflict. Other groups revert to leader dependence to avoid the conflicts. Both these reactions make the work in a group ineffective. To move on, they need to resolve the conflict and arrive at a unified view of the groups' purpose and workings. Only when the conflicts are solved, or the group comes to term with their differences, the group can start to truly collaborate.

Stage 3: Trust and structure

When a group has gone through stage 2, the commitment and the cooperation in the group increase. The members stop competing or fighting with each other and start to focus on the work at hand. The members start to find useful working relations with each other instead of relations built on status. The members finally agree on the goals of the group.

Stage 4: Work

In stage 4, the group becomes increasingly effective and productive. The group focuses its energy on achieving the goals of the group. The group can also divide into subgroups when the task at hand demands this.

Not all groups go through all these stages. Group can tend to get stuck in a stage or even revert to a previous stage. It is more difficult in groups with diverse members, for example, members with different professions.

A European project I took part in as a researcher dealt with new methods of increasing productivity for the tile industry. The members of the project all had deep professional knowledge but in very diverse fields. Apart from tile company engineers, we had experts on industrial control electronics, image processing, artificial intelligence, and ceramic processing. The project work plan was to combine this knowledge and use image processing to find troubles early in the process and automatically correct them instead of having to sort out bad tiles at the end of the production line. The problem was only that the experts did not understand each other. Because of this, they did not trust each other's competence. This created major difficulties in cooperating in the beginning, and it took a long time to reach the working stage for the group. A project leader with more knowledge of group processes would have been able to support the group move much faster during these first difficult phases.

What can you do as a leader to help the group develop? What you do on an individual basis is important, but it will not automatically solve the group's processes. As a leader of a group, you also need to be aware of and take group processes into account.

What role do you play as a leader as the group develops?

In the first stage, the group will always be looking for your directions. They will feel unsure about the goals of the group. The group members will feel unsure of what is happening in the group, but they will not ask questions during meetings. What you need to do as a leader is to state the goal, purpose, and working processes again and again. It is also good to remind all the participants that they are welcome and needed in the group. The group member will try to be very compliant and focus more on being accepted than on the work at hand. You need to make allowance for this.

The group members need to be sure that their place is in the group and that it is safe to express their views. With a group that is quiet, you can go around the group with a simple question and ask each member for their thoughts. If a person does not want to say anything, you give them a chance to think and then come back to them after the other persons have spoken. If somebody takes up too much time, you politely pass the word on to the next person by saying that you want to hear all the persons in the group. If you repeat this, you show that you value the thinking of everybody in the group. The group members will slowly start to feel safer to express their views.

Eventually, conflicts will surface, and this time they are inevitable. As a leader knowledgeable about group development, you can welcome this conflict. What the group members need to understand (by trying out) is that it is safe to disagree. They will not be excluded from the group because they have a different view. They need to be able to engage in conflicts and work it out.

Here we are talking about conflict around goals, issues, and methods. Conflict that deals with personality is not productive. Conflict should not be allowed to take time from the group if possible. As a leader, you should encourage disagreement around goals, task roles, and so on. But blaming or shaming other group members or criticising their personality should be stopped. Personal conflicts undermine the security of the group and stop development and creativity.

A method to handle this is to have the group agree on rules for group meetings. You can have rules that say that: That discussions are only about issues and that no criticism of persons are allowed during group meetings. That each person will have a turn to speak and that no interruptions of the person speaking are allowed during their turn. While the group may agree to rules like this, they will also tend to forget the rules during meetings. Your job as a leader is to remind group members to stick to the agreed rules when they forget them. Any personal criticism that needs to be voiced can be dealt with outside of the group meetings.

You will also need to remind yourself that these conflicts are useful. That they help the group to develop and go to the next stage. That listening to a person who is really upset without interrupting will often defuse the situation. You can listen respectfully, but you don't have to back down on things you know are right and necessary. You can say "I understand that you are upset, and I am sorry you feel this way, but the reality is still…" and then you will need to listen some more to their feeling upset. If you can keep from being upset yourself, you can often defuse the most difficult situations this way. But some complaints are very valid and need to be acted upon. It is also important for the safety of the group that the leader is willing to step up and stop any mistreatment of any group member.

When the group matures, it will spontaneously create subgroups. These subgroups are often an efficient way to handle tasks that don't need the whole group. So don't be nervous about them. What can be problematic is something that can be called pairing. That is when two persons bond so closely that they exclude other persons in the group. Apart from this, the mature functioning group will solve the problem at hand in the most effective way. The trust for the other members will allow a subgroup to deal with a specific problem or task without the involvement of the entire group (see Table 4.1).

An important part of leading is fostering new leadership. There will always be a demand for more new leaders as an organisation develops or as people move to other jobs. When subgroups are formed, it is an excellent opportunity to develop new leadership. In learning leadership, it is important to face challenges that you succeed in completing. If there is no challenge at all, it becomes boring. If the challenge is too difficult, we get discouraged by

Table 4.1 How groups develop and strategies for leading them at each stage

	Stage	*Signs*	*Leader strategy*
1	Dependency and inclusion	Depends on leader, afraid of not being included, uncertain about goals.	Reassure members, make them feel welcome, repeat goals, repeat the working process.
2	Freeing themselves from dependency and fight	Conflicts and disagreement.	Encourage conflict and discussion about goal but not personal conflicts. Supervise meetings to this effect. Listen with respect to upsets.
3	Trust and structure	Conflicts subside and group starts to trust each other and form structures.	Expect group to be more independent. Subgroups will form.
4	Work	Efficient work, subgroups take care of problems that do not need the whole group.	Expect subgroups but try to stop "pairing". When persons leave or new persons join the group, the process might start over again.

failure. As a leader, you can try to develop leadership by giving challenging task that can be completed successfully. If the task becomes too difficult, you take one step back and let the person try with a simpler challenge. Keeping track of successes and failures will help you develop more leadership that can alleviate pressure on your own leadership and create a readiness for new emerging tasks and that needs new leaders.

A leadership that creates psychological safety

If we go back to the research of Amy Edmundson that was mentioned in Chapter 2 (How to make your team creative), we know how important the concept of psychological safety is for creativity. It is important to note that safety in this sense does not mean avoiding conflict. It means feeling safe enough to express a difference of opinion. This makes it possible to question old established prejudice and think fresh. The development of a well-functioning group leads us through stages to a place where people will feel safe enough to be creative.

Paul Moxnes, a Norwegian psychologist and writer, and professor at the Norwegian Business School describes the Norwegian bank crisis of 1987–1992 (Moxnes 1995). During those years, 15 Norwegian banks had acute problems. The Norwegian state eventually had to enter as a major owner in several of the largest banks to resolve the problems. This crisis was preceded by the US Savings and Loans crisis in the 1980s. But the Norwegian banks learned very little from this US crisis. Paul Moxnes describes the Norwegian bank culture and inability to deal with the crisis. An interesting result of his study is that the banks with the most homogenous culture and least conflicts had most difficulties in dealing with these problems. The banks where there were open conflicts were best at surviving the crisis. Moxnes does not use the concept psychological safety, but, in other words, the banks where the employees were safe enough to voice their disagreement had better discussions and could analyse the risks better.

During a period, I was a member of the managing body of a research institute. We had many heated discussions in this group, but we usually ended in consensus. When my CEO evaluated my performance in the group, he appreciated me for daring to express my views. This made me feel safer in the group when I realised that he appreciated my views even if he did not always agree.

Creating psychological safety is not about avoiding conflict. It is about feeling safe enough to take part in a discussion where there are differences of opinions. It is about feeling safe enough to try things that might be a mistake. If you as a leader can help create this type of safety, you will lead a team that will handle difficulties better and that will lead to the possibility of making ground-breaking innovations. Large innovations are disruptive. They will threaten existing structures and views. Because of this, they have similarities to large crisis.

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5 Inclusion in innovation leadership

Using everybody's ideas

All people are creative. It is an inherent function of the human brain to be creative. We can be more or less creative, and we can have hang-ups that prevent us from using our creativity in certain situations, but the creativity is nevertheless there. It is true that a large part of inventions is made by a small number of people. These are persons who have been able to liberate their creativity or who have been part of a very supportive creative environment.

When you hire new persons, you might be able to choose people whose creativity works well and is easily accessible. But in most cases, the team of people already exists. Then the question becomes: How can we use what we have available? How can we create a climate that will support their creativity and make it flourish?

There is a prejudiced picture of the inventor as a nerdy person with low social skills. This is often an exaggeration. But it is also true that many inventors can have personalities that makes it difficult for them. In a creative organisation, there must be room for odd personalities to make use of their unique talents. Whatever the difficulty might be, it can usually be solved with some active support. A developer might be terrible at presenting ideas to management to secure continued funding of a good idea. If a colleague helps with the presentation, it might stop a very good invention from being shut down before it is realised.

If you meet a group of people engaged in research or development or meet an inventor, you will often find some common traits. We are a group of people who, for different reasons, decided to trust only our own thinking.

To trust only your own thinking is very practical when you want to develop new knowledge or new ideas. If you have decided to find out yourself how things work, you have a very good starting point.

Unfortunately, many of us have made this decision because of traumatic experiences. We decide often to trust only our own thinking as a child because we felt misunderstood, let down, or fooled by the grown-ups we had trusted. This might have been an accurate decision in that context, but it also becomes rigid and unworkable in many other situations. It creates an

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isolation where you don't trust others and tend to think that you must do everything yourself.

Many of the big advances in science and technology have been made when somebody has questioned the established truth. We needed a Galileo who questioned the idea of the earth as centre of the universe with the sun and stars revolving around us. We needed Ignaz Semmelweis who introduced hand disinfection to combat childbed fever. Galileo was threatened by the church, and Semmelweis was ridiculed by colleagues, but they both kept to their own thinking and history has proved them right.

But we can also see the negative effects of researchers' and inventors' tendency to trust only their own thinking. Researchers can discuss the most trivial questions with the same pathos as if it was a matter of life and death and with the same total conviction. When a group of scientists are deciding on which restaurant to choose or how to design an invitation to a conference, they can be just as certain that just their own suggestion is the best one. This sometime makes it difficult to engage with creative groups.

Linus Pauling was a brilliant chemist and a Nobel Laureate who made important progress in crystallography and the nature of the chemical bond. But he also claimed against better knowledge that large doses of vitamin C could cure both colds and mental illnesses. Kary Mullis, another Nobel Laureate who invented the polymerase chain reaction (PCR) method, believed that HIV did not cause AIDs, that the ozone hole did not exist, and that climate change was not caused by humans. William Shockley received the Nobel Prize in 1956 together with two other scientists for their research on semiconductors and the transistor effect. His move to California is believed to be the start of the electronics and computer industry in Silicon Valley. But he is also known for his extreme views on race and eugenics. Eight of his co-workers deserted his company Shockley Electronics and formed the successful company Fairchild Electronics because of difficulties to cooperate with Shockley. Being a brilliant and innovative person does not automatically make a person easy to cooperate with or a trusted authority on all subjects.

As seen above, it is important to create groups or teams with a diverse set-up of experiences and backgrounds. This is guaranteed to create conflicting views and discussions. But leadership needs to keep the group together and not let the conflicts become personal. More importantly, the leadership must stop any mistreatment or harassment of any group member. If they don't, the group will tend to become non-working and face a high risk of breaking up.

Researchers need close human appreciation and encouragement, but they do not need to be admired or regarded as superhuman. If we start to look up to them and place them on a pedestal, we are not doing them a favour. If we do this, we only increase their isolation and difficulties to acknowledge that other persons can contribute with valuable thinking.

A creative climate means including people of all types and backgrounds

My own experience as a young engineer was that I had great difficulty in getting a positive response when I had an idea that was outside of the box. With time, I learned how to navigate past this and "sell" my ideas better. Young people generally have a much more difficult time being heard. Their ideas are not often respected and listened to. They often get put off for no reason. As a leader, it is an important job to see to that all persons in your group or team are listened to with respect and that their ideas examined.

Gender is another issue that excludes and stops creative contribution. Women often have the same difficulty to be listened to as young people. The same can be said about ethnic minority groups.

I went to high school with classmates from varied backgrounds; many came from small villages outside of the small town of Borås in Sweden where I grew up. The small town had very few high schools, so each school had a good mixture of backgrounds. I went on to a university in the bigger town Göteborg. I was fascinated by the subject we were taught, but I did not feel very comfortable in the beginning. I did not really understand why but I felt I had landed in a much more conservative and old-fashioned education compared to my high school experiences.

I am glad I did not give up. I had friends who sort of turned in the door at the university. They gave up after the first weeks of feeling that they did not belong. Not because they were less intelligent or had less stamina. The only reason was they could not handle the feeling of an outsider who was not welcome.

From female colleagues I have heard many stories of the special difficulties that female students have had especially studying science or technology. Professors who organised teaching so that the female PhD students were teaching the more fundamental undergraduate courses while the male PhD students got the more advanced courses. I had the opportunity to work in research institutes where there were several female researchers and female managers. But in research and development in materials in general (which was my field), there is often just a small minority of female researchers. This can often make life difficult for female researchers.

So far, I have not talked about outright abusive treatment. If we look at what the #MeToo brought up, we know that sexual harassment of women is all too common. If we have the perspective of that we need safety to be creative, we can understand that sexual harassment needs to be stopped immediately before any other progress can be made. This is of course not different from any other type of harassment whether it is based on skin colour, ethnicity, sexual orientation, physical differences, and so on.

As a leader for any group or team, it is paramount to listen with respect to any complaints about harassment and to act quickly to stop them. Without this, the team or group will not be safe enough to do important work.

But we also need to examine ourselves. How we treat each other is largely a product of how we were brought up and the culture around us. So even if we decide to treat everybody alike, we might still subconsciously be influenced by the general culture. So as a man, I should be aware that I might tend to not listen to a female colleague in the same way as I would to a male colleague. As a member of the ethnic majority, I will probably show prejudice to ethnic minorities. I can only try to be as aware as I can. Listen, apologise, and try to learn over time.

Why are groups with heterogeneous backgrounds more creative?

The most creative climate exists in groups where people complement each other. To put together, a development team of people with education, knowledge, experiences, and interest that complement each other can be much more creative than a homogenous team.

A study by Jun-You Lin that was conducted in Taiwanese industries showed that collaboration with outside research and development resources (universities, institutes, etc.) is strongly linked to the industrial performance. Increasing the diversity of research and development sources, that is, collaborating with several external partners, increases the performance. Different categories of staff (researchers, technician, administrative support) also have a positive effect on performance. A large research infrastructure (buildings, pilot plants, equipment, and IT resources) has a moderating effect since the investments and maintenance costs tend to limit the expenditure on research personnel (Lin 2014).

The key word here is diversity. If you, for example, only focus on collaboration with only one collaborator, you decrease the diversity. If you favour academic merits to the point where there are not enough engineers and technicians that are part of the development, it decreases diversity. Administrative support in several areas is necessary for success in innovation. Having research equipment available is necessary, but heavy investments without enough technicians to run and support and without enough researchers to plan and interpret experiments is not a road to success. Keeping diversity alive on all fronts (gender, ethnicity, education, skills, equipment, etc.) is crucial for performance.

History is full of examples of persons with very different personalities that cooperated successfully. The visionary Swedish engineer Baltzar von Platen wanted to prove that the second rule of thermodynamics was wrong. The skilful engineer Carl Munters wanted to build practical things that functioned. Together they invented and built the first condensation fridge. It was a unique invention that laid the foundation for the major whiteware industry Electrolux (Granryd 2014). They continued to invent and together they received 47 patents mainly regarding refrigeration. After separating, they made more important inventions such as the Quintus press that could be used to make synthetic diamonds that was invented by Baltzar von Platen.

Carl Munters invented the rotating air dehumidifier and got the first patent for foamed plastic that was later commercialised by Dow Chemicals.

Crick and Watson received the Noble Price for the discovery of the structure of DNA. This revelation laid the foundation for much of modern genetics. Watson was a biologist from his training, came from the USA, and had visions but rather shallow chemistry knowledge. Watson was not afraid to use a very unconventional method at the time to build models to understand how the complicated DNA molecule was built.

Crick had English background and was able to furnish the mathematics and do the theoretical deductions that were necessary. He lacked the social ability that Watson had to create the contacts to access other knowledge that they needed to solve this difficult problem. Together they made a team that was able to solve one of the major problems around our genetic heritage.

The picture of what happened as recounted here is Watson's view as he described it in the book The Double Helix (Watson 1968). Rosalind Franklin was another important researcher whose contribution was crucial to this research but she did not receive the Nobel price. She made the x-ray crystallography that was necessary for solving the DNA structure. This fact is often mentioned as an example of how the roles of female researchers have been omitted (Maddox 2003).

Lise Meitner was a physicist born 1878 in Wien, Austria. She worked together with Otto Hahn in Germany. When she interpreted his experiments, she proposed the revolutionary theory that nuclear fission had taken place in the experiment when uranium was subjected to neutron radiation. Lise Meitner had to flee the Nazis and lived in Sweden 1938–1960. In 1944, Otto Hahn received the Nobel Prize in chemistry for discovering nuclear fission. Lise Meitner was not acknowledged for her discovery until much later. This is an example that the cooperation between more experimental and more theoretically minded persons is important. But it is also a reminder that women's achievements too often have been overlooked.

Take a look at the influence of culture

Long time ago, I happened to visit the Optisches Museum in Jena in Germany (at that time still in the DDR). I stopped in front of a picture of Carl Zeiss and his associates. Carl Zeiss is well known as founder of the Zeiss Company that is a leading optics equipment company. This was a small group of about ten people. I was struck that I recognised most of their names. There was Köhler known for Köhler illumination (a way to arrange the light in a microscope), there was Abbe known as the inventor of the Abbe refractometer (an instrument to measure refractive index of a liquid), and so on.

Several of his associates had given name to a new discovery or an invention within the optical field. Without knowing too much about the history, I started to speculate. Could Carl Zeiss have been so lucky or been such a good judge of people that he picked so many talented co-workers. Or was Carl Zeiss an extraordinary leader for researchers and developers? I would guess it was his leadership ability and ability to create an environment where creativity could flourish.

In 1987, I was a guest researcher in Japan when Susumu Tonegawa was the first Japanese Nobel Laureate in medicine. The only two previous Japanese Nobel Laureates where Yasunari Kawabata who received the literature prize in 1972 and Kenichi Fukui who received the chemistry prize in 1981. Tonegawa spoke in very strong words and claimed that he would never have been able to go through with his ground-breaking research if he had stayed in Japan. Thanks to the freedom he had been given in the USA, he had the possibility to develop his research.

There was some truth in these statements that a person with unconventional ideas could have a hard time in the Japanese culture. But at the same time, we need to acknowledge the large innovations that already were made in Japan at that time, for example, regarding cameras and home electronics. But what we can learn is that there must be room for persons with unconventional ideas. Japan has historically been very successful in innovating some products. With passenger cars, we can see how car production was gradually improved regarding both price and quality. The development of the first hybrid car was an innovative leap. Innovative research was historically not as successful in Japan.

When the Japanese ministry of education evaluated Japanese research in the year 2000, they found that the results were not in parity with the financing of research. Japan spent 2.5 times more money on research than Germany and nearly five times more than Great Britain when the evaluation was done. Despite this, Japanese researchers published about as many research papers as Great Britain or Germany. The intellectual influence, that is, how many Japanese papers were cited, was also much lower than for both Great Britain and Germany. The ministry's own explanation was that a rigid budgeting and control system resulted in inefficiency. My guess is that this shows that a certain amount of money is not enough, but it is the expectation and the support for good ideas that was lacking. In a rigid authoritarian system, the psychological safety is low, and this causes uncertainty, which hampers new ideas. While inventions might be culturally approved, new theoretical advances might not get the same support.

The Japanese government made a strong effort to change this culture. Since the 1950s, Japan had sent out study delegations and guest researchers to the USA and Europe to bring home new knowledge. This worked to a certain extent, but it was not enough. In the 1990s, they shifted strategy and started to invite guest researchers to Japan, which until then had been fairly closed to foreign researchers. This was part of a strategy to take larger leaps in science and influence culture towards bolder and more creative steps. The Synergy Ceramics programme that I had the opportunity to take part in set very high goals. The researchers in this large research programme that included universities, institutes, and industry were challenged to develop ceramics with completely new properties or combination of properties. To a certain extent, this worked. Several new ideas surfaced and were developed during this research programme. And the attitude of perfecting and applying what was done by researchers in other countries was changed to an attitude that Japanese researchers will take the lead into new unchartered territories.

Creativity also needs to cross organisational boundaries

The creative development team consists not only of the companies' employees or your universities' research group. The cooperation with suppliers and customers is often crucial to the development process. A well-functioning development team will build a network of contacts. Development will go so much faster if you do not have to do everything within your own organisation and build on the knowledge and developments of others. There is often knowledge that has been developed for a completely different purpose but that can be used for your development.

Using suppliers and their knowledge is often self-evident to developers but using the knowledge of customers is just as important. They can help you define the requirement of a new product. The customers can also supply valuable information on how the product functions in real use. New products must be developed using compromises. You cannot add all the features that you would like to have. Similarly, it is difficult to know what features of the product might be problematic for the user. Without an intimate contact with your customers, it is not always evident what kind of compromise is acceptable and what is not.

In research, some of these processes are formalised. You build new research by reading and understanding what has already been done. Researchers do applied research, read the more fundamental research, and try to apply it on the specific problem at hand. You build research networks by going to scientific conferences to discuss and exchange information with other researchers. The customer for research might be other researchers but the customer can also be industry or healthcare or public management. Even the most fundamental research has the public taxpayers as a customer. There is a need to communicate with the public, and their needs and problems should be taken up by research.

Co-operation and competition

When we are looking at creativity and innovation at the organisational level, we also need to look at competition. Competition is sometimes believed to be the most important driving force for development. But competition does not automatically lead to development. A company operating under fierce competition might not have the resources needed for development since all efforts go into reducing prices.

Fierce competition inside a development group can also be detrimental. If you never share your knowledge with others, you stop creativity and development very effectively. If your own position or status in the organisation is your main concern, you become afraid of taking risks and pursuing new ideas.

As a young researcher, I was involved with research for the porcelain industry. At our institute, we did research for groups of companies in this area. One of the research managers always asked lots of questions at each project meeting and made lots of notes of all new findings. We assumed that he told his colleagues at his company so they could use the knowledge. We were appalled when we found out that he did not share this knowledge. He kept these findings to himself and only parcelled them out piece by piece when he had the opportunity to appear especially knowledgeable himself. On one occasion, when a colleague and myself visited his company, we listened to him talk to people who came to his office. We heard him give one story to the first person and a different story to the next person to control people in a Machiavellian type of way.

Development must accommodate failures along the way. A cooperative atmosphere is necessary to create the safety that is needed to dare to be creative. The tight rope walker's partner who holds the safety line provides the safety that enables the rope walker to perform more difficult tricks. The good friend who encourages you when you have failed miserably can be what is necessary to make you give it another try and finally succeed.

Daniel Shanefield (1930–2013), researcher at Bell Labs and later professor at Rutgers University, together with Richard E. Mistler invented the tape casting process for ceramics (Shanefield 1984). At that time, he worked at AT&T's famous Bell Labs where they had started development integrated circuits. The silicon chip in the integrated circuit needs to be placed on a ceramic substrate that is an electrical insulator but also conducts away thermal heat from the chip. To mass-produce integrated circuits, it was necessary to develop a cheap method of mass production for the thin ceramic plates (substrates).

I had the opportunity for work briefly in a research project together with Professor Shanefield. His comments on the development work at Bell Labs was that all important projects have been done in close cooperation with other industries. Only through this cooperation they could speed up the development process and solve the difficulties they encountered. In tape casting, the cooperation was mainly with chemical companies that delivered organic binders. The customers in this work were in the other parts of Bell Labs that needed ceramic substrates.

External forces are often an important driver of innovation

There are several examples of how public private cooperation drives new developments. Here the customer defines the need for new development. The telecom company Ericsson had a huge success with the electronic switchboard AXE that replace older electromechanical switchboards at telephone stations. They started a new project with the aim to integrate data and telephony. This project ran into huge technical difficulties, and the swift development of the Internet and uses of the IP protocol made it obsolete.

At the same time, the Swedish National Telecom company (Televerket) decided to develop a new mobile telephone system. The government gave an order for a mobile system with a standard that was common for the Nordic countries, named the Nordic Mobile Telephone (NMT) system. This was a predecessor to the international Global System for Mobile Communication (GSM) standard (Åsgård and Ellgren 2000). On the military side, Ericsson was involved in several projects that involved the Swedish fighter JAS. These projects regarded advanced radiocommunication with encrypted messages and jumping frequencies. This is the same technology that is required to develop mobile telephone systems.

Both Televerket and the military customers had large competence and they pushed for a development that would have gone much slower otherwise. Instead of allowing several companies to compete for the orders, they formed an intimate cooperation with one company and specified and developed together with them. The NMT system was never a large business, but when the GSM standard was set, Ericsson already had the key competence that made them a major international player in first in the mobile business. While they never were able to be a real competitor for smart phones, they still are a major player in the base station business for mobile telephony.

Ericsson's success was also linked to a major university research with public funding. When the mobile phone still was a small business for Ericsson, the universities were funded to do research that formed the basis for roaming (the transfer of connection of a mobile phone from one base station to another base station. This included some complex mathematics and signal theory. Ericsson was selling a few hundred mobile phones at the time and was not eager to finance this research. For the universities, this was not deemed to be an important research area at the time. The officers at the major Swedish body for funding-applied research (at that time called Swedish Board for Technical Development [STU]) understood the needs and the potential. They financed key research at the universities that laid a theoretical foundation for Ericsson's base station system (Arnold, Good, and Segerpalm 2008).

Competition also serves a purpose

This does not exclude that competition can be an important driving force. Scientific discoveries are often made when you are not satisfied with the current explanation and want to give a better explanation yourself. Researchers sometimes have a fierce competition for funds and fierce fights about which theory is the right one. But at the same time, they rely on other researchers' results and exchange ideas and data frequently. The culture both in science and in industry is a combination of competition and cooperation. Most developments are in fact done in an environment where you have both co-operation and competition.

Today there is a trend to work in more open systems often called open innovation. This means that other companies, research institutes, and universities are invited to take part in the product development of a company. This puts complex demands on the handling of confidential information and ownership of inventions, but it also give the possibility to speed up innovation. Possibilities and pitfalls of collaboration will be described more in detail in Chapter 8 "Innovation in a collaborative environment".

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6 Project management for development teams

Project criteria

Research and development are often done as projects. To be called a project, there are some general criteria:

A project should have

- a limited timespan
- a set of goals
- a work plan with a subset of goals (milestones and deliverables)
- a project group
- a project leader
- a budget

It is an advantage if the project has

- a project committee (external reference or steering committee)
- a project support/mentor for the project leader

There is usually also a line organisation besides the project organisation. The line organisation in a company is responsible for personnel resources and common resources that are used by several projects or non-project-related work. The line organisation is the part of the organisation that is responsible for administrative and technical service function.

Project planning

A project has a limited time span. Even if the end date is changed during the project, it is still important to have a time plan for the project. The time plan can be made more concrete by specifying a milestone that should be achieved within a certain time. The time plan can also specify delivery dates for things that are developed in the project and that are delivered either to the project owner or to another participant in the project. The deliverables can, for example, consist of different versions of prototypes or descriptions of processes.

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A project should always have a set of goals. Sometimes, it will seem difficult to promise concrete goals for a high-risk project. It can also be difficult to set dates for deliverables or milestones. But deliverables and milestones can be set without dates. By following if and when the milestone and deliverables are achieved, it is possible to follow the progress of the project. This also makes it possible to evaluate the potential value of the development project. It is not possible to see the real value until the project is finished. Unforeseen things do happen in a project. At the same time, the time plan should not be regarded as static. It is the best guess that you make at the start of the project and will need to be revised. Projects that slavishly follow plans often show trivial result with limited use (Hall 1982).

Project group and competences

The idea of having a project group is that you can gather several sets of competences that are needed for this project. By having different viewpoints, you ensure that nothing important is left out and that you have the resources to deliver on all parts of the project. This makes the composition of the project group a crucial matter for development projects.

I once took part in a project where the goal was to develop a new forming method for hard metal cutting tools. The idea was to use injection moulding as a powder forming method. This would give more freedom in shaping compared with the traditional pressing method. Powder injection moulding had recently been developed for use in forming ceramic and metal powders; using it for hard metals was relatively new. The project partners consisted of a university, an institute, and a company that already produced cutting tools. We could complement the company with knowledge about several parts of the process like developing a feedstock with the right rheological properties, choice of binder, and binder removal prior to sintering. But we lacked knowledge about how to design tools for injection moulding. The company had lots of knowledge about designing pressing tools, but that knowledge was not very applicable to injection moulding. The intimate knowledge of tool design for injection moulding lacked in the project. This eventually proved to be a serious setback for the project.

Project manager

A project needs a project manager to work well. It is important to understand that the project manager role is different from a line manager role. A project manager does not have the same power as a line manager. This is especially true if the project is a collaborative project with several organisations taking part. The role of the project manager is more to organise and inspire and less to demand. It is a question of inspiring the group rather than directly managing it. A project manager does not have to know all the technical details of the project but must be able to understand the need for coordination and get the partners to interact towards a common goal.

A European research project that I took part in was set up by the industrial liaison office of a university. The industrial liaison office had a very good idea and wide contact network. They set up a partnership with all the important technical competencies for the project. But, probably because of lack of resources, they appointed a new PhD as the project manager. This person had only managed his own PhD project before and the project included a much wider range of technology than his original research area. He did not understand the need for coordination of the work of several research partners that had to deliver results to each other for each to be able to do their job well. At project meetings, the project manager did not reserve the time for this. Some of us who were more experienced partners in projects used the coffee and lunch breaks to talk to each other and coordinate the project during the start up. We were very frustrated, but we got most of the job done despite the lack of project management.

Budgeting

A project needs a budget. Sometimes, the budget only consists of certain personal resources, but often there is a need for money to buy materials and sometimes external help. There might be a need also for an internal budget for costs that go across departmental borders in a company. When there is public funding, there are accounting rules that must be met. This requires that a separate project account is maintained, with both personal and other costs for the project kept separately.

Project committees

An external project committee is a valuable resource for a project. Cooperative projects with partners from several organisations often have an internal steering committee to make important decisions about the project. Apart from this, the project can have an external project committee that serves as reference and guidance. This could consist of external or internal costumers or external experts. The idea is to include partners who will use the results at an early stage and get a response that can help steer the project.

Applied research should be communicated to potential users of the results and hopefully put into practice by them. This is a demanding and sometimes difficult task. Involving potential users as members of the project committee is often a quicker and better way than trying to communicate after the end of the project. Project committees can often be useful also for more fundamental research when the committee might consist of research colleagues.

But you should be aware that some members of a project committee will have difficulties handling that role. It can be tempting to foremost be a representative of your own organisation or your own interest. You should try to choose members who are able to shift perspectives and also look from the project's perspective. This requires a maturity that does not automatically come with experience. A less experienced person who is willing to learn might be much more useful than an experienced person who is set to guard their own territory or status.

When a project committee meets, you report the current status of the project. It is important to make good presentations of the results especially for external partners. If you present results in an understandable manner, you get better feedback.

The functions that are needed in a research and development project

There are several functions that should be filled within a development project. Because of this, there is a need for resources that can fill these needs. This could be persons who are directly involved or are close to the project. Some of these functions are generation of ideas, defence, contact outside the project, and sponsoring.

Generation of ideas

A very important function in a development project is the generation of new ideas. There will always be new ideas that surface in a project, but the project becomes more effective if these ideas are seen as important and supported. Previous chapters have dealt with the creation of an environment that supports creativity and innovation that can be used in this context.

Defence

There will be situations where the project will be questioned. There might be a time when management wants to close the project or remove necessary resources. A project that reports to the steering or reference committee will be subject to pressure.

A common pressure is to demand that a development and innovation project should resolve daily problems. Another pressure the reference committee easily can cause is that it supplies suggestions that should be studied and further developed. This is the main idea of a reference committee but if the list of important points grows too much, it might sidetrack or divide the project and make it impossible to do a good job with existing resources.

These described problems do not have to be difficult to handle. What is needed is an experienced project member, often the project manager or the project support person, who can defend the project. This person needs to explain and remind the participants why the original project is important and what a development project is best at doing. It might also be important to remind the participants what resources are available and what is realistic to achieve with them.

If there should be a severe attack on the project, it is often necessary to find support from the outside. Persons not directly involved do not have to argue their own case and have more credibility in defending against an attack.

Project management and coordination

A common work in a group requires an internal project management and external coordination with projects around it. The leadership can be formal or informal, but it must exist. Psychological and sociological studies have shown that a laissez-faire attitude is not effective. Laissez-faire leadership can be defined as a leadership that abdicates responsibilities and avoids making decisions. This leadership behaviour can even be destructive and associated with workplace stress, bullying at work, and psychological distress (Skogstad et al. 2007), Similarly, an hierarchic autocratic leadership is also not very functional(Tepper 2007; Kiazad et al. 2010). What works best is a leader who not only strives for consensus but also can take own decisions when the group cannot reach a consensus within a reasonable time.

In a project, the project manager does not have the formal authority to control the project members in the same way a line manager can. Additionally, many projects involve cooperation across the borders of organisations. The leadership of a project is more like the leadership of a club, or an organisation driven by volunteers. This makes it important for the leader to create good personal relations with the project members. It is important to listen carefully to their views and their suggestions. Then the leader should try to summarise the best ideas from their suggestions and present the summary back to the group, trying to unite the group behind it.

The project leader should not be afraid of making suggestions for solutions. If you only present a problem without any suggestion for a solution, it often creates confusion. It is much better to suggest a solution. If the suggestion is not a workable one, you will at once hear alternative suggestions or amendment. This is especially true if people feel safe to contribute to the group.

Everybody can contribute with good ideas. But all people also have prejudice, suggestions that are not well thought through, and confusing ideas. It is the project leader's job to sift through the suggestions and try to focus on the good thinking and see that those thoughts get noticed.

Connections to the outside world

A project must keep connections to the outside world. The project is dependent on receiving information from the outside that might not be directly available to the project members. It is not very effective to reinvent the wheel. Therefore, development projects should start by reviewing literature, reports, and other investigation within the field. There is much open information available, but it might also be worthwhile to get help from research libraries or patent search experts.

One way of achieving quick success in a development project is to use information from another area that has not been used in your own area yet. This comes at a price of having to learn new terminology and having to learn from another field. But when you have overcome this initial resistance, it might be a very worthwhile exercise.

In my own research field, which has been technical ceramics, this was very apparent. In the beginning of the 1970s, when high strength ceramics were developed, a huge step was taken by using fracture mechanics. The science of fracture mechanics had been developed by researchers working with metals. By using fracture mechanics, the important factors that determine the strength of ceramic materials could be identified. This enabled a rapid progress to take place. From the 1970s and two decades forward, the strongest ceramic materials went from 300 to 2000 MPa in strength. This is like starting with cast iron and ending up with high strength duplex steel, a process or a development that took considerably longer time.

In the beginning of the 1980s, researchers borrowed knowledge from surface and colloid chemistry to improve powder processing and forming methods. Without all the available knowledge in surface and colloid chemistry, the development would have been much slower. The threshold for this development was a bit higher. The reason for this was that many researchers and developers in the ceramic field had a background in metallurgy and material science. To understand and apply surface and colloid chemistry there, it was necessary to have additional chemistry knowledge. But once that chemistry knowledge was attained, the already existing knowledge could be reused for ceramic development.

Documentation and structure

Creativity and new thoughts are necessary, but documentation and structure are also essential for development projects. When the results from a project should be used, it is necessary to also have all important details documented. This can prove crucial when the results are applied on a bigger scale.

You need both a structured planning of experiments and a thorough documentation. This is especially true if you need to go back to solve problems. The time you are forced to change a raw materials supplier or component supplier, you need good information about why the initial choices were made. Everybody who does development is encouraged to document all tests and experiments carefully. This is an important aspect when you choose members of a project group for a larger project. There are more competences that are needed in a project team apart from creativity.

Resources and support

A project needs resource. It must have a budget. In its simplest form, it is just a personnel budget. The real zero budget project is done by somebody in their spare time.

But a project might demand investments in equipment, models or mould costs, external consultancy, costs, patent costs, and many other costs. It is important that the project has access to the resources in the form of money, time, and internal and external resources. For this reason, somebody in the project should have the role of obtaining the necessary resources.

Many development projects have taken place even if there was a lack of resources. But by borrowing or "steeling" resources from other departments or persons, it is still possible to find what is needed. Limited resources are seldom the explanation for failed projects. The lack of a person who really believes in and fights for the project is often what makes project fail.

Astra Zeneca's ulcer medicine Losec (known as Prilosec in the USA) that inhibits the production of hydrochloric acid in the stomach was a big success for the Astra company and made up 45% of the total sales in 1996. This was before Astra was merged with Zeneca. The medicine was based on a well-known substance, named omeprazole, that could inhibit acid production in the stomach, a so-called proton pump inhibitor. This substance had a very short-term effect. The invention was creating a pill that enabled a slow release of the active substance in the stomach. The development was not well supported by management initially and was threatened to be shut down on several occasions when it ran into problems. But with some internal cover-up and with external help from the university, researchers made studies free of charge the success was eventually a fact. Losec was followed by Nexium that improved on the initial concept ('Omeprazole' 2021).

When you fabricate a large porcelain object, the drying of the clay must be done very carefully to avoid drying cracks. The insulator for high-power electric transmission can be over 2 m in height and the thickness of high-voltage insulator walls can be over 10 cm. If you form an object like this from plastic clay, it takes a very long time to dry. Even if you dry it carefully, there is a large risk of forming cracks during drying.

Engineers at ceramic producers invented a way to form insulators with a dry ceramic powder. This reduced the time for drying and the risk of cracks. A dry ceramic powder was put in a rubber mould. This mould was put in an isostatic press (press filled with liquid) and liquid compacts the ceramic to a solid body. Since the powder was nearly dry, there was a very short drying time, and the risk of cracking was eliminated.

But management did not like this idea, so the engineers had to try the idea without telling management. The company that manufactured the isostatic press was eager to test a new application for their press so they could get access to the press and do the test in secret. It turned out to be an excellent method and was eventually featured as the big competitive advantage for this ceramic company. Today, similar methods are used to form ceramic whiteware, for example, plates, since the speed of forming surpasses old forming methods using plastic clay.

Triage in projects

Edward Yourdon was a software engineer (1944–2016) who among other things co-developed a method for object-oriented software design. In his book "Death March – the Complete Software Developer's Guide to Surviving Mission Impossible Projects", he describes a common dilemma for projects in a very entertaining way (Yourdon 1997), Yourdon's definition of a death march project is a project where the time plan, the number of persons, and the budget are half of what it should be and the expectations are double of what is reasonable.

Yourdon gives good advice on how you can survive such projects. A death march will always end with casualties. In war, it is death that threatens. In industrial projects, the casualties are divorces, depressions, and good people leaving the company for other employment.

He compares such situations in projects with medicine at the battlefield or a major disaster where the numbers of wounded overwhelm the capacity of the medical personnel. In this situation, it is necessary to use triage. Triage is the procedure when you try to determine who will survive without medical help, who will die whatever help they get, and who can survive by treating them first. You focus the initial efforts on the last group of patients. In the same way, you should choose the functions in a computer programme under development that you can live without because they are not so important, the functions that are totally unrealistic to achieve in time, and the functions that are most important and can be achieved.

It is often possible to reach 80% of the functions with 20% of the work. At the same time, you might be able to do without the last 20% of the functions that might have needed another 80% of effort. My own experience is that most applied research project proposals are unrealistic in what they claim to achieve.

In research, it is difficult to assess what you can achieve with the available resources. To get a project approved both by participating companies and by the funding agencies, it is often necessary to promise too much. But usually everybody is aware that when you try to do new things, you also find yourself facing new problems. This means that if you only can show clear progress, even if you don't reach all the planned objectives, the project will still be deemed a success. In the best case, the limited success will give you more resources to do the rest of a necessary work.

Another important concept is handling of risks. All projects involve several risks. When you develop something new, you must take risks. It is important to plan for these risks and try to understand them. You need to plan escape routes that you can take if one of these risks makes it impossible to follow the original plan. During the project, it is necessary to review these risks and the status of the different project parts to avoid a catastrophic scenario that might jeopardise the whole project.

Quality and quality measures

There are several quality standards that are used in industry that might be applied to projects such as the ISO 9000 quality, the ISO 14000 environmental, and ISO 56000 innovation management standards series. These systems all have merits but also drawbacks when it comes to leading creative work. The ISO 9000 relies heavily on fixed documented procedures and while these might be crucial when developing for the avionics or pharmaceutical applications, they are not always suited for early-stage development.

The ISO 14000 standards have valuable procedures that can be used to evaluate the environmental impact of product or process. But the standard procedure for life cycle assessment might be very difficult to use in an early-stage development where the product or process is not yet fixed. Recent research by Mats Zackrisson has explored the possibilities of using life cycle assessment prospectively to help researchers in an early stage of development do rough assessments and compare ways for developing with minimum environmental impact (Zackrisson 2021).

The ISO 56000 series is a relatively new standard tailored for innovation management. It is in large parts a descriptive standard that gives a general description of how to manage innovation. There is still a lack of results from practical uses of the standard.

The Japanese method for quality improvement is called Kaizen. It is a method of small improvement rather than fixed standards. It tries to involve all employees in a gradual improvement of work, for example, in a factory. Potential quality problems are analysed, and improvements are made in small steps against a goal with very high expectations.

Quality goals

Good validity is hard to measure quantitatively; it is usually a qualitative property. You can strive for good validity by reviewing what you really want to achieve or understand and compare that to what you are doing in the project. Doing literature surveys and interviewing other experts in the area is one way of increasing the validity. To ask open questions to your customers or end-users is another way of trying to examine validity.

In projects with large steering committees, you can use formal project evaluations. George Walters, a management researcher at Rutgers University, developed a system for these evaluations for the Center for Ceramic Research that was formed at Rutgers University in the 1980s. This was one of a series of university-based research centres that had paying industrial members that were created under the (Industry-University Cooperative Research Centers [IUCRC] programme by the National Science Foundation.

The research centres that were created had the goal to make university and industry cooperate closer together. This was done by creating a system where industry could become member in the centres and influence the research. This was a shift in trends for the USA where it was common for large industries to finance research mainly to get a good reputation and be able to recruit highly qualified staff more than benefiting directly by the research they were financing.

The new research centres were built with the idea that the research should be within areas that were potentially useful for their industrial members. George Walters designed a system with questionnaires to evaluate the usefulness of this system.

At this time, I worked at the Swedish Ceramic Institute and managed a similar programme that had been running for a while where we had industrial members that financed the research programme. We were invited to be part of a cooperative project with Rutgers University. We also took part in using the questionnaires to measure the effectiveness of our research and of our cooperation with Rutgers University. We had great difficulties in using some of the elaborate questionnaires that had been developed. The people in industry who were supposed to answer did not submit their questionnaires and the high nonresponse rate made it impossible to rely on the answers.

But one part of the system worked exceptionally well. We had project meetings where the status and current results of several ongoing projects were presented. A simple questionnaire was used after each project presentation. The results were summarised during a break in the project meeting and presented back to the participants. The evaluation results were then used to suggest and agree on improvements of the work in the projects. This direct feedback increased the interest both in the industrial representatives and the researchers.

At the project meetings, there was often vivid discussion around suggestions that came out of the evaluation questionnaires. There were often suggestions for changes to the projects. The suggestions did not always result in the proposed change, but they nearly always resulted in some type of change to the project. At the end of each year, we could demonstrate that industry had a large impact on steering of the projects by just summarising the number of changes that were made to the projects at suggestions by the industry representatives.

Reliability is another measure of the quality of research and development. A measurement has good reliability if you can repeat it and get the same result. You need stable measuring instrument, good calibration, and people trained in measurement procedures. You also need a thorough documentation. If everything around an experiment is documented, it is much more likely that you can repeat it. If you cannot repeat, it is easier to find out what is different this time. You also need to know that you are measuring on a representative sample. Questionnaires with a high non-response have a low reliability as mentioned above. There are statistical methods that can be used to measure reliability. These methods however need to be properly used and understood.

A thorough documentation does not need to hamper creativity. You can do preliminary trials to try out freely without large investments in time. But if you want to reuse the results for further development, you need documentation. By using databases or forms, you can ensure that you are reminded not to leave out any information that you deem important.

Time planning

"Hofstadter's Law: It always takes longer than you expect, even when you take into account Hofstadter's Law". From Douglas R. Hofstadter's book *Gödel, Escher, Bach* (Hofstadter 1980)

Hofstadter uses this "law" to illustrate how a recursive paradox works. But there are widespread ideas that say that it is impossible to plan time for development projects. And it is true that there sometimes occurs unforeseen problem during a project that takes time to solve. But it is also true that developers or researchers with experience are good at estimating how long it takes to perform a certain work.

When I was project manager of a development programme, there were recurring problems with work that was not finished in time for the project meetings. We were developing strong ceramics and we had to go through several stages in powder processing, forming, sintering, machining, and measurement of mechanical strength. There were several people involved, each a specialist on their part of the process. I started to walk around to each participant in the project asking them what their process steps were and how long it would take to complete them. With this information, I set up a time plan. Then I went around several times adding steps that were forgotten in the first plan and modified and got everybody's agreement.

What happened was that all the persons involved had a very good idea about how much time they needed for their part. When we put the plan into action, we were able to deliver the results in time for the next project meeting according to the time plan. An unexpected failure of a major equipment or something else unforeseen could of course still have caused delays.

What had made the plans fail in the past was the complexity of all the steps and the involvement of many persons. But just as important was that nobody had gone through the steps and accounted for what time they took. When this walk through was completed and everybody had agreed to their part, then the planning started to work.

Many development projects are run as a matrix organisation. This means that several persons work with several projects. Each person does the job they are best at doing. This type of organisation puts extra demands on time planning. The biggest problem is often that each person in the project had not had a chance to plan their job and to sum up all the requirement for a particular time when they are supposed to work with several projects simultaneously. If a particular person's work is essential for the project, this might cause unavoidable delays.

A study of collaboration in more than 300 organisations showed that 20% to 30% of value-added collaboration comes from 3% to 5% of employees. These persons are both capable and willing to help. Being willing to help and competent, they are quickly drawn into important roles, and they become increasingly valuable for the organisations. But this quickly escalates beyond the person's capacity to be useful. The person then becomes an institutional bottleneck (Cross, Rebele, and Grant 2016).

It is important to use key persons in an effective way. A collaboration where the key person is asked for information or asked to point to where the information can be found is less time consuming and exhausting than when the key person is asked to do the job. By streamlining and encouraging people to collaborate more efficiently, the key person can contribute better to a successful job. It is also important to use key personnel to teach or mentor other employers so that they become independent and gradually can take on more complex jobs.

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7 A strategy for managing intellectual assets

Introduction to intellectual assets

When you develop something new, you invest time and money in this process. To be able to make this investment count, it is necessary to look at intellectual assets. What would stop a competitor to take over your ideas and do the same without the need for a prior development investment? The answer to this is the possibility to own intellectual property. Patents and copyright are perhaps the most well-known types of intellectual properties, but there are several other types that can be used to protect your development effort.

Patents

A patent makes it possible to have an exclusive right to an invention. Patents make it possible to protect an invention and the development work and keep competitors from copying your product or process. The following is a short description to enable a further discussion with a patent expert (patent attorney) and to be able to discuss strategies around patenting. This will be a very brief description and will not be a replacement for expert knowledge and contact with patent agency.

You can apply for a patent, but to get the patent application approved, there are three basic requirements. The invention should have novelty, an inventive step, and it should solve a technical problem reliably.

Novelty means that the invention should not be known already. This means that the invention should not have been presented in a publication, lecture, conference, online, or some other way. If the invention has already been described by yourself or by somebody else, the demand for novelty is not fulfilled, and the invention cannot be patented. The novelty can be that an existing technology is applied in a new area or in a new way that is not obvious. In university research, you need to publish the results, and it is very common that researchers publish in a way that makes it impossible for them to patent. So it is important to patent first and publish later. This might seem like a trivial statement, but in my experience, it is very common that a researcher makes patenting impossible by publishing too soon.

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Inventive step means that the invention should solve a problem in a way that is not obvious to a person who is trained in the technical area of the invention. This means that a standard solution cannot be patented. This requirement is less clearer than the novelty requirement, and there is sometimes a discussion between inventors and the patent office about the inventive step. So if your patent application is met with a lack of inventive step from the patent office, there is a chance that it will be accepted if you can explain why your solution would not be obvious to a person versed in the field.

The invention must also solve a real technical problem to be patentable. This means that a patent must have a potential commercial value, and you cannot patent a scientific discovery that only describes a phenomenon or that only creates new understanding. You cannot patent a work of art. Work of art is however protected by copyright as will be described later. For biological natural organisms, it is not allowed to get a patent on the organism, but it is possible to patent a discovery of a way to use the organism. But organisms created in the lab by gene modification can be patented.

The technical effect must be repeatable. You must get the technical effect if you apply what is suggested in the patent application. This means that it is impossible to patent a perpetual motion machine, for example.

A patent is granted for a particular country. If you apply for a patent, you have one year, called the priority year, where you can apply for patents in other countries than the one you first filed in. It is however possible to apply for European patents. But the European patent must be validated in each specific country in Europe to get protection in that country. This is however more of an administrative procedure since all European countries have agreed to use the same grounds for approving patents.

To apply for patents is costly. It is especially costly if you want protection in many countries. To apply for a patent in a country other than your own, you need to be represented by a patent attorney who is authorised in the country where you apply.

When a patent is issued, it is usually valid for 20 years. In some cases, it is possible to get an extension for pharmaceutical patents, but 20 years is the standard. Each year, you pay a yearly fee in each country to keep the patent in force. The older the patent, the higher the fee. This means that as an inventor you need to exploit the patent as soon as possible – either by selling it or by starting a business that manufactures products or uses the process described in the patent.

If a particular product is protected by a patent, it grants the owner of the patent a monopoly to produce in or to import products to the country where the patent is valid. In countries where there is no valid patent, it is still allowed to produce products, but it is not allowed to export them to a country where there is a valid patent.

If you own a patent, you can also license the right to use it for other companies. A license of a patent can work in many ways. You can license generally or only for a certain application area. You can license exclusively for one company or for several companies. A company that buys a license can pay a one-time fee or a royalty based on how much you use the patent or both. The conditions in licenses are negotiated between the licensee and the licensor according to the situation.

It is important to note that the owner of the patent does not have to be the inventor. The inventor who is designated in the patent application should always be the real inventor. It is a basis to dispute the patent if you include the wrong inventor in the patent application. The owner can be the inventor, but it can also be somebody to whom the inventor sold the invention. The owner can also be the employer of the inventor who by law or agreements has the right to take over the invention. Many inventions are made by employees, and depending on local regulations and employment contracts, the invention can be owned by or transferred to the employer. The inventor is always a physical person, but the owner can be a legal entity as well as a person.

In many countries, an employer has a right to employees' invention by law. It is however common that the employee is granted monetary compensation for the invention. But this can also be regulated in employment contracts and in other agreements between companies. In Sweden and a few other countries, there is an exception for university researchers and teachers who own their inventions. But in most countries, the researcher's inventions are owned by their university. But this right can be transferred by agreements. It is common that companies that finance research at universities have agreement that transfer the right of any invention within a project to the financing company.

The parts of a patent application

A patent application consists of a title, bibliographic data, an abstract, a background description, a description of the actual invention, examples of how the invention has been realised, and claims. Examples of bibliographic data are dates for submission of the application and status of the application. The bibliographic data also include the inventor, the person or the organisation that has applied for the patent, patent attorney, and so on. Examples are often included to describe how the invention is to be realised in practice. The description often includes drawings to clarify the invention. The claims are a list that specifies what the patent will protect. They are often in a hierarchical order where the widest claims are shown first and more specific claims that reference the first claims are included later in the list of claims.

When you read a patent application, you can read it for several reasons. One reason is to find out if your own invention has already been described in the patent literature. In this case, all the text in the patent applications can damage the novelty of your invention. It does not matter if it is a patent or a patent application or in what country the application was filed. Everything that is published in the patent literature (and in other literature) influences novelty.

Another reason can be to see if a particular technology or invention is protected. This is specified in the claims. Anything that is not specified in the claims is not protected. This protection only exists if the patent is granted and active. Many patent applications are not granted as patents, and if they are granted, they still might be inactive since the owner of the patent might not have paid the yearly fee. The protection is only in countries where the patent is granted. During the examination process, there might be different objections by different national patent offices. This might have required changes to the patent claims to get the patent approved in a specific country. This means that the scope of the protection can vary depending on the country in question.

You can also read patents to learn more about technology in a particular field. Especially the examples can contain much information about technology that can be valuable. Since there might be many patents in a particular area and patents also reference other patents, it is possible to map a patent landscape. By looking at applicants, you can get an idea of the strategy of a company by looking at its patents.

How to find and read patents

There are free resources available to find and read patents. One such resource is the Espacenet, a resource that is available from the European Patent Office ('Espacenet – Patent Search' n.d.). This is a worldwide database of patents and patent application. You can search with an easy search interface or make more complex searches. You can use a query language and combine keywords using logical operators like AND, OR, NOT, and so on. It is also possible to search using the patent classification system. This system classifies all patents into classes of similar technology.

When you find a patent document, it can be a published patent application or a granted patent. Patent applications are confidential initially. After a maximum of 18 month, they are published. The actual time can vary depending on the country and how the application is handled. The applicant can withdraw the application to keep it from being published. But unless it is withdrawn, it becomes public. Granted patents are of course always published.

If you search for patents online, you will find something called a World Patent (WO followed by a number). Documents with WO are patent applications and not granted patents. They are a first step to apply for a patent in other countries than the country of the first application.

Patent disinformation

Society grants an inventor a monopoly to use a certain invention. In return, the inventor must give a description of the invention, and this is made public. A company might not want to disclose too much information in patents and would rather keep them secret. One common strategy is to make the patent less obvious. This is done by making the title and the abstract very non-sensical. An extreme title might be "a method to produce a product". The abstract can also be written in a way that makes it difficult to find the patent. This tactic is less important with modern search tools. It is also a reason to use a commercial patent search tool where the title and abstract are rewritten in a way to make it as easy as possible to find a certain technology.

In the examples of how to realise the invention it can be inserted examples that are not functional. One of the examples might be the most efficient way to implement the invention, but it might be buried among several less efficient methods. So it is advisable to read patents with a critical mind if you want to learn technology from them. The patent literature contains much information but also much disinformation.

Patenting strategies

Getting your patent granted

Writing patents is a craft in itself. After reading hundreds of patents, I wrote my own first patent application myself with very little external help except from my research colleagues. I was lucky to get the patent granted with very little professional help. Today I would say that I was the sole inventor but, on the patent, I have two co-inventors. I got the idea and put together a new type of equipment. A colleague of mine who did most of the experimental work to verify that the principle worked is mentioned as a co-inventor. The project leader who supported my idea and found resources in the project that were needed to build the equipment is also mentioned as a co-inventor. The inventor is the person who made the intellectual effort to create the invention, and this should be separated from the work of "reducing the invention to practise". But I did not know this at the time. I have been part of other inventions where it was difficult to know who got the idea first, but in this case, I knew it was my own idea. But I was happy to have my colleagues get part of the credit so there was no harm done.

I would strongly recommend using a patent agency to help with formulating a patent application. If something is worth patenting, the fee to the patent attorney will be only a small part of the investment that has to be made in the invention. The probability of getting a patent granted and the quality of the patent will probably be much higher with professional help.

What might seem like a previous patent or publication that would stop your patent might not be that by formulating the patent application in a smart way. When you file for a patent, you want that patent to protect as much as possible. That will help you avoid competitors doing a small change to the product to avoid your patent. You try to formulate the claims so that they cover a wide area that will make it difficult to avoid the protection of the patent. The patent office on the other hand does not want to grant patents that protect everything. They will often find open information that makes it difficult to claim novelty for a wide area. To navigate through this difficult landscape, the competence of a good patent attorney is invaluable.

The patent attorney you use needs to understand your invention to do a good job. Without knowledge and understanding of the invention, it is difficult to write a good patent.

I was once part of a research group that invented a new way of forming ceramics. This forming method was potentially very interesting to a large company that mostly produced mechanical parts. We had developed the method in a work for hire and the company owned the invention according to our research contract. They went to their regular patent attorney who was used to handle their inventions that usually dealt with mechanical properties and products. They have had very good experience with this attorney who had helped them secure several patents. We gave them a description of the invention, but after several iterations, the patent application did not seem useful. The company then shifted to a patent attorney who had much experience with patenting in the chemistry field. We immediately receive a good application for a forming process. This was understandable since the forming process was mainly chemistry based.

The competence of a patent attorney is personal. A large firm has a choice of several persons with different competences, but it is still one individual who gets to write your application. If you have an excellent patent attorney who has learned about your technology area that moves to a new agency, it is good advice you stick with the person rather than with the company.

Worldwide patents

There is no such thing as a world patent. But technology often needs international protection. There is a European patent that is granted by the European patent office and that covers most European countries. But to get a European patent granted in a particular country, it must be validated in this country. This simplifies the process of applying for patent protection in European countries but is still a slow and expensive process. Many products are sold on an international market and needs protection in more than one country. The most important places to have protection are countries where similar products are produced. Unless you have a very large budget for patenting, you need to pick strategic countries for you protection.

The USA used to differ from Europe because of the principle that the "first to invent" receives the patent. This meant that if you could prove that you had already made a particular invention you could claim the patent even if you were not the first to apply for a patent. During Obama's presidency, a new patent law in the USA, the "America Invents Act", changed this. So now the principle of granting patents is the "first to file" for a patent, not first to invent. This makes it much easier to determine who is the inventor when inventions are made close in time (Jackson Knight 2013).

The Patent Corporation Treaty (PTC) is a treaty signed by most countries in the world. This means that patent protection is treated in similar ways. It means that a patent office in one country will respect a news search done by a patent office in another country. By using a PTC international news search, you can get a document that describes any patents that might interfere with your patent application. The result is published as WO application with the patent application text and appended to the result of the new search. This is an early way to understand the likelihood of getting your patent granted. It is also a way to make patenting in several countries easier. But the WO application can only become patents in countries where the applicant decides to make a national application and where a national office grants the application and issues a patent.

Strategy for patenting on a tight budget

Make a first application that could be either a patent application in your home country or a European patent application. Read other patent applications in the field and try to put down the information of your invention in the same form. Check both the general and patent literature for anything that might destroy the novelty of your patent. The more groundwork you have done, the less work the patent attorney has to do. Choose a patent attorney familiar with the area of your invention. You can give the patent attorney a fixed budget to work with if you want even more control of your budget. A place to get information and help is the Intellectual Property Rights (IPR) Helpdesk, a function in the European Union (EU) that supports in IPR questions. They don't write patent application, but they answer questions and give advice; they also have much valuable information on their website ('European IP Helpdesk' n.d.). Other places with information about patents are your national patents office or the World Intellectual Property Organisation (WIPO n.d.).

When you have submitted the application, you have approximately 18 months to get funding for additional patent application in other countries (see Figure 7.1). Use this time to find out if there is interest in your patent application. Is your own or some other company willing to fund protection? Does the invention still seem valuable enough to pursue? If not, drop the patent application at this stage. Because when you start applying for patents in other countries, the costs will increase rapidly. Before a patent is published, you can withdraw it and it will not become public and will not stop a later patent application.

Sometimes you get new ideas or find out new things that you would like to include in the patent. You are allowed to change the wording of the patent, but if you include new information in the patent, this will shift your priority date forward. But you can withdraw a patent application before it is published and send in the revised application. This application will have the later date of resubmitting, but if the first patent was not published, it will not stand in the way of a resubmitted patent application. It is quite likely that you will get more ideas with time, so it might be a good idea not to be too fast when you apply for a patent.

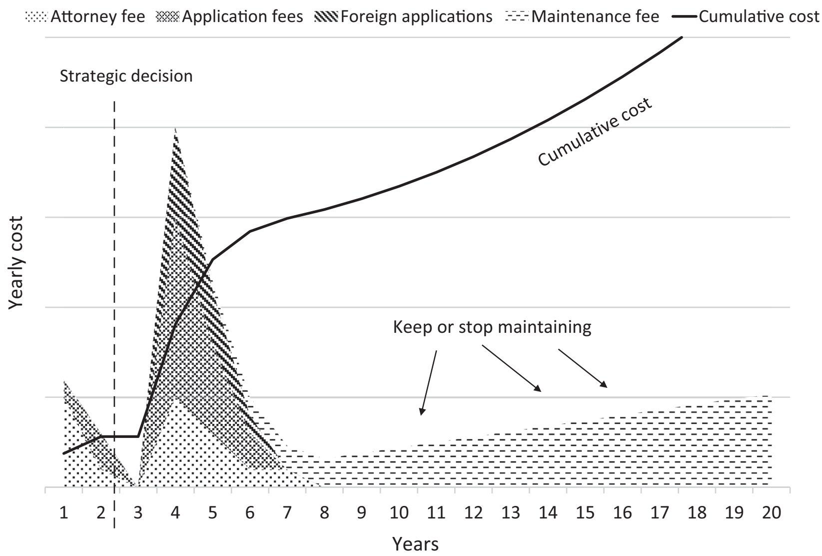

Figure 7.1 Example of relative costs for patent protection.

Why do you want to patent?

Patenting costs money, it takes time, and the outcome is unreliable. So why bother to patent? There are good reasons not to patent. And you might keep ahead of your competitors just by a speedy development.

The basic argument for patenting is to create a unique position in the market. If you can offer something that no competitor can offer because you are protected by patents, you are in a good position. Patents create a monopoly for a certain technology.

But patents also create an image. If you want to be seen as a technology leader whether you are a company or a research institute, it is good for your image to have patents.

I started my career at the Swedish Silicate Institute (later renamed the Swedish Ceramic Institute). The institute was formed after the war as a support for the Swedish traditional ceramic industry that manufactures brick, refractory, and porcelain. The founder of the institute Arvid Hedvall was a famous researcher in the field of solid-state reactions. An important factor of solid-state reactions – the Hedvall effect – is named after him. But the traditional Swedish ceramic industry was slowly shrinking when I joined, and the institute had gone through some rough times. But things were changing as the automotive industry had become interested in a new type of strong high temperature ceramics and the institute had a new dynamic leader, Roger Carlsson. For a long time, the institute had done applied research supporting the traditional ceramics industry with well-known processes and materials.

Now we had to move into a new territory of technical ceramics where we were a completely unknown player. We specialised in powder processing and forming of these new materials. This was much needed in a situation where labs could fabricate strong samples but where actual components with complex shapes were difficult to produce.

We put out some publications in this area that were well received but we also applied for several patents. Most of these patents were not a commercial success although some of them were taken over and used in industry. But the main effect of these publications and patents was to put our institute on the international map. It showed that we were not only studying the new materials but also trying to improve the processes for fabricating them. It had the effect that large companies outside of Sweden wanted to have contact with us. We were also invited to research cooperation both with US and Japanese researchers.

If you run a start-up company and want to attract venture capital, it is often necessary to have some patent protection. But this also depends on the type of your product. If you sell new information technology or if your business idea is a major part of your competitive advantage, you might not need patents to attract capital.

Valuation of patents

Valuation of patent portfolios

If you are looking at the value of patents in an entire company or the value of patents in a certain technology area, there are statistical methods to do the evaluation. To get an overview, you can use software that maps a group of patents and see how they cluster and give some indication of how they are owned (Camus and Brancaleon 2003). It is also possible to use statistical patent information to guide research within a particular research area (Pettersson et al. 2012).

There are also methods to find indicators of a commercial success. These methods rely on indicators that can be extracted from patent database. Examples of such indicators are the length of a patent, number of claims, number of independent claims, and number of technical advantages mentioned in the patent (Trappey et al. 2012; Reitzig 2004).

For many patents, the correlation between these factors and real (historical) successes is relatively large. These methods can be used to get an idea of the value of a patent portfolio consisting of many patents. If you look at single patents, the value is strongly affected by factors that you cannot obtain from the patent database, so the method is not usable for single patents.

Valuation of single patents

If you are going to decide if you should patent a particular invention, you need to at least have a rough idea that this potential patent will be valuable.

Here is a description of factors that can be used to evaluate single patents or a certain technology.

Many of the factors are described by Wartburg and Teichert (Wartburg and Teichert 2008). They point out that there are several levels that you should consider. You can look at either one step of the value chain or the entire value chain. Modern products are often manufactured by a chain of suppliers. For a textile apparel, the steps might be growing or manufacturing of fibres, spinning of yarn, dyeing of yarn, weaving of cloth, sewing an apparel, shipping, and selling. Each of these steps can be made by different enterprises in different countries. For each step or for the entire value chain, you can look at both static and dynamic effects. Introducing a technology that is new to the company often has dynamic effects since this opens for other types of technology shifts. For example, within the trend to work with digitalisation, you can often find dynamic effect where introduction of digital technology might influence the entire development of a company.

Static valuation of patents

A static valuation for one step in the value chain is influenced by several factors. One of the most important factors is the protective value of the patent. The value of a patent increases when the associated IPR becomes stronger. The strength of the IP-rights depends on how wide the coverage of the claims is and how easy it is to show that there has been an intrusion. The value of the patent is also dependent on the value of the technology that is protected. To judge the protective value, in a patent or a patent application you should look at the following subfactors.

The performance of the technology compared with existing technology

Performance can consist of several factors such as functional capacity, flexibility, efficiency, environmental footprint, and work environment. These factors are often not possible to combine as a single measure.

The performance of a product depends on the type of product you want to describe but it is also possible to describe the performance of a product from different angles that might represent different groups of customers. For a car, the number of passengers, baggage space, acceleration, and mileage might be used to measure performance. For a software, there might be other relevant parameters such as user experience, flexibility, and integration with other software. Environmental performance can be measured by, for example, energy efficiency, carbon footprint, ozone depletion, eutrophication, or ecotoxicity.

Manufacturing cost

What does it cost to manufacture a product compared to existing technology? Or what does the new process cost to set up in comparison to the existing processes? Does it require expensive new equipment or other special resources? For some inventions, this is relatively easy to calculate as there are standard ways of manufacturing certain products that are easy to estimate. But you nearly always will find that manufacturing costs vary with the volume of products that you need to manufacture. For small products (low weight per product), forming (machining, moulds), handling, and assembling costs are often dominating. For larger products (higher weight), the material cost often dominates. There is a rapid decrease in cost with the size of production series for manufacturing method that uses moulds or specially designed tools or manufacturing that uses a high degree of automation.

It is valuable to have an intimate knowledge of manufacturing methods when you design a product where cost is influenced by manufacturing. There is an interaction between design and choice of manufacturing methods that will influence price.

If the invention is a software, there might not be much of manufacturing costs. There might be costs for licensing if the software uses other software modules that have a license cost. Substantial costs associated with delivering a software to the market could be the cost of regular updates or bug fixing, adapting to new platforms, adapting to new versions of the operating system, and so on.

Readiness of the technology

How far from a finished product or process is the invention? TRL (Technical Readiness Level) and MRL (Manufacturing Readiness Level) are measures that can be used for this. These measures are described in Chapter 10 "Strategy for innovation". There is a huge difference if we have an invention that works in the lab compared to a field-tested prototype.

Coverage of the claims

If you have a wide coverage of the claims, it is very difficult to circumvent the patent with an alternative method. A wide claim covers the principle behind the technology encompassing several possible solutions. A narrow claim covers only a small feature of the product or process.

Imagine that you have discovered the first window. If you want to patent the invention of the window, you might claim: "A transparent glass pane in a wooden frame for application in a house". Compare this to an alternative claim that says: "A transparent material is fitted in a frame that transmits light between the environment and the inside of a manmade structure". The first claim does protect a number of possible windows but only for use in housing. A car window would not be protected by this claim. You could also avoid the patent protection if you use an acrylic window instead of glass or if you use a metallic frame. The second version of the claim is much wider. If you make the claim too wide, there is always a possibility that there is an existing invention described that fits the claim. Then your patent would lose its novelty. So exactly how the claims are formulated is crucial for the protective coverage, and this will influence the size of the potential market and consequently the value of the patent.

Detection of an intrusion

How easy would it be to detect an intrusion to your patent? Can you see it on the outside of your product? Do you need to take a product apart to detect the intrusion? Do you need to inspect the inside of a competitor's factory to detect the intrusion? A patent of a process to produce a material will have a higher value if you can detect an intrusion by examining the material. It is still possible to get a court order to examine the process if you suspect a patent intrusion. But this is a more complex process than just examining a product. In the paper and pulp and the iron and steel manufacturing industries, there has traditionally been few patent applications compared to other types of industries. The reason has been that many potential patents in these types of process industries only would protect something that is not visible outside the plant. But with time, patenting in these industries have increased.

At the ceramic institute where I worked, we invented a process to make a ceramic that was whisker reinforced. The process involved a method called freeze granulation that froze the whiskers in place during granulation. This is a process that proceeds the sintering of the material. The advantage with this process is that the whiskers are oriented in all directions and not preferential in just one direction. This was an important advantage in producing cutting tools. In our internal discussions, we did not think of this as an important invention, especially since we thought that it was a process invention and process inventions are often difficult to protect against intrusion. But the company that we cooperated with understood that we could patent the microstructure and not only the method to produce it. By including the microstructure in the patent claims, we could get protection of a feature that could be examined in the product.

Depending on when the patent application was submitted, there might or might not be options to extend the patent to more countries. This might influence the value of the patent depending on the customer who wants to exploit the patent. You might have invented a product that you think has a small market in China and not filed for a Chinese patent. If your major market is Europe and the USA, you would still be protected from a Chinese import. But a company that has a major market in China might want to extend the protection with a Chinese patent.

Protected part of the value

An invention is often a component or a product that is part of a larger value chain that might consist of many products. It is important to not count the whole value chain as the value that is protected if the patent only protects a component. This is especially true if the component can be replaced by

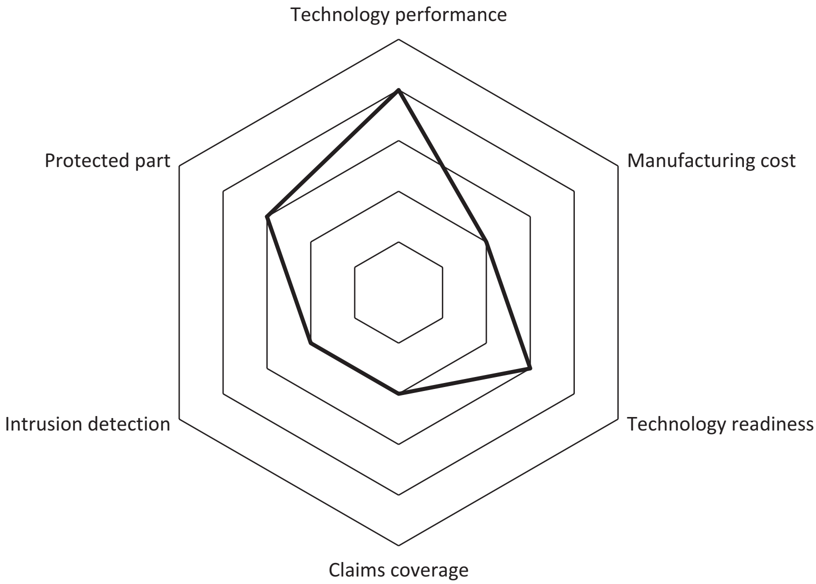

Figure 7.2 Factors that influence the static value of a patent.

other components or if the product can be redesigned to work without this component. But the value can also be larger than the value of the component if the component is a strategic and invaluable part of the value chain (see Figure 7.2).

Xerox patented the mechanism for the electrostatic copier with a patent that protected the strategic key components in the copier. There were other methods that could be used to build copiers but none of these methods could compete with the Xerox method for a long time. In this case, the patent was much more valuable than the single component it protected.

Resource environment for exploitation

It is not possible to value a patent without relating it to a potential owner that benefits from the patent. For this reason, it is important to include the potential owner or owners in the evaluation of the patent. The value of a patent will increase if it is strategically placed, that is, when the company has the right resources to exploit the patent (competence, manufacturing resources, marketing resources). The value also increases when it protects a technology that is within the central strategy of the company and protects a technology that is essential for the company's products. This means that the value can differ greatly between different companies. It also means that an inventing research organisation that can supply the lacking competence that is needed to exploit the patent can give the patent extra value. Research and

Technology Organisations (RTOs) that have large demonstration facilities can help a company take important steps in exploiting an invention not only by developing production methods but also by training company personnel in technology that is new to the company.

Metal injection moulding was a new technology for forming of metallic components that was developed in the 1990s. As the technology developed, several spin-off companies were started to exploit the technology. These companies had to build a new customer base, develop a technology that was not totally ready for the market, and build competence in injection moulding, design of moulds, and sintering of metal powders. Injection moulding gave a new freedom of design compared to previous powder technology methods, but this design freedom also had very strict limitations that needed to be understood. Many of these companies had a partial protection of their technology. But most of these companies did not survive in the long term. The successful exploitation of this technology comes from companies that produced in-house. These companies did not have to explain their process to a new market. The in-house producers had internal customers that could use the design freedom of the new technology and work closely with the producers to solve any production problems. Another successful example is the BASF chemical company. BASF developed and patented a special composition for injection moulding that solved one of the major technical issues, which is removal of the polymer prior to sintering. As a large company that already delivered polymeric raw material to the injection moulding industry, they knew what an injection moulding company needs to produce successfully. They could deliver the complete technology with compounded metal and polymer ready for injection moulding together with processing data. In this way, they took over a large part of the metal injection moulding market.

Market position

The value of the patent increases when it makes it possible to create a more competitive position for a company in their part of the value chain. The value is influenced by earlier market successes. A company that dominates the market for a certain product will feel a large threat by new technology that might jeopardise their market position. The company also has larger resources both for paying for an invention and for developing the invention (see Figure 7.3).

Dynamic valuation of a patent

The previous section describes the value of a patent or technology in relation to the present situation. It does not consider future potential regarding technology, positioning, or business logic. It is also possible to make such a dynamic evaluation where you try to account for future effects. The following factors should be considered.

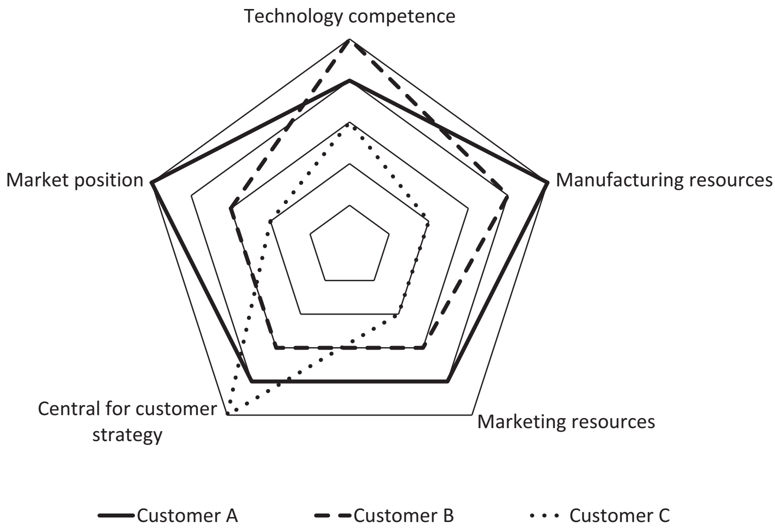

Figure 7.3 Value of a patent for three potential owners with different situations.

The protective potential of the patent

The value of a patent increases in proportion to the probability that the patented technology becomes a necessary ground for dependent patents. A patent that opens a new area can often lead to further inventions that cannot be utilised without access to the main patent. Such dependent patents can be applied for by the holder of the main patent or by competing companies, but they cannot be utilised without a license to the main patent.

Tetra Pak protected the principle of creating a cardboard tube that was continuously filled with a liquid where the cardboard tube was welded together and cut and folded to a container for liquids. The original inventions that were protected by patents have been the foundation for further development that also have been protected. For example, the development of aseptic containers and containers with a screw lid in plastic – these were packing that relied on the original invention. Such dependent patents can also function as a prolongation of the protection when the original patent expires after 20 years.

Resource development potential

The value of patented technology increases when a company increases its ability to control the knowledge and competence that it develops when it develops and implements the patented technology and creates a base for transforming it into future products and/or solutions.

A company complements its present competence and capacity within mechanical machining with competence within injection moulding to be able to produce new metal products with new shape capability. But apart from this business opportunity, the company might develop by being better at integrating components where metal parts are combined with polymeric parts. This can happen because of increased competence in injection moulding that is required for integration with metal parts. It could also happen because injection moulding of a polymer around a metal part is an efficient production method for such parts and can be done if an injection moulding machine is available.

Competitive potential

A patent's value increases if it is likely that the patent's owner in the future can create a better position in their competitive environment and in their part of the value chain. A dynamic view is especially important to be able to answer the question if a company should choose to license out a certain technology to other companies. A strategic question is if out-licensing of a technology could make the technology an industrial standard, which in that case would create a new competitive position.

Historically, Apple and IBM made very different choices for other companies to make use of their patents and industrial secrets. For IBM, this led to that the IBM-PC became the industrial standard, something that dramatically increased the market for the IBM-PC. But with time, it also led to that the IBM lost control over the market. For Apple, their more closed strategy gave them a smaller share of the personal computer market but it also enabled innovations that required control over both hardware and software, for example, the handling of copyrighted music in iTunes on a computer and later on the iPod and iPhone.

The monetary value of patents

The cost method

One way of valuing a technology asset is to measure what it would cost to develop the technology. This can be done in several ways. One way is to get historical cost and recalculate them to the current price level. Another way is to make a prognosis for the cost to recreate the technology or the cost to develop a new technology with the same use-value. An estimation with the cost method can also include cost reductions that the user can get with the new technology. The cost method is a relatively simple method for calculation of a value. The problem with this method is that the value for the customer might be far from the cost to develop the asset.

The market method

The market method measures the value by getting a picture of how the market estimates the value by comparing prices for similar IPR that has to be sold or bought. To be able to make a just comparison, you need to identify comparable units. Common units in this case are market shares and capital investments needed for exploitation. Data from transactions then must be collected. After this, the ratio between the value for the transaction and the operative value is calculated. The method requires that there is a market with enough actors and that the transactions are public. Both these conditions are seldom fulfilled in practice, which makes it difficult to use the method. But the technology transfer office at a large university or a large enterprise might have enough internal data to use the market method.

The income method

It is possible to calculate the value of an asset as the present value of a future stream of income from exploiting the technology. To calculate this, you must sum the net cash flow (incomes minus expenditures) for a number of years. The net cash flow should be adjusted for the inflation, interest rate, technical risk, and market risk. To be able to perform the calculation, it is necessary to make a projection of sales figures for the total market, the company's market share, and market penetration (how large part of the own market is replaced by the new product). Then the costs for manufacturing as well as the sales price must be calculated. There are large difficulties in doing reliable calculations in most cases. But in general, these types of calculations show that the time to put the product on the market is a key issue. A positive cash flow that is closer in time is more valuable than a future cash flow. This fact is important for decisions on investments in product development.

The option method

The limitation with the income method is that it handles future possibilities and risks in a very schematic way. The income method assumes that the prognosis for the revenue flow is correct, and it handles all risks with just one risk factor that is very difficult to determine.

Real cash flows are stochastic and full of risks by nature and the risk varies over time. The option method is a further development of the income method where you try to account for uncertain events. From a number of factors that describe both cash flows and risks, the value can be estimated with Monte Carlo Options simulation (Razgaitis 2009).

In Monte Carlo simulations, each input variable is not only given a fixed value. The variable is described statistically. In the calculation, you can choose a minimum and a maximum value with values in between having an equal probability, or a symmetric distribution such as a normal distribution with a mean value and a certain standard deviation. But you can also choose a skewed distribution such as a beta-distribution. When the variables are described, the simulations start with many calculations with input values randomly chosen with a probability based on each variable's description.

Instead of one result, the simulation will show a mean value and a statistical spread around this mean value.

Trade secrets

Instead of patenting, it is possible to safeguard intellectual property as a trade secret (or industrial secret). The advantages of relying on a trade secret are that there it can be done directly without any external approval. The secret can be licensed out just like a patent but there is no time limit. A patent expires after 20 years in most cases, and after it has expired, anyone is free to use the technology in the patent. There are no external costs such as a patent attorney fees or patent fees in the case of trade secret. An invention that might be difficult to guard against intrusion, for example, a process patent, can often be better protected as a trade secret. The downside is that industrial secrets cannot be used on inventions that can be observed directly from the product. Also, anybody who invents similar technology is free to use it. They are also free to patent the technology.

There are some requirements for an industrial secret. You must show that you are keeping it a secret. Everybody who encounters the secret within your organisation should be reminded regularly that it is a secret. It is a good practice to keep the number of people who know the details of the secret as small as possible and keep a record of who they are. Trade secrets are often deposited in a sealed record at a notary public to retain a proof of when the invention was made and what the invention consists of. This record can be used to claim the right to keep using the secret even if somebody else should patent it. Trade secrets are often used to safeguard knowhow from being lost when employees leave a company. They are also often licensed as a package together with one of several patents.

Copyright

Copyright is another type of intellectual property. It is the right to make copies, performances, or in other ways transmit a work of art to a public audience. A work of art can be a written text, a painting, a drawing, a video, a piece of music, and so on. That it is called a work of art does not mean that there is a quality requirement. Every original text (at text that is not a copy of another text) is considered a work of art in the copyright context and it is similar with illustrations or music. Copyright is an automatic right that gives the creator of the work of art the sole right to create copies or transmit the work of art to the public. Copyright does not require registration and it does not require the © symbol or a copyright message. It is advisable to use the symbol and include a message, but this is as a reminder and not mandatory. Most countries in the world have signed the Bern convention that regulates copyright in similar ways.

With patents, you must apply for the patent before you publish. To get copyright, you just have to publish. You get a copyright protection in most cases that will last 70 years past the death of the creator of the work of art. Patents are usually valid for a maximum of 20 years provided that the patent is granted and that you pay the yearly fee. But the copyright protection only protects the form of the work. It does not protect the idea or the principle behind the work.

You can sell or licence the copyright. By doing this, you can transfer the whole right or part of the right to another party. When copyright is licensed, it must be specified. Therefore, it is important to know for what purpose the copyright is licensed. Copyright is often assigned very specifically for a certain time or a certain number of copies. The license to print copies of a book does not automatically include the license to make a movie of the book. If you create an illustration, you might license it for use in a book. This does not automatically mean that it can be used in a magazine publication.

It is common that a work of art consists of parts that are protected by several types of copyright. A TV series might be based on a book that has a copyright, but it might also contain music that has a separate copyright. When the TV series is broadcast or streamed, the copyrighted material might have licences that allow performance for the public that differ between different geographic areas. The pieces of music used in the series might be different copyright holders in different countries, for example.

Design protection

It is also possible to protect the design of a product. Design protection protects the appearance of the product but not the function of the product. A sofa can be protected by design protection. If the sofa has a new smart way to be converted into a bed, this function could be protected by a patent. The design protection will only protect the appearance of the sofa as a sofa and as a bed. Without a patent, another company can use a mechanism with similar function, but they are not allowed to give the sofa a similar appearance. In the same way, it is possible to protect software. The appearance of the user interface of a software can be protected by design protection. This protection will not protect how the software interacts with the user; it will protect only the graphic design as such. Currently, it is not possible to include animations or videos in design protection. It is possible to include a limited number of drawings or photos. But if you want to protect a dynamic design that moves and evolves, the possibilities are limited with design protection.

Designs must be new, which means that they should differ from any previous design. It must also be an elaborate design. This means that very simple geometric shapes cannot be protected. A design must be new, and after it is disclosed to the public, you have one year to register the design. The design cannot include elements that are protected by copyrights and trademarks that are owned by another party. Design protection can be sold or licensed in a similar manner to other immaterial properties. You can prolong your protection up to 25 years. Design protection must be applied nationally. After you have filed to register a design, you have 6-month priority to file in other countries.

Trademarks and branding

Trademarks protect a trade or a brand name. A trademark can be a text mark protecting just the name of a product or the name of a company. But a trademark can also be a picture that, for example, can show the product name written with a special font in a special colour. Trademarks can also be colours, music melodies, or other sounds. The trademark is valid for a certain category of product.

If a company has a trademark, this prevents other companies from marketing or selling similar types of products or services using the trademark. It also prevents other companies from registering a similar trademark in the same category of products. A registered trademark (both locally and internationally) is denoted by the ® symbol. An unregistered trademark is denoted by the ™ symbol for products and the ℠ symbol for services. For the owner of the trademark, it is important to use the symbols as a reminder. For an unregistered trademark, it means that the company is claiming it as a trademark. To a third party, it can also be useful to point out that you are referring to a trademark by using the symbols, but it is not mandatory.

Apple was originally a trademark for the record company formed by the Beatles. The computer company Apple also used the same trademark since it was used for a different type of product. But when Apple started selling music via iTunes, it was more problematic and required an agreement with Apple Records. The music group ABBA was not the first to use the ABBA as a trademark. ABBA is also well-known in Sweden as a trademark for preserved herring.

In science, there is also a type of branding that is important even if it is not a question of exclusive trademarks. If you are the first to discover a certain phenomenon, principle, or a chemical, you might be able to brand your discovery or your invention. Many chemicals are not described by their systematic name but by something chemists call trivial names. For example, sodium carbonate is commonly called soda, sodium sulphate is called Glauber's salt. Sometimes, a trademark or a brand name becomes the commonly used trivial name like, for example, Teflon for PTFE polymers. Spark plasma sintering is a new rapid way of sintering ceramic materials. Today, it is used, for example, for making optical lenses for smart phones. Spark plasma sintering might not even work by creating a plasma, but the name caught on and is widely used. Graphene is a name for a material that consists of a single layer of carbon atoms. The branding of this material as graphene means that when it is referred to in the literature it is easy to find, and it points to the original discoverers who in this case received the Nobel Prize. So if you coin a good name for your discovery, you might not get the Nobel Prize, but you might receive more citations and more recognitions than without a catchy name.

There is no process for registering the name or controlling the name, but if you can get it generally accepted, it is often an advantage.

IP protection of software

IP protection of software is different from IP protection of other products. It is not possible to patent a computer programme as such. But it is possible to patent algorithms that can be implemented as software. You have the same requirements as with other patents of novelty and an inventive step. It must also be possible to make a technical implementation of the algorithm. A business model cannot be patented if it must be implemented by the people executing it. A business model that is an algorithm automated in software could in principle be patented if it is novel and inventive.

If we look at Spotify as an example, it was not possible for them to protect the basic subscription business model they use. It might also have been difficult to claim that it was a complete novelty. But they have patents and patent application, for example, regarding the streaming process for music, algorithms for predictions of breaking music and for cleaning the sound during transfer to digital form, as well as hardware patents.

However, patents are not the main form of IP protection in the software industry. The patents that exist and have a commercial value are mostly compression algorithms and for other methods of processing sound and images.

In a typical commercial software, the source code is often an industrial secret. The software is not sold but licensed to the end-user. The end-user must sign a license agreement to be able to use the software where reverse engineering (decompiling) of the programme code to reveal the source code is not allowed. This protects how the functions in the software are implemented. But it does not prevent a competitor to write new source code with the same functionality.

There is often other IP in relation to the software. Patents exist but are not common as described above. The graphic design of the user interface might have design protection. But this will only protect the design and not the function of the software. The name of the software can be a registered trademark.

But there is also a possibility to distribute software as open-source. This means the source code is open and not kept a secret. In most cases, the software still requires the user to accept and sign a license. There are several standard licenses for open-source software. One type of license allows you to distribute the software freely. You are also allowed to distribute new versions of the same software but only under the same license. This means that any new version will also be open-source and non-commercial. One such common license is the GNU GPL license.

Other types of open-source licenses allow the user to distribute new versions free of charge but also to make new versions that are commercial and that do not include the source code. But new versions must attribute the owner of the original version. Example of such licenses are the BSD license (named after the license for the Berkley Software Distribution a free Unix-like operating system) and the MIT license (named after the Massachusetts Institute of Technology).

Open-source distribution can be part of a commercial operation. The Linux operating system is open-source but sold as "distributions", that is, with preinstalled collections of software. Open-source software is often free to download but you might have to pay a subscription for customer support or extra functions.

The trend is to move towards software as a service (SaaS) where the software is executed by the supplier's servers or hybrid solutions where one part is executed in the cloud while another part is executed by a local device. This enables the supplier to keep control of the software, compliance with licensing, and control the updating process.

Putting it all together

Protection of immaterial assets is often done by a combination of IPR. This could include patents, copyrights, designs, trademarks, and/or trade secrets. A large part of the value of a company can consist of the trademark of the company and its products. Coca Cola is a company where the trademark is an important part of the value of the company. There is no patent for the beverage Coca Cola but is still well protected by a trade secret (the formulation), by trademarks, and by design protection, for example, of the cans and bottles.

In other cases, a company might license a patented technology, but to apply this technology successfully, you will also need to have access to a secret know-how that is included in the license and makes the license more valuable.

If you are in the process of selling or licensing a patent, you should ask yourself what other intellectual assets I have that can be part of the package. You might have knowhow that cannot be protected by a patent but that might be very valuable to the buyer. If you already have a catchy name for your invention, you might think about registering it as a trademark. You might have experimental data or calculation methods. You might be able to promise to provide consulting. All this will make a stronger package when you are selling a patent.

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8 Innovation in a collaborative environment

Why collaboration across organisation boundaries?

Companies become increasingly more dependent on cooperation with researchers when they need to develop new products or increase the capabilities of existing products. The speed of product development is a very important factor in being competitive. This requires a quicker exchange of knowledge between actors in the innovation ecosystem. There is an old understanding of innovation as a linear system where an innovation starts as fundamental research at a university, moves on to applied research, and then is developed into a product by a company. This does happen and it happens often in some selected technology areas, for example, in the pharmaceutical industry. But it is also very common that an innovation is made in a company and exploited by the company. The innovation might then be studied by universities to be understood and theoretically explained. In the best case, this theoretical explanation makes it possible to optimise the innovation further. A way to speed up innovation is to use information and knowledge that already has been developed for a new purpose in a new context.

In the automotive industry, there was a long period when car engines were gradually made more efficient by stepwise improvements. The basic principle of the engine was the same all through the 19th century. But then a new process of electrification with electrical drivelines and batteries or fuel cells started. Here major technological leads were required. Next step will be electrification of aircrafts, which put even higher demands on incorporation of new technology. On top of these major changes are new demands for a circular economy where products and materials need to be recycled or remanufactured. New materials like carbon fibres or graphene create the possibility of new performance or new products. Digitalisation with technologies like 3D printing, image processing, speech recognition, and other applications of AI make it possible to create products like autonomous vehicles.

To stay competitive, companies often need to develop or apply technology that is outside of their traditional competence. One of the best ways of doing this is to get involved in collaborative projects with universities, research institutes, and other companies. The study by Jun-You Lin in

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Taiwanese industries that was mentioned in Chapter 5 "Inclusion in innovation leadership" showed that collaboration with outside research and development resources (universities, institutes, etc.) is strongly linked to industrial performance(Lin 2014).

But there are also difficulties involved in external collaboration. We often must bring together two sets of cultures when industry or other private companies start collaboration with research. Researchers and developers at private companies need different things, and if you take this into account, you can reach agreements that benefit both parties.

Understanding what drives researchers

What drives researchers at universities?

Researchers need to publish their research. A common expression in research is "publish or perish". It is difficult to get a permanent position as a researcher, and publications are necessary merits for achieving this goal. Of all PhD students, only a very small number end up as tenured track professors, that is, with a permanent employment. After a PhD, you often do a postdoc at another university, often in another country. When you have completed a postdoc, you might get a limited time position as a research assistant. Only after this, you have a chance to get a more permanent position as a lecturer or a professor. Many researchers have a constant need to raise money for new projects to be able to keep working in research. The merit that really counts for you to remain as a researcher are your publications. These publications should be published in prestigious scientific journals (that often favour more fundamental research), and they should be well cited by other researchers. Teaching, patents, the use of your research in industry are in theory also merits, but in practice, it is publications and citations that really count.

Receiving research grants is crucial for researchers. If you do more fundamental research, you will apply mainly on your merits from your publications. If you do more applied research, you need to apply for research projects together with several partners often including private enterprises. This means that you will need to have network of contacts in industry or other places in society and be able to build research collaborations.

What is published within a research collaboration could reveal industrial secrets or potentially patentable results. But if you understand the driving force of researchers, it is possible to give room for publication but without revealing results that need to stay secret. In some cases, you can solve the problem by applying for a patent before publishing. Sometimes you can anonymise certain parts and sometimes you can work with a model system that does not reveal important facts about real production. The important part is to understand the need for researchers to publish while at the same time considering the need of a company to keep information confidential or to apply for patents before publishing. This can and should be regulated in research agreements or contracts that will be described later in this chapter.

Researchers at research institutes

Researchers at research institutes have driving forces that differ from those of university researchers. In this context, I am talking about institutes that have the role to directly support companies or other parts of society, institutes like the Fraunhofer institutes in Germany or the Tecnalia Institute in Spain, or CEA in France. These organisations are sometimes called RTOs (Research and Technology Organisations), and many of them are organised in European Association of Research & Technology Organisations ('EARTO' n.d.). There are other types of institutes that function more like universities with the exception that they do not have undergraduates, for example, the Max Planck institutes in Germany, or universities that just have institute as part of their name, for example, MIT (Massachusetts Institute of Technology) in the USA or the Royal Institute of Technology in Sweden.

The primary function of most RTOs is to do research that is useful for different parts of society. Researchers in such institutes are also interested in publishing results, but they are not dependant on this in the same way as a university researcher. They usually have a steadier employment even if they are required to initiate projects with external funding. While the main research workforce at a university is PhD students, the main workforce in an RTO are people with more experience both from industry or universities or a mixture of both. This means that the researchers are not only more expensive but also more experienced. A PhD student has more time to learn new things but also needs time and guidance to become a competent researcher. This is a slow process over the years but often with a very good final result. An RTO researcher will be able to get results much more quickly and it is possible to conduct projects within a shorter timeframe at an RTO. RTOs are often connected to certain types of industries or other activities. While a university might drop a certain research area completely when a PhD student finishes, an RTO will generally keep some type of constant service. Equipment at universities might also be left with nobody that can operate them if the research in a certain topic stops, something that often happens when a PhD student graduates and moves on. An RTO will probably not invest in a certain equipment unless they see a more permanent use by the companies they cooperate with.

Involve the research group in the development strategy

If it is possible, it is a good idea to involve the research group that you want to collaborate with in your company's research strategy. Understanding the long-term goals of your company will both motivate researchers and guide them to be more useful. If you are involved in applied research, you want your research to be used and applied. Sometimes you need help to see a bigger picture to understand how what you are doing fits in. When industrial collaborators whom I or my colleagues have worked with have taken time to explain the development strategy of their company, it has be very motivating.

It also helped us plan the next step for the direction of our research to look for other collaborators that would fit the strategy without competing.

Building long-range cooperation with research

To build competence within a new research field takes time. Researchers know that they must capture the interest of the funding agencies, and they are often experts at formulating proposals that match the requirements of the funding agencies. But it takes time to build real competence, and you cannot expect excellent results in a new area in a short time. Researchers are often not the best persons to solve acute problems in industry. They might have solutions sitting on the shelf or they might have very valuable understanding that can be used to solve the problem. But the system of using PhD students is a slow system. It builds real competence, but it also takes a long time. When they have a solution to the acute problem, it might already have disappeared. The reason for this is that some type of fluctuation caused the problem and it both appeared and disappeared before the researchers had time to find a solution.

Another important reason to build long-range cooperation is that it takes time to build trust. If you have time, you can build an understanding for each other's needs and competences. There is also a need to build a common language. Researchers might have useful theoretical knowledge, but unless the persons on the receiving side have time to learn and understand, the knowledge will never be used. Industry often uses terms that are unfamiliar to researchers.

To make a research cooperation work, there needs to be people on the industrial side who have enough time to cooperate. This means enough time to not only teach the researcher about how it works in their industry but also to learn from the terminology and theoretical base of the researcher. There also needs to be a commitment to work with a long-time perspective with the research group.

Limits to cooperation

The basic rule is that private enterprises should compete and not cooperate. One of the main functions of the European Union (EU) is to ensure a fair trade and fair competition among its member states and against the surrounding world. On an international scale, the WTO treaties serve the same purpose. The reason for this is to allow better and more affordable products a competitive edge on a free market. To guard free competition, private enterprises are not allowed to cooperate around prices or markets, that is, they are not allowed to create cartels or monopolies. It is also not allowed for governments to support private enterprises in a way that gives them an unfair advantage and endangers free competition.

There are exceptions that allow private enterprises to cooperate around certain issues. One of these exceptions is to cooperate around research and development. In EU law, these exceptions are called the Block Exemption

Regulation (BER; 'European Commission – Competition' n.d.). The BER regulates how companies can cooperate around research and development. The regulation allows governments to fund companies to take part in research and development. But there are limitations to this funding. In the EU, rules that limit government support to private enterprises are called the state support rules. Often, the private enterprises are only funded to 50% of its cost while a university might be funded with 100%.

Governments can fund collaborative research that is not pure product development. They cannot fund single companies, but they can fund a group of companies working together with universities or research institutes. There are special more relaxed rules for small and medium-sized enterprises (SMEs). When the EU or a national funding agency issues a call for research and innovation proposals, they have limitations to these calls for proposals that make them compliant with the state support rules.

Since funding agencies are required to follow the changing and sometimes complex state support rule that universities and enterprises just need to follow the funding agency's instructions in a particular project. But when you build research cooperation, for example, within a certain branch of industry, there are a set of rules that must be followed strictly – that is, that this cooperation must be strictly limited to research, development, and innovation. At conferences, project meetings, or other gatherings, it must be strictly off limits to discuss markets or prices or other non-development issues. It is common to set up research cooperation as centres at universities, as membership programmes at institutes, or as foundations with a purpose to fund research in a particular area. These types of cooperation must have a strict code of conduct that excludes market and price discussions.

In 2017, three German steel manufacturers were fined 646 million EUR for rigging the price of plate steel. The Stahlinstitut VDEh (German Steel Institute) that had worked with steel research and development was found to be complicit in this illegal cooperation and was closed as a consequence in 2019. This example shows that there can be large consequences in breaking the BER codes not only for companies but also for researchers.

The state support rules do also have an impact on how you can construct agreements regarding results from cooperative research as will be detailed in the next section.

Research agreements

Research agreements are necessary for research cooperation. These research agreements or research contracts are sometimes called consortium agreements when they are made between groups of partners.

Non-disclosure agreement

A simple type of agreement is the non-disclosure agreement (NDA) sometimes called a secrecy agreement. This type of agreement works well when you need to discuss confidential material before entering an actual cooperation. An NDA conducted between two organisations bind the organisations to keep confidential information secret. With an NDA, you might disclose problems that you want to do research on and disclose details that you do not want to become public.

An NDA between two organisations can also have a personal appendix that has to be signed by each person who gets access to the information. There might be a transfer of confidential documents that are agreed to be returned or destroyed after the cooperation has ended.

A typical structure of an NDA consists of the following parts:

- Who are the parties in the agreement?
  - The legal names and addresses of the parties are noted
  - Is this only between organisations or is there a personal part to the NDA?
- What is the purpose of the NDA?
  - The purpose of the transfer of confidential information is described
- A definition of confidential information?
  - Is all transferred information confidential?
  - How is oral confidential information treated?
- What is not confidential?
  - Information that is already public
  - Information required by authorities
- Damages and liabilities if the NDA is broken
  - Limitation of third-party damages
- For how long is the NDA valid?
- Clause about returning or destroying confidential information
- The national law that should be used to interpret the NDA

There are some things to be aware of when signing an NDA. Everything cannot be confidential. If somebody tells you something you already know, they cannot hold you to keep that secret. There are usually exceptions for information that the recipient can show is already in the public domain or becomes public but without breaching the NDA. There also needs to be a possibility to disclose information that might be required by a court order.

Damages and liabilities if the NDA are broken are often given a maximum value. The exception to this is if the agreement is broken by wilful act or gross negligence. In that case, it is difficult to limit the liabilities. It is standard practice to limit the liability so that no third-party damages are included.

In old NDAs, there was often a clause that specified that all written information should be returned or sometimes returned or destroyed. Today, much information is transmitted electronically. If you receive and store information electronically, there are probably automatic backups of the information in your system. In practice, it is very difficult to selectively erase information on a backup. Because of this, it is difficult to control and guarantee that a specific information is erased. If one of the partners require that the information be erased, there needs to be an exception to automatic backup or the confidential information needs to be kept on paper.

If the NDA is agreed between organisations in different countries, it is important to specify which law will be used when the NDA is interpreted. In countries that use common law (like the USA, the UK, and Canada, etc.), the agreement will always be interpreted literally. In a court proceeding in countries that have civil law system (like most European countries apart from the UK), the court will interpret the NDA according to the purpose if something is not specifically regulated. Because of this, it is important to specify the purpose of the agreement.

If the NDA is made with a US company, it will be interpreted according to a state law if that is specified in the agreement. These laws differ somewhat from state to state. A major concern will always be that if you cannot use the law of your own country, you will need to find a lawyer versed with the law of the agreement in the case of a dispute, and this might be difficult and expensive. A common way to solve such problems is to use a third country law that is well known to both parties. In Europe, the Belgian Law is commonly used for this purpose since all contracts with the EU are interpreted according to Belgian law.

An NDA does make it possible to discuss confidential matter. But if you start a cooperation together and generate new results, there also needs to be an agreement that specifies how you can handle these new results. If somebody is part of an invention, that person has rights that might vary depending on the employment contract and local laws and regulation. If you only have an NDA, it will be a very unsure situation both for your organisation and for the individual inventor.

The project or consortium agreement

A project agreement is needed for any research and development project with more than one partner where you generate new results. This agreement should regulate confidentiality, publishing, ownership of inventions, and other immaterial properties that might be generated in the project. The project agreement is also necessary to handle how decisions are made in projects with several partners. If there is funding from an external funding agency involved, there are typically conditions with that funding that must be met. These conditions are often called grant agreements or the general terms of the funding agency.

Project agreement with several partners can be very complex. For EU projects, there is a model agreement called the DESCA Model Consortium Agreement ('DESCA Model Consortium Agreement' n.d.). This agreement seeks to balance the interest of large and small enterprises, universities, and RTOs. It is also in line with the EU Model Grant Agreement, which includes EU's terms for funding research projects. There are extensive annotations with explanations of the DESCA agreement, and it is revised from time to time.

The Lambeth Toolkits is a set of agreements issued by the Intellectual Property Office of the British Government (GOV UK n.d.). This toolkit consists of several agreements that can be used for research cooperation. The toolkit includes support to choose an agreement for a particular type of project and then there are several model agreements available.

A particular national funding agency might also have a proposed model project agreement that can or should be used.

What is important to understand is that there often are options to choose between in these model agreements. The options will have different effects depending on the situation for your organisation. There might also be other changes made when you receive a proposed agreement for signing. If the agreement is based on the DESCA model, the project coordinator who sent the agreement for signing (or the coordinator's lawyer) might have made changes to the original that are important.

The structure of an agreement for a research project

The following is a comprehensive description of the main parts that should be included in a research agreement with several collaborating partners.

Who are the parties (partners) in the agreement?

For a small company, this might be obvious, but large companies might have several entities and it is important the right entity is specified with its correct legal name.

Definitions

It is common to use definitions of terms in more complex agreements. The terms are defined in a special section (or sometimes in the text). They are then used with this specific meaning in the agreement. A capital letter as a first letter is used to denote that the term is used according to this specific definition.

Purpose

The general purpose of the project is described. This might be important if the agreement is interpreted by a court or in a mediation or arbitration.

Entry into force and termination

The project agreement should be valid for the entire project even if it is not signed at the very start of the project. Some obligations and rights also need to survive after termination of the project.

Obligations

This part describes what task each partner is responsible for in the project. It also describes other obligations of each partner such as an obligation to report new inventions to a project committee. The original project application or a work programme is often used as an appendix to specify what each partner has undertaken to deliver during the project.

Organisation and decisions

Depending on the size of the project and the number of partners, the organisation of a project can be complex. A large project might be divided into several work packages where each work package has a separate work package leader. This might not be necessary for a smaller project. But when there are several partners, there needs to be a formal procedure of how decisions are taken and documented.

Results

When results that might constitute new IP are produced in the project, there needs to be a procedure to determine ownership and there might be a need or an obligation to transfer ownership. Normally, each partner will own their own result, but results that are generated together (joint results) need special procedures to determine ownership. When patentable results are generated, it is important to specify both inventorship and ownership. The inventor is always the person who did the intellectual work of the invention. The ownership can be regulated by agreements. This can be the project agreement that regulates relationships between organisations, but they can also be employment contracts that regulate the relationship between employers and employees. National laws can also determine the relationship between the employer and the employee regarding inventions.

If a patentable result is generated in a university, there might be an option for a company in the project to take over the ownership. Such transfers of ownership in the EU need to be done according to the EU state support rules. If a university has public funding and creates patentable research, the ownership of the patent must be transferred to a company with a fair and reasonable compensation. If not, the company has received a direct support from the state in a form that is not allowed.

Background and access rights

An innovation often builds on previous innovations. Such previous innovations are called background in this context. If a previous innovation is protected by a patent, you need access rights included in the project agreement. Access right is a right to use a protected background. All partners are usually granted access rights to background that they need to perform their tasks in the project. Sometimes, it is necessary to have access to background to use the results of the project. There is often provision for partners (sometimes extended to a partner's affiliated company and sometimes to a partner's subcontractor) to access background that is needed to exploit the results of the project. Since all partners are not at liberty to include background, for example, co-owned background in a project, there is usually an option to include or not include background. The project agreement can specify that partners pay a certain price for the licence to use the background. In some cases, it is crucial that the possibility of obtaining such a licence cannot be denied since the whole project might be meaningless without it.

Background in agreements is often misunderstood and the partners believe that they should account for their general knowledge in the area of the project. But in project agreements, background only refers to immaterial property rights, that is, something that a partner owns and controls. A partner should never include background in a project if it is not essential for being able to conduct the project or to use the results of the project. In most cases, including background means giving away some of the rights to other partners. When background is included, it is possible to limit it to certain applications of certain purposes. It is not necessary to give away everything if it is not needed.

The first collaborative research project I was involved in started in 1976 and was a Nordic project funded by the Nordic Research Council. The project was aimed at producing a new glass ceramic material that potentially would be superior to the material that was used for ceramic stovetops at that time. The project was planned with research partners in all the Nordic countries and with a special material in mind. As the project started, the project coordinator discovered that one of the partners had a patent that covered fabrication of the material that the project was planned around. The partner had kept this patent a secret, and this caused a harsh conflict in the project. Eventually, the partner with the patent was excluded from the project and the project was replanned for another type of material. This new material unfortunately had much less potential than the original material. There was no project agreement for this project and the partners had very little experience in handling patent questions. A much better solution to the conflict would have been if the partners had been given access rights to use the patent (maybe to limited types of applications) and been able to further develop the material in the project. This also shows how important it is to review the patent literature before a project application is planned and especially before a project agreement is signed.

Publishing

There is often a need to publish results from research projects. University researchers always need to publish. They need to attend conferences and they need to publish material to be included in theses. This make it difficult to wait a long time for being allowed to publish. Companies sometimes want to publish to be able to show good result for a product or a material. But it is also important that there is a possibility to submit a patent application before publishing. This is regulated in the research agreement with rules that guarantee that a partner's confidential information is not published by another partner and that enough time is given to submit a patent application before publishing

Liabilities and damages

Project agreements often include liabilities and damages that need to be paid in case of a serious breach of the agreement. But third-party damages are often excluded. Liability for the possibility to use the result is also often excluded. Even if the research is done correctly, it is difficult to promise that a new technology will work when it is used in practice. There is often development left until a final workable product can be realised. The responsibility for this can only be taken by the company that puts a product on the market.

Research conduct

The agreement also needs to have procedures to handle research misconduct. Falsification and fabrication of results as well as plagiarism are examples of gross misconduct. In a collaboration with partners from more than one country, the laws around research misconduct might vary between countries. In research collaborations where industry has industrial secrets to guard, it is important to have reliable procedures to handle suspicions of research misconduct. There should be a possibility to investigate allegations of misconduct and all partners should cooperate by making it possible to conduct such investigations. Information about research misconduct can be found in The European Code of Conduct for Research Integrity published by ALLEA the European Federation of Academies (ALLEA 2017).

Applicable law and conflict resolution

It is important to specify the law that should be used to interpret the agreement if a conflict should arise. In publicly funded projects, there is also an agreement that is entered with the funding agency. This might be formulated as general terms and conditions or as a special grant agreement. Any research agreement in a project with external funding must be subject to these external conditions and the applicable law of the grant agreement should preferably be the same as the applicable law of the consortium agreement.

The project agreement often specifies that conflicts should be resolved by mediation, and if the conflict is not resolved by arbitration, this can be done at a local Chamber of Commerce or at the International Chamber of Commerce. These organisations have procedures that are balanced between the partners and are experienced in solving such matters. It is possible to specify that regular court proceeding should be used. The disadvantage with using a regular court is that it often takes a longer time and there might be a lack of competence unless it is a court specialising in intellectual property. It can also be more difficult to control confidentiality in a regular court.

Signatures

A project agreement needs authorised signatures. In large enterprises, there are often just a few persons authorised to sign contracts that involve intellectual property. The persons signing will usually have to take advice from the legal department. It is a good practice to identify early on who should sign a particular contract and plan and allow time for this process. In projects with many partners spread over many countries, it is sometimes specified that each partner signs on a separate sheet and the original signatures are collected and stored by the coordinator. This is done to avoid the time-consuming process of sending the agreement around from one partner to the next to give all partners a complete set of original signatures. To specify electronic signatures is another way of speeding up the process of signing.

Negotiating a project agreement for collaborative research

A tricky part of research project collaboration is negotiating the project agreement and securing approval from all the partners. If you understand the requirement of all partners and recognise the differences, the task becomes easier (Figure 8.1).

Different organisations have different requirements

Large companies

Large companies generally have a legal department. This department is usually fully occupied with large mergers, business deals, or patent litigation. A research project agreement is often a complex agreement that takes a lot of time but does not usually have the highest priority. This is a reason for using a model agreement that is well known by the large company if possible. It is also important to identify early on the procedure and the persons who need to take part in approving the agreement. A developer in a large company that is not used to this type of projects might not know who needs to be involved and might be unrealistic about how long it takes to get approval and a signature. Sometimes, a developer asks his or her manager who also has limited experience and gets pointed to a standard agreement that is used for subcontractors. These types of standard agreements for subcontracting are useless for research cooperation and sometimes even dangerous for researchers to sign. A subcontracting agreement generally specifies that the contractor must guarantee the freedom to operate. This means that there are

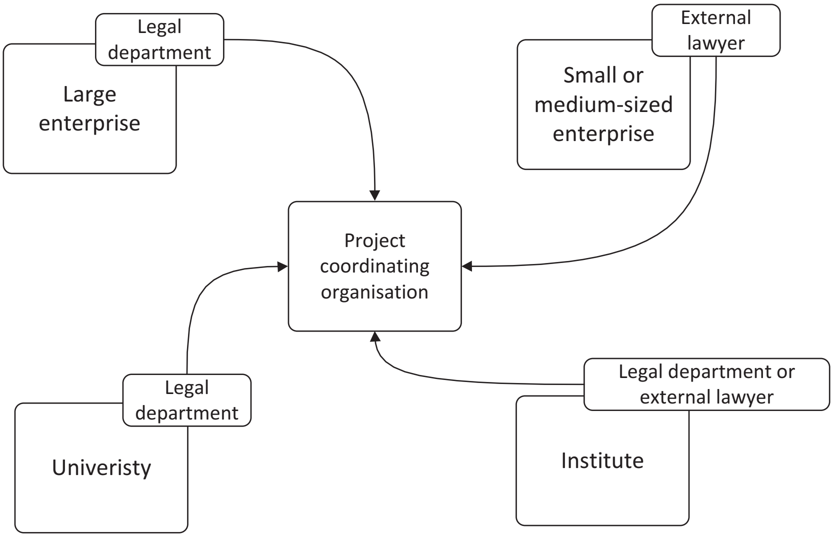

Figure 8.1 The different types of organisations that must be accommodated in a project agreement.

no patents that protect the technology. To guarantee this for something that is not yet fully developed is in principle impossible. Subcontractor agreements also regularly specify liability for third-party damages. This would mean that a researcher might have to face responsibility for the failure of a product based on a technology that is developed in a project and then implemented by a company.

Small- and medium-sized companies

SMEs usually don't have their own company lawyer but consult a company lawyer on an external law firm. This lawyer is often a business lawyer with little experience in project agreements and intellectual property. The SME will often need explanations of how the project agreement works and why it is formulated in a certain way.

Universities

Universities often have a legal department. This is often a department with ample experience in working with companies in applied research. They are often used for common model contracts. However, the legal department of a university often sees its main goal is to reduce all risks for the university. One of the main jobs of a university legal department is to ensure that the university follows all rules and regulations. This might mean that they cannot accept any liability and damages. Most partners that do business understand that you always must accept a certain risk in each deal. The idea that you can reduce your risk to zero also means zero deals. The right to publish results is crucial for universities. They can accept that publications are delayed enabling patenting, but they cannot accept that they cannot publish their own research.

Research and technology organisations

RTOs' main job is to be useful for industry and for private and public enterprises. This means that they need to be able to work with many different organisations, and to be efficient, they need to reuse their results. It is difficult for RTOs to accept agreements where a patent is transferred from them to a partner in a way that might stop the RTO from continuing work in a certain area. If an RTO discovers a generic technology, they can often give the rights to this technology for a certain type of application but not for all applications. The right to continue to do research despite patent protection is often granted to universities. This type of right is often not so useful for an RTO because the RTO needs to continue to work with the technology with a customer that also can exploit the technology in real production.

Using a stepwise approach for research agreements

The project coordinator is often also the person who coordinates the proposal writing for publicly funded projects. It can sometimes be done by professional consulting organisations, but most proposals are written by researchers at universities or RTOs. If the proposal coordinator is aware and prepares for the task of negotiating the project agreement early, it will be much easier to get an accepted agreement.

When the roles and tasks in the proposed project are assigned, you can think about if single or joint results will be generated. Single results are easier to handle and should be preferred if possible and tasks can be distributed to support this. If the project description is clear, it also becomes clearer if a result is a single or a joint result. The partners will have different goals with the project and different possibilities to exploit different types of technology. The common way is to assign ownership to the organisation that got a particular result. But there is an alternative way by which the application areas are assigned in the project agreement and that ownership of inventions is assigned according to these application areas. According to the state support roles, the partner that invents something should be reimbursed according to market principles. But it is possible to argue that the value of an invention is very small for a particular partner that does not have the possibility to exploit it. Enterprises often have a particular market where they are active and usually have little interest for other markets.

When the structure of the application is clear, the project coordinator can propose a preliminary agreement. This is preferably done as a term sheet. A term sheet is a document where the important principles and terms of the agreement are specified. I have often used a PowerPoint presentation with bullets describing the main purpose of the suggested agreement. These general terms can be discussed and agreed on before the project application is submitted. It serves to discuss the agreement without getting stuck in details. If the project is granted, the next step is to circulate a first detailed version of the proposed entire agreement.

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9 Innovation and society

Interaction with many forces

As innovations develop, we can sometimes see a progression from science discoveries over applied research to product development. The way that innovation interacts with society is much more complex than that. The interaction is with several forces such as with market, with science, with financing, with public society, and with commercial enterprises (see Figure 9.1). In the following sections, I will try to describe some of the interactions and show that they are often a two-way street with influence in both directions.

Market and innovation

Innovation creates new markets. "If I had asked people what they wanted, they would have said faster horses" is a quote that is attributed to Henry Ford. This illustrates that demand for new products is often created by the innovation itself. When Henry Ford started building automobiles, the product already existed. Anybody could imagine the need for a car at that time even if they thought it would not be possible to buy one. Ford made cars more affordable and more reliable. This made it possible for more persons to own cars, and so the market expanded. But before the first cars existed, the obvious demand for faster and better transports would have been faster horses and better horse carriages.

The wearable cassette player Sony Walkman was introduced on the market in 1979. About 20 years later, 186 million units were sold globally (Sony Global 1999). There were small portable tape and cassette recorders before the Sony Walkman, but they were larger, more expensive, and targeted for portable recording not for listening to music. If somebody had conducted market research in the beginning of the 1970s and asked people if they would go around with a tape recorder and earphones listening to music in the street or while commuting to work, most people would probably have said no. In the beginning, only young people wore headphones in public and the older generation was very slowly won over by the idea of listening to music on the go. The market did not exist prior to the Walkman and

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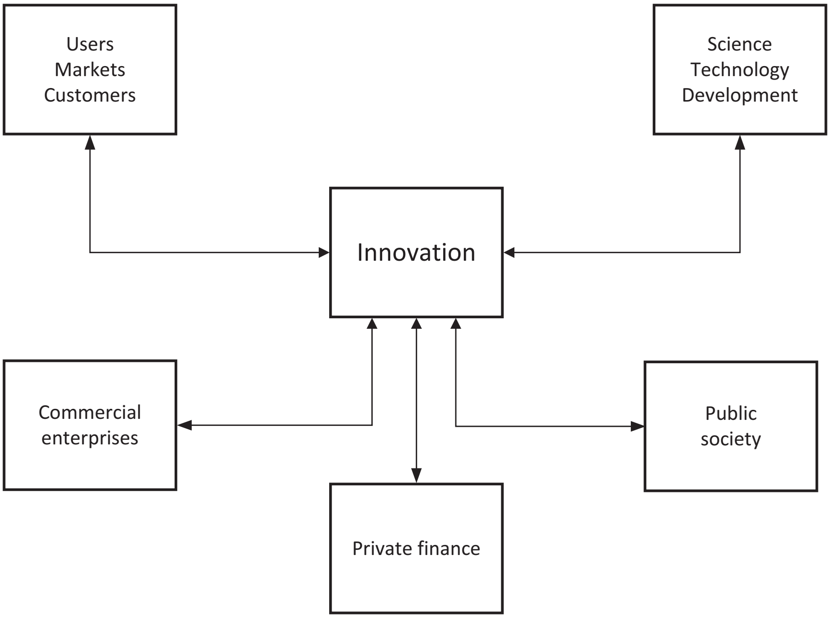

Figure 9.1 Relations between innovation and society.

was developed by this innovation. Later, the market developed much further with new technology, better sound, and more storage capacity.

The demand for new technology does not always exist if you just ask for it. But when the market already exists, there is often a market pull for cheaper, better quality, and better capacity technology. This can be exemplified by the development of cameras for mobile phones. In the beginning, cameras on mobile phones had poor quality. The screens of the phones were small and had bad resolution, so the market for these types of mobile phones were limited. But as the quality of the screens and cameras improved and the invention of the smartphone improved the ease of use, the market increased rapidly and no smart phone today is sold without a camera. In this case, there already was a market especially among young people and the pull to make better phones and better screens to show the pictures was apparent.

Large enterprises and innovation

Many innovations are made by established enterprises working on an established market. These innovations can be developing new functionality or improved properties on existing products and occasionally of introducing completely new products to customers.

For some material companies, there is a constant market for improved properties. Steel and concrete are two materials that have improved in strength continuously over many decades or even centuries. Traditionally, such companies have had large central laboratories where they have improved on existing products. If there was a new product with improved features, there would be a market. The higher the cost, the smaller the market but an improved reasonably priced product would create a competitive edge. Companies of this type have been able to afford large development departments and long-standing cooperation with universities to create better understanding and new ways of improving products. But large central labs often proved less successful over time and have often been shut down to move development closer to the customers.

If an enterprise wants to be more useful to its customers, it needs to know more about the customers' requirements and this means that they have to be knowledgeable not only about their product but also about how one can use the product in applications. This can only be done with a broader area of competence. A large paper producer stated something like this: "We used to sell carton by the roll to our customers. Today we sell advanced packaging solutions". This requires intimate knowledge of your customers' applications and the ability to adapt your products not just against a certain property but against exactly the properties needed for this application. You can do this only if you widen your own knowledge to areas that are not your traditional areas.

A producer of superalloys used in jet engines can easily find a couple of basic properties that will be fundamental for the use of such materials. Strength/corrosion resistance, creep resistance, and oxidation resistance at high temperature will be of the highest importance. Improved high-temperature properties will increase the efficiency and longevity of the jet engine. But this might not be the only considerations. How well the material can be machined will also be an important factor, and this might vary with the geometry and planned production method for a certain jet engine. So intimate knowledge and cooperation with customers will be important in most cases. Over the years, we can see a trend of jet engines getting better fuel economy, and this is partly explained by the improvement of the material properties in the hottest part of the engine.

Sony put its main effort on creating technology for high-quality sound and miniaturisation. This led to a stream of inventions following the introduction of the Sony Walkman. Parallel to technology development, they also introduced products adapted to their different markets. In the USA, sturdier sports versions adapted for jogging were marketed while the smallest lightest versions were adapted for use in the crowed Tokyo subway (Sanderson and Uzumeri 1997).

Public society and innovation

Fundamental research is funded by public sources. This funding is often distributed to universities based on the merit of the researchers rather than the merit of specific research projects. It is important to fund research driven by curiosity and pure desire to know more. The quality of such research is often measured by the number of citations from other researchers. This can be both researchers from the same field and researchers from other fields. If researchers from other fields cite specific research, this is an indication that there is a general scientific value of the research, and this is often deemed as a special merit.

The other part of public research funding supports more applied research. This is research where there is a specific need in society. The funding is more distributed for specific projects with a specified goal. To get funding, the researchers often must have an original idea for the project that leads towards a specific goal. The researchers must also demonstrate that they have the capacity to do the required research to reach their goal. The research funds are often distributed by inviting researchers to respond to calls within a specific area by submitting a proposal for a research project. These research projects often include participation of several research partners as well as industrial or other actors.

There has been a development over the years of such calls for proposals. The initial calls for proposals were targeted to specific application areas such as supporting development in a specific industrial area. With time, this has developed into call for proposals for projects that can solve a specific societal problem or enhance a specific societal development. These calls for proposals for research projects provide a way for society to handle challenges and other aspects of the development of society. Innovations as such are deemed to be beneficial for society, and since new ideas often develop with new companies, there are special measures to support research and development in small and medium-sized enterprises.

But society also has ways to prioritise certain areas. Societies have prevented and banned certain types of research through history. Science had a long battle to become independent of religion. The German universities were the first to establish the principle of a free university and free research (Watson 2011). This established the ideal for research to be free from church dogmas and the influence of worldly leaders. This has been very important for development of science. Today we still have some prohibitions left. We do not allow research that mistreats human subjects. We do not allow cloning of human beings. So there are limitations, but they are few. We do not want society to dictate the results of research, but we might want research to help solve important problems in society.

The idea that society could steer research into solving important problems was probably first shown in large scale by the Manhattan project. This was the project where researchers from all over the world were gathered by the USA in a project to develop the first nuclear weapons. This involved taking fundamental research on nuclear processes and using them to develop a new type of weapon. The driving force for many of the researchers was that they did not want the Nazis to get the nuclear bomb first. The fear of that might have been exaggerated by a misunderstanding that Germany was much closer to developing a nuclear weapon than they were. But nevertheless, this was the impression that the scientists worked under. The Manhattan project was an impressive project where fundamental research and engineering research and development together solved a difficult problem. Later a similar approach was used for the space programme to put the first human on the moon.

These first attempts were strictly guided with a very specific target in mind, and even if there was room for some unsolicited activities, most of the projects were directly planned. An era of applied research ensued where funding agencies in different countries set up calls for projects. These calls were designed to cover most of the current research areas. The calls were often formulated by committees of researchers. This made the research follow the trends that were already there in the research community. It also made it very difficult for completely new ideas to be funded for applied research. These applied research calls for projects were parallel to funding of more fundamental research that was more dependent on the individual researcher's merits than on the actual project proposal but also left more room for new ideas.

A shift happened in the funding of the EU Framework Programme Horizon 2020 (European Commission 2013). The concept of grand challenges was introduced with this framework programme. The grand challenges were general challenges for the EU society such as dealing with climate change, an environment free of toxic chemicals, or an aging population. By defining and agreeing on the grand challenges, there was a possibility to make more general calls for proposals. The proposals could have a wide range of content as long as they contributed significantly to handling one or several of the grand challenges.

For the Horizon 2020 Programme, the EU identified seven priority challenges where targeted investment in research and innovation can have a real impact benefitting the citizens:

- Health, demographic change, and well-being
- Food security, sustainable agriculture and forestry, marine and maritime and inland water research, and the bioeconomy
- Secure, clean, and efficient energy
- Smart, green, and integrated transport
- Climate action, environment, resource efficiency, and raw materials
- Europe in a changing world – inclusive, innovative, and reflective societies
- Secure societies – protecting freedom and security of Europe and its citizens.

In the current Horizon Europe Research and Innovation Programme for the years 2021–2027, these thoughts to direct research towards the most important challenges have been developed further.

This made it possible to appeal to individual scientists' motivation to make a difference and at the same time align the projects with far-reaching goals.

At the same time, the proposed projects could be innovative and projects did not have to be imagined by the people who wrote the calls.

UN sustainability goals

The United Nations has defined 17 sustainability goals (United Nations n.d.). This includes goals like No Poverty, Zero Hunger, Industry Innovation, and Infrastructure. All goals have associated targets and actions. The sustainability goals are a comprehensive summary of the most important problems for the international community. These are grand challenges in the sense that they are formidable challenges. But they are also grand challenges in the sense that they point to the most important priorities, and developing solutions in line with these goals will be a step forward.

These goals are increasingly used by public research funding agencies. Calls for proposals are linked to these goals, and proposed projects must be motivated in light of one or several of the sustainability goals. One project naturally cannot address all the goals, but if you try to address one of the goals, it is also important to look at associated targets and proposed actions.

Private financing of innovation

Private funding serves an important role in innovation. There is often a need for investments long before the innovation will start to generate income. A variety of funding options are available for the private sector. Business angels are private persons who finance early stages of innovation. Venture capital are enterprises that fund start-up companies against part ownership. When the company has developed enough to be introduced on the stock market, the venture capital makes an exit selling their shares. The idea is to take a larger risk than a normal company or bank would do and that even if a majority of the investments never become profitable a few can be extremely profitable making the investments worthwhile. Venture capital usually do investments at later stages than business angels and can make larger investments. Venture capital often concentrate their investments on particular types of technological areas that they specialise in.

Crowd funding is a more recent way of funding innovations. Crowd funding is done on websites on the Internet. An entrepreneur that wants to develop a certain technology can offer private persons to contribute. This is often done by promising the contributors to buy the product in advance. If the desired level of funding is reached, the product is developed and delivered to the contributors. This works for funding products that are close to the market and that are interesting for the public. For products that are sold to businesses and that require more extensive development, this method is not usable.

Industry can often fund its own product development and often use their own development departments to realise new products sometimes using external consultants. But when the innovation is further away from the market and when the internal development does not have the required capacity and knowledge, there is a possibility to do the development as collaborative research. Several companies can come together and fund joint development of technology. This is often done by creating industry-funded research and development at research institutes (RTOs).

Open innovation

Open innovation is a term that is used when an enterprise goes outside and uses external resources for development. This might be that external resources and knowledge are used in the product development, but it can also be that an internal innovation that does not fit in an enterprise's strategy is spun out to an external company to be exploited outside. Collaborative research projects can often work as a way of realising open innovation. It is important to note that open innovation does not mean that everything about the innovation is public. Open innovation means that a company is open to external partners that work together usually with confidentiality agreement and project agreement that regulate confidentiality and ownership of IP.

Innovation hubs is a method that large companies use to boost innovation. Small innovative companies are offered space at large companies. They are often given access to lab facilities, and they get more direct contact with large companies. For large companies, this is a way to get better contact with new innovative ideas and to try to bypass some of the bureaucracy that can stifle innovations in large organisations.

It is possible to do product development openly. One such example is the operating system (OS) Linux. This OS is distributed under an open-source license and users are invited to take part in debugging and development of the OS. In the book *Makers*, Chris Anderson describes how products can be developed openly with contribution from its users (Anderson 2013). He describes both how it is possible to put designs openly on the Internet and invite contributions from anybody that would like to contribute to the development. The limitations of this method are obvious, but it shows that new types of collaborations can be designed for special purposes. Chris Anderson also describes the maker movement that helps people to realise inventions by creating maker spaces, places where it is possible to get access to machine tools as well as 3D printers to be able to affordably realise ideas and make prototypes.

The Internet also makes it much more available to realise new products both by easily available manufacturing resources and also service bureaus that offer access to professional 3D printers that are not limited to a few plastic materials but also can print in a variety of polymers, metals, composites, and ceramics.

There are organisations that can help a company to set up an open innovation collaboration. A company that would like to have a new technology can put out a technology request through these organisations. Any researcher, inventor, or company that has such a technology can respond to the request and get contact with the company. The initial response to a request should not reveal any confidential or potentially patentable information.

A company that issues such a request can choose between responses and enter collaboration around promising technology or find a promising technology development partner. The responses will also typically give you an idea about the stage of development that exists around the world in a particular area.

The problems with using such intermediaries and issuing open request for technology is that it can be costly and the company issuing the request might have to reveal important strategies to get interesting responses.

Personal driving force

Matts Andersson discovered many patients in his dental practice who could not eat properly because of missing teeth. He had a large rural elderly clientele of patients. His vision was to create an efficient way to replace teeth that could not be fixed by filling them anymore. His entrepreneurial work has been described in Chapter 2 "How to make your team creative".

Hans Lindell discovered the trauma that persons working with vibrating tools were suffering from. He set out to eliminate vibration injures. This led to making practical use of a very old invention, the automatic balancing ring. By getting them to work in new applications, he could reduce vibrations caused by rotating imbalances. Today, this method is implemented in many professional hand grinding machines. Later he invented a completely new method to reduce translational vibrations. He designed a method to autotune counterweights that made it possible to develop tools for stone cutting and construction work with reduced vibration. The balancing with counterweights is an old technology, but in the established form, it had a limited use. It could be used only when a vibration had a fixed frequency. The new method autotuned the counterweight system to a varying vibration frequency. This made it possible to use the technology in, for example, a jackhammer or hammer drill. While conventional jackhammers will cause vibration injuries if used during long working hours, his prototype with reduced vibrations was safe to use (Lindell et al. 2015). He then went on to look at high-frequency vibrations. These types of vibrations had been difficult to measure and because of this they were disregarded in health and safety standards. This type of vibration hurts people who work in the dental industry with high-speed drills. High-frequency vibrations are also caused by impacts and cause vibration injuries for mechanics in industry that uses riveting hammers or car repair that uses impact wrenches (Zimmerman et al. 2020). He invented a measurement instrument for characterisation of this high frequency and is lobbying for stricter regulation of high-speed vibrations.

Meeting people in the stone cutting industry and realising that most of them received vibration injuries that handicapped them and forced them into early retirement was a strong motivator. Vibration damages the blood vessels giving you "white fingers" or Raynaud's syndrome. It is painful and makes you become very sensitive to cold weather. Vibrations also damages the nerves in your hand taking away your ability to grip strongly, feel a soft touch, or use your fingers with precision. Hans Lindell often recounts a story that moved him deeply, a story about a father whose child did not want him to touch her because his hands were so cold.

Anna-Karin Jönbrink impressed me with her solid commitment for sustainability from the first moment I got to know her. She started with a small research group at Swerea IVF that continued to grow each year. Together with her group, she set up roadmaps for the research group's different areas. These roadmaps were showed where the group aimed to develop further, and whenever a possibility for a new research project opened, they could check to see if this project could be used to move in the direction of the roadmaps. The overall goal was to help each industry they worked with to prioritise its most important sustainability and climate impact issues and enhance their competitiveness by addressing and solving these issues. This created a climate of innovation and purpose in the group.

These are just some examples of inventors and researchers whom I have seen up close. Inventors are often driven by a vision to make a difference to create something that will make people's lives better. This fuels innovation and serves as a driving force to keep trying again and again until a working solution is found.

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10 Strategy for innovation

Meeting technological change

How does market/technology leading companies meet new technology that has a potential to take over their current products/technology. Research shows that it is very unusual for a company to disregard the problem. But still many companies handled this type of situation badly.

Some companies make early investments but give up before the technology has matured enough to become profitable. The first versions of new products are often expensive, clumsy or are unreliable. The first electronic watches and the first electronic typewriters were often more expensive and had worse performance than their mechanical alternatives. But later versions with improved performance and price completely outperformed their mechanical competitors.

Problems with early products of a new type make it easy to give up early when you invest in new technology. It is also easy to underestimate the difficulties with the new technology. Companies decide to invest in new technology early, but they invest too little to have a realistic possibility to develop competitive products.

The mechanisms behind this are easy to understand. The new technology is often represented by a new department. A small department that only shows loss or/and even if it shows a profit, it will still be an insignificant contribution compared with traditional products. This makes it difficult for a small new department to attract enough resources in negotiation for an investment budget. This is a reminder that an innovative culture must provide protection for new innovations and innovators.

New technology does not only affect technical solutions, but it can also influence organisation, sales, marketing, and service. Sometimes the established product is sold in a manner that does not fit the new product. Mechanical typewriters were sold through a network of brand stores. These stores also provided access to qualified service that was needed for these products. When electric typewriters emerged, they were quickly sold through other channels (general office stores) since the service need was much smaller for these machines. This made it easier for new manufacturers

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to take over the market. It was no longer necessary to build a service network to introduce a new brand on the market. You could use the existing office store to sell the product and did not have to take the cost of investing in special stores and service organisations. So established typewriter manufacturers like Remington or Olivetti suddenly had great difficulties with the new competition.

Those who wait to invest until the technology is more mature often lose ground and tempo. There are single cases of early investments that fail but this is not a common problem. The most dangerous is new technology for companies that don't have their own technology development resources. This situation makes it much harder to absorb new technology. Even if the company can afford to outsource development projects externally there is a lack of ability to use the results and steer the projects in an efficient way if you lack in-house competence.

Strategic positioning

If a new technology is introduced, it can pose a large threat to existing companies. One example of how dangerous this can be is from the US cement industry. During the large depression in the 1930s only one cement company went into bankruptcy. But when computer control was introduced for the rotary cement kilns, dozens of companies went bust. It was far easier to handle economic difficulties and a receding market. That could be handled by economic cutbacks. But new technology had to be handled by getting competence that was completely new for this industry. When computer-controlled kilns were introduced, it was not obvious how important they would be. It is often very difficult to predict the influence of a new technology. This problem can be handled by strategic positioning.

What is a strategic positioning in the context of technology development? Strategic positioning can be compared with an option when you trade on the stock market. The cost is limited to the option, and this is all you can lose (maximum loss). If you use the option you can have a large advantage if the value of the share exceeds what is specified in the option. If the stock does not develop favourably, you can decide not to use the option and make a smaller loss. In a similar manner a limited research and development effort can be used to create a strategic position where you can choose to develop a product based on your position if the market and the technology develop favourably.

If you decide to go ahead you will need further investments but with the limited investment you can judge the area better. The risk of expanding to a larger effort can be minimised. The higher the fluctuation of a particular stock the higher the value of an option. In a similar manner the higher value of the research and development effort the greater the potential of the area and the larger the need to minimise the risk (e.g. if competitors are investing heavily).

Portfolio thinking

You can use similar thinking for investments in a development project as you would use when you create a stock portfolio. In a similar way that you would choose stocks with different risks for your stock portfolio you can do this when you choose development projects. This thinking is most useful for large companies that handle several development projects simultaneously, but it can also be used on a smaller scale.

In the pharmaceutical industry, the development of a new drug is to a large extent a screening process. Early in the development process, a large pharmaceutical company can afford to look at several ideas. But before a new drug can be put on the market it has to undergo several expensive clinical trials where it only is economically feasible to test a small number of potential drugs. Of 1000 project ideas they would typically choose 50 projects. From these 50 projects you might get 10 potential drug candidates and from these only one new drug will be put on the market. The total development time from the initial project ideas might have taken 10 years. In this context it is of course very important to make the screening process as reliable as possible.

In materials development you improve the properties of a material in the same way. You start with theories about how a material can be improved in a certain way. You might want a stronger material, more corrosion resistant or more high-temperature-resistant material or a specific combination of several properties. The theories then must be tested by experiments. Usually, you make several parallel experiments where you manufacture materials with different compositions. Then you do tests, typically starting with tests that can be conducted rapidly and cheaply. These tests are used to screen material compositions so that only the most promising candidates are tested in the costly and time-consuming tests.

In the automotive industry where the risks have been traditionally lower and the development more incremental. When development with screening was introduced, it was regarded as very innovative. At the beginning of the 2000s Toyota added the concept of lean development to the earlier lean production concept. Lean development is not really related to the lean production philosophy it is more similar to the concept used for development in the pharmaceutical industry. Instead of choosing a development concept early Toyota worked with parallel ideas. With time ideas were screened out until one remaining idea was developed into a component or system for manufacturing. The discontinued ideas were archived in order to preserve the gained knowledge for the future possibilities (Morgan and Liker 2006).

In a typical development portfolio, you should have both high- and low-risk projects. You should use most of the resources for projects with a relatively high probability of success but also some small high-risk projects. Project that demands a long-term effort should have a potential for high payback if they succeed. Project that will only result in small improvement can only be valuable if they can give result within a short time frame.

Adapting strategies to your organisation's situation

It is very important to try to figure out what a specific development project would require of your organisation. Some projects need much new competence in their own organisation. Building this competence will not automatically be reflected in how a new product will be received by the customers. A product that is perceived as very new by the customers might on the other hand be developed with technology that is already well established within the organisations.

When Arla, the largest dairy producer in Sweden, started to sell mineral water at the beginning of the 90s called "Linné" it was a new thing for the company. Milk for drinking had been a shrinking product for some time while mineral water had increased in popularity. This made it natural for Arla to consider selling mineral water. Mineral water was naturally no big news for the consumers. But production, distribution, and sales were very different from how you handled dairy products. To handle this Arla had to make a large investment to provide something that customers were not very excited about. The supermarkets were also not very excited. Arla was very dominant in selling dairy products but compared with other suppliers of beverages that had a full assortment of everything from sodas to beer Arla could only supply mineral water. The "Linné" mineral water by Arla was sold to another company in 1995.

When Arla started to sell a new type of yoghurt (called Onaka) based on a Japanese bacterial culture it was a big success. The new yoghurt could be produced in ways that were very familiar to Arla. It was distributed and sold in a similar way as other dairy products. But the idea that yoghurt could be specially designed to improve digestion and strengthen the intestinal bacteria was very new to the customers. The new product was very well received by the market in a way the mineral water was not.

IBM had a factory for printers in Järfälla in Stockholm that was evaluated as one of the best factories within the IBM group. It was one of the first companies that received the Swedish national SIQ quality price. When IBM restructured, the factory in Järfälla was made an independent company called JCC Järfälla.

During this process JCC was developing a new type of inkjet printer that was based on piezoelectric technology. The technique had been developed by a UK company and bought by JCC. A key component was made from a ceramic material and was a central part of the printhead in the printer. There were several potential advantages in using a piezoelectric material instead of the droplet evaporation technology (bubble jet) that Cannon had pioneered for their inkjet printers. The main advantage was that you could use new inks that contained pigments and that were water resistant and did not bleach with time. The ink in the early inkjet printers was all water soluble so the ink could easily be smeared if it was exposed to moisture.

A major problem with the new technology was that it was based on a ceramic material that JCC had no previous experience of. They encountered manufacturing problems that were very difficult and expensive to solve. The development project collapsed from acute lack of money and the JCC printer factory was closed down in 1995. This is an example of the need for own competence in developing new products.

Working through strategic cooperation and alliances

Collaboration does not only take place between companies and research organisations it also happens between companies. Collaboration in the form of strategic alliances between companies often plays an important role when new products are developed. A first customer can often be a strategic partner. A demanding customer will help to steer the development in the right direction. A first customer can be given special advantages for example exclusivity for a certain area against contributing to the financing of the development. Other strategic partner can be suppliers that contribute with competence in their respective areas. For small- and medium-sized companies, the suppliers are often a source of new technology and sometimes the only source.

The small Swedish company Bestmatic AB had developed a method to use water jets to cut jigsaw puzzles. They were able to develop this water jet cutting method financed by a customer that sold the puzzles. By agreeing to not work with other customers in this area for 10 years they could secure financing from their customers.

Several new companies were entering into this area, so Bestmatic made a strategic decision to improve its competence to keep ahead of the competition. They choose to work with cutting of hard materials something that required higher competence. They needed more competence on technology for high-pressure pumps and robotics to control movements of the nozzle for the water jet. To do this they formed an alliance with Ingersoll and Rand for the pumps and ABB for robotics. This meant that they could concentrate on knowledge of the cutting applications. Bestmatic became a very profitable company and was eventually bought by ABB-IR a joint venture between Ingersoll and Rand and ABB.

Lithoz is an Austrian company that sells 3D-printers for ceramic materials. Ceramics are more difficult to 3D-print than polymers or metals. The reason for this is that ceramics cannot be formed by melting and solidifying. Ceramics must be sintered, and the component will shrink during sintering. Ceramics are also sensitive to defects. This means that small cracks or pores will lower the strength dramatically. Lithoz probably manufactured the first commercial 3D-printers that could manufacture high-strength ceramic components with high precision.

They developed their first printer in close cooperation with a potential customer within the dental industry. This is a demanding application that needed both high dimensional precision, high surface finish and a strong material. This strategic cooperation made it possible for Lithoz to enter the market. Lithoz has now developed to a world market leader in ceramic

3D-printing. In 2021, they were chosen by the "Spin-off Austria Initiative" as one of Austria's top five university spin-offs.

Market studies for strategic product development

A classic strategy for developing products is to do a market study. This can be used to understand what the customer expects of new product and how large the market is. Market studies can be valuable, but they can also be misleading especially for ground-breaking new products. An alternative method is to introduce a product on the market and then use market reactions to improve the product.

Corning's development of optic fibres

When Corning tried to market optic fibres for communication in 1967 the largest US telephone company AT&T had the position that optic fibres would not be interesting before the year 2000. In 1970, Corning had developed a fibre with very low attenuation. They could manufacture a fibre that only had 16dB/km attenuation which was a remarkable result at that time. Low attenuation was a prerequisite for using optic fibres for long-range communication.

Marketing consultants recommended Corning to market their fibre for information-rich transmissions where price was no major issue, that is, for local computer networks. In 1976, the first trials were conducted with networks built with optical fibres. But the use of optical fibres for local computer networks grew very slowly. The long-distance telephone communication was the largest early market but as this market was dominated by AT&T that was not interested in optical fibres.

Corning gave up AT&T and created alliances with telecom operators outside of the USA. They also tried the cable-TV market and made trials with video telephony but with little success. Eventually improved performance and reduced price resulted in a breakthrough for long-distance telephony in 1982. The development had then been going on for over 10 years with large costs (Lynn, Morne, and Paulson 1997). Today optical fibres are crucial for all long-distance and information-dense communication and Corning has created another strategic alliance with Apple regarding the glass used in the display of the iPhone.

General Electrics and computer tomography

The method General Electrics (GE) used to develop their Computer Tomography scanner is an example of putting an early product on the market instead of doing market studies to understand customer requirements. Commercial computer tomography (CT) was invented by Godfrey Hounsfield at EMI in the UK. The idea was conceived in 1967 and the first patient was scanned in 1971. GE was a major producer of x-ray equipment for hospitals. The market was receding and when the new CT technology was marketed by EMI GE decided to develop their own CT scanner.

GE developed a CT scanner based on a new technology called fan beam. In the first attempt they developed a CT scanner for the diagnosis of breast cancer. This required a small equipment that was easier to develop. At the same time GE did not think that this would be the best market. The result of the market introduction also showed that the demand was low for this equipment.

GE then took the next step and developed a full-body scanner. This scanner was well received on the market and many orders were placed. When the model was fully developed many of the orders were annulled since the resolution of the scanner was too low. Now it was apparent what the market wanted and a new model with improved resolutions was developed. The result was that GE quickly captured 60% of the world market of CT scanners (Lynn, Morne, and Paulson 1997).

The original inventor EMI failed to keep ahead of the competition. They did not have access to the hospital x-ray market in the same way as GE had and lacked their service and education organisation. To be successful EMI would probably have needed a strategic partner to collaborate with.

Marketing strategy

It is useful to do simple evaluations of the market, but you need to be very aware that they also can be misleading. Sometimes a market evaluation is used more as an alibi for making an investment than for real knowledge. Early market introductions can be used as an alternative to market evaluations. A common way is to approach leading users and/or users who have an extra advantage by using the product and selectively market the product against these groups. If you have a good cooperation, it is possible to get a quick response without destroying the market reputation. This can also be a good way to get information about trends and preferences of the customers.

In the software industry it is possible to develop products incrementally. Users who wish to be early adopter and help with testing are given access to new functions before they are rolled out to all users. Problem reports from these users are used to spot problems with the new software functions and serve as a testbed for the software developer. This gives the developer information about any problems but also gives information about usability and preferences for new functions.

Dominant design

When a new revolutionary technology emerges, it can restructure the entire market. If it is a product, new companies can often become market leaders. In this phase there is often a quick development of the technology, and it can be very difficult to know what design will be dominant. When the new technology has stabilised, a dominant design usually emerges. Early automobiles had a great variety in designs for steering wheel, and pedals for brake, and accelerator. Today most cars look the same in this aspect and attempts at new designs such as replacing the steering wheel with a joystick has so far been unsuccessful. When personal computers emerged new companies like IMSAI, and Apple led the development. IBM was at this point since long an established company that produced large mainframe computers for companies. When IBM introduced their first personal computer, the PC, it quickly became the dominant design for personal computers. This happened despite that the IMB PC in many ways was inferior to the Apple products at this stage.

This is typical for new ground-breaking product innovations. After a first turbulent period where new companies drive innovation with a variety of designs a dominant design emerges. Process innovations (for physical processes) are more often developed within existing businesses and more likely to be dominated by established companies.

The dominant design for products is nearly always established by companies that are veterans within the area. These are companies that are market and/or technology leaders of the old technology. A design becomes dominant (as defined here) when it accounts for more than 50% of the new purchases. A dominant design usually emerges within 3–4 years it is not stopped by patents or decisive new innovations (Tushman, Andersson, and O´Reilly 1997; Tushman and Murmann 2003).

Choosing the right research group as a cooperative partner

When you create a research collaboration it is often to solve difficult problems or to develop something completely new or something outside of the technological area where you already have experience. If it is something that needs to be solved in a short time it is usually better to use internal resources or to hire an external consultant. Research does not give fast results and it does not always deliver what you ask from it even if it delivers something else very useful instead. This is a reason to create a long-term collaboration and choose the right collaborative partner.

Researchers are often part of a research group, and the group is part of a university department or centre. The group may be led by a professor or a senior researcher. But the main "work force" nearly always consists of PhD students. There are other possibilities to cooperated with universities that will be described later but PhD students are the most common way of cooperating. They are research students learning how to become researchers by working on real research tasks. The probability that a PhD student will do a good job increases dramatically if the student is part of a well-functioning research group.

How do you recognise a well-functioning research group?

A PhD student needs to be part of a group that does research within the same field. They need common methods, equipment or other things that keep the group together. Sometimes a group has researchers that have a research area where neither the academic supervisor nor the other students have enough knowledge to give support. A PhD student always has a supervisor and sometimes an assistant supervisor. A key question is how many PhD students have the same supervisor and if the assistant supervisor can compensate if the main supervisor lacks time. In fast-growing popular research groups, you can find professors and other senior researcher that have so many PhD students that they hardly can do a good job. You also find professors that take on PhD students within an area where they lack competence. New methods to organise research in research schools with common course work and an external evaluation of the student's supervision has improved this situation.

Another important question is the level of support from the research group and the supervisor. A good way of finding out is to be present at an internal seminar with a group. What is the discussion in the group like? Do the participants encourage or support each other, or is competition and status what dominates the group?

One of the most competent professors that I have met that really had creative research happening in his group also had such a harsh environment that nobody wanted to stay in the group. The professor had a very harsh attitude and put enormous pressure on his students. As soon as the PhD student had submitted their thesis they moved out to other universities or companies. The research group blossomed for a short while and then withered away. Another prominent professor had two positions at two research institutes at the same time. He expected his students to work around the clock. So, the students in one of the institutes organised a telephone jour. When the professor called in the night there was at least one student that answered the phone (this was before everybody had mobile phones). The person the professor asked for was always in the lab and would call back presently. In reality most of the students were at home in their beds in the middle of the night getting the sleep they needed. In this way the students survived without too many angry words from their professor.

But I have also been present at internal research group seminars with some of the most successful scientists in the area. In these groups the students were listened to both by the professor and by each other. They were respectful and supportive against each other, and their groups were stable and produced excellent and creative research for many years.

This means that the choice of a research group that can give solid support to the PhD student is a top priority.

Match the research groups knowledge and research field to your interest

When you try to understand the competence of a research group you cannot only look at the headlines that describe the research. Many researchers are very specialised in a narrow area. A researcher that works with autonomous vehicles might have deep knowledge about software for image recognition but no knowledge about the software that steers the vehicle and even less knowledge about the electronic hardware needed. When you want to collaborate with a research group you need to review what knowledge you already have as a company and what you require and then match it against the research group.

An excellent way of finding out what a research group really does is to read publications from the group. Often it will be enough to read the abstract to get a general idea, but you might need to read the entire paper to really understand what the research is all about. It is important to note the difference between what I would call analytic and synthetic research. Analytic research is research that observes, studies, and tries to interpret. Synthetic research is research that tries to create something new such as a new material, new process, or new system.

Does the group keep up with the international competition?

If you want to know if a research group is internationally successful and respected there are ways of measuring this. Citations are one way to show that other researchers have found a publication useful enough to mention it in their own publications. The H-index is a general measure of who well cited a researcher is. It compensates for the effect that there is a large spread in how many citations there are for a single publication and gives emphasis to the best-cited publications (Hirsch 2007). You can use the h-index to compare senior researchers but not PhD students since they seldom have enough publications to be quantified. Digital tools for searching scientific papers such as Scopus, Web of Science, Dimensions, or Google Scholar can automatically calculate and show the h-index of a researcher. But how often you cite other researchers varies much with different fields of research. There are also large variations in how you choose co-authors and how many co-authors are added to each publication when you compare different fields of research. This makes comparisons across research fields difficult. Also, there is a risk in relying on quantitative measures on something as complex and qualitative as research. The h-index can give a rough idea but needs to be used with caution.

Another important measure is to look at who a particular scientist co-publishes with. There are tools that can map a research field and show collaborations and how central a research group is in this field of research. This can be visualised using a network diagram. In the network diagram the researchers (authors) are displayed using circles that are connected with arrows. In a network diagram showing co-authoring, a large circle with a central placement will indicate that the author has many co-publications with several other authors. The size of the ring indicates the number of publications and the width of the arrows indicates the number of co-publications with a specific other author. A similar diagram can show citations and indicate the number of citations and who is citing a particular author.

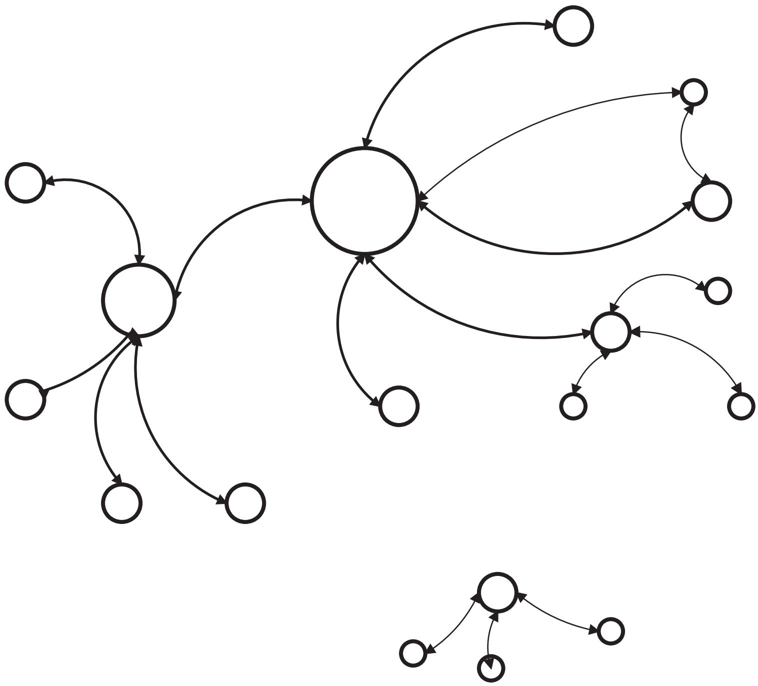

Figure 10.1 A schematic showing part of a network diagram for co-publications. The names of the researchers are omitted from this diagram.

The co-authoring diagram will typically show cluster of authors that cooperate. Often the clusters will be within a separate university but collaborations with other universities and organisations will also show up. The citation diagram will show how central and influential a particular researcher is to the research field. Citations will typically go across the organisation's boundaries.

Network diagrams can be created using software such as the freeware VOSviewer (van Eck and Waltman n.d.) a programme developed at Leiden University. The VOSviewer works together with the free version of Dimensions.ai but also with many other scientific search tools such as Web of Science and Scopus. The analysis can be done on a research group level instead of at a researcher level. But this requires more complex preparations since the researchers that publish in a certain research group will vary over time. By looking at the most senior researchers within the field will provide a reasonably accurate picture of the research groups (Figure 10.1).

How far from actual applications is the group?

Research can focus on a fundamental understanding of phenomena that might be very far from actual applications. When researchers are interviewed

Table 10.1 Technology readiness level definitions according to the EU Horizon 2020 Programme

TRL 1	Basic principles observed
TRL 2	Technology concept formulated
TRL 3	Experimental proof of concept
TRL 4	Technology validated in lab
TRL 5	Technology validated in relevant environment
TRL 6	Technology demonstrated in relevant environment
TRL 7	System prototype demonstration in operational environment
TRL 8	System complete and qualified
TRL 9	Actual system proven in operational environment or competitive manufacturing

in news media, they often are questioned about the usefulness of their research. The response of the researcher is often to motivate the research with potential applications. Sometimes these applications are very far from reality and even if they can be realised, they are far away in the future.

There is a scale called the TRL (technology readiness level) that is widely used in industry to characterise how far from real application a certain technology is. The scale starts at 1 a level that designates pure discoveries and new fundamental understanding and ends at 9 when there is a product ready to be introduced in the market. This scale is widely used in the aerospace industry. In this industry it is common to estimate it takes 1 ½ years to advance one level on this scale. In the research programmes funded by the EU this scale is adopted to show what level projects are expected in call for project proposals (see Table 10.1).

In the pharmaceutical industry there are other scales that start with trials in cell cultures, moves to animal experiments and finally to clinical trials with humans. In the manufacturing industry the manufacturing readiness level (MRL) can be used to estimate how well developed the technology to mass-produce a certain product is (see Table 10.2).

If you are interested in developing a catalyst that can be used to clean exhaust from an industry you might not be interested in theoretical simulations of single molecules on the surface of a catalytic material. You might be more interested in measurements of efficiency and endurance of catalytic materials. The research groups that do these two types of research will use different equipment and have very different base competence. But they might motivate their research by saying that their research aims to solve the same industrial problems. If you are interested in developing 3D-printing for larger products you might not be interested in research on methods that build with one atomic layer at a time. If you want to develop a drill for stone cutting that does not vibrate you might not be interested in complex mechanical simulations that only describes existing products. If you want to start a research collaboration it is important to understand what the research really does and how far it is from actual applications.

There are other considerations that are important when choosing to cooperate with a researcher in a certain field. If you are looking for a

Table 10.2 Manufacturing readiness levels according to US Department of Defence definitions

MRL1	Basic manufacturing implications identified
MRL2	Manufacturing concept identified
MRL3	Manufacturing proof of concept developed
MRL4	Capability to produce the technology in a laboratory environment
MRL5	Capability to produce prototype components in a production relevant environment
MRL6	Capability to produce a prototype system or subsystem in a production relevant environment
MRL7	Capability to produce systems, subsystems, or components in a production representative environment
MRL8	Pilot line capability demonstrated and ready to begin low-rate production
MRL9	Low-rate production demonstrated and capability in place to begin full-rate production
MRL10	Full rate production demonstrated and lean production practices in place

stronger concrete to build bridges, you should be a bit critical before you start cooperation with researchers that want to add graphene to the concrete to strengthen it. This might improve the concrete immensely. But adding one of the more expensive materials that is still produced in small quantities to a low-priced material that needs large quantities in each application might not be realistic. In that situation it might be wise to look at other more short-term ways to improve concrete strength.

But prices of expensive materials and products can fall dramatically in some cases as products and production methods are improved and as production is scaled up. The range of applications of batteries in products has widened by the year as the lithium battery has been improved and produced in larger quantities.

Economy is one important but not the only aspect that needs to be considered. Sustainability is another aspect that needs to be considered. Materials like PTFE and asbestos have excellent technical properties. PTFE is manufactured by perfluorinated chemicals that are bioaccumulating, persistent and have toxic properties. Some of the perfluorinated chemicals are already regulated and others in this large family of chemicals are on the list of chemicals of high concern. Asbestos is a material that already is banned in most countries in the world. If you look at when the legislation was introduced, you can see those countries with asbestos mines were the last to ban the use of asbestos. The knowledge of the dangers of asbestos is a very old knowledge. This means that there will be warning signs well in advance for any regulatory legislation in most cases. Chemicals are entered into the European Chemical Agency´s list of substances of very high concern well in advance of any regulation. This makes it possible to avoid development avenues that involve chemicals that might be regulated in the future, and it is also possible to avoid methods that would involve a high energy demand with large CO_2 emissions.

In January 2022 new EU regulations prohibited the use of made many inks commonly used by tattoo parlours. This was received with shock by many in the business. But the regulations had been prepared for a long time. One of the problems that was a basis for the regulation was that heavy metal particles from the inks collect in the lymphatic glands over time. This had been researched and made public several years before. This example shows that it is necessary to follow research and regulatory measures in many types of businesses and that there will be early warning signs before regulations are introduced.

Researchers are often involved with optimising one property. In real applications it is often a combination of properties that are required. If you are building the fuselage of an airplane, you might think that you need a material with very high strength. But the real need is for a material with high stiffness per unit of weight. A fuselage is basically a shell structure that is most sensitive to buckling. The most important property to avoid buckling is stiffness. Since an airplane must lift its own weight in addition to and other load it is stiffness per weight that is interesting and not only stiffness. Most metals have approximately the same stiffness per weight. Low-density metals like aluminium and titanium also have lower stiffness. The common choice of aluminium for a fuselage is determined by the ease of manufacturing complex shapes and the resistance to corrosion. Glass fibre reinforced plastic also has both a low density and low stiffness so it cannot be used to improve the capacity of an airplane (Gordon 1976). To improve the stiffness to weight ratio you must choose carbon fibre reinforced materials. These materials have very high stiffness from the carbon fibre while retaining a low density. Carbon fibre reinforced polymers are used in modern aircraft design to improve the fuel efficiency and capacity.

Choosing the right company if you are a researcher

If you are a researcher or an inventor, you might want to establish collaboration with the industry. It is not uncommon that inventors approach large companies with an invention.

Finding potential companies

Before approaching a company that is a potential collaborative partner it is important to do some research. Try to find out more about the company by visiting web pages, searching in trade magazines. Does the company already have access to the market where your competence or your inventions could make a difference? Is the company innovative, do they have innovative products or processes? By looking at the scientific literature for co-publications you can see what researchers that already have collaborations with the company.

By looking at the patent literature you can find out it a company is actively patenting. If you search for a certain technology and certain geographical area you can find companies that have an active development work in a certain area. Without active development and a large budget for innovation it is not possible to have a large number of patents. But all companies that develop new technology cannot be found in this way. Companies have very different strategies for patenting. Some companies will have a strategy of putting out a large screen of patents in their core area of business. Other companies rely on industrial secrets and their speed of development to keep ahead of the competition. The information about ownership of patents is also limited in patent databases. A patent can be sold or licensed exclusively without any formal registration of this.

For some companies it is good publicity if they are mentioned in scientific publications. A material supplier will want to be mentioned in publications where their materials are tested for properties or used in applications. But other companies do not want to show their competitors that they are interested in a particular technology area. A company that is well established but weak in a certain technology area that is growing will probably be more open to collaboration than a company that already has a solid competency within the technology area.

It is also important to find the right part of the company and the right person. In a small company there are few managers and they usually all have a good overview of the company's operation and interests. In large corporations the production and the development are distributed over many locations in different countries. It is also very difficult to have a good overview of the entire company's interests. Finding the right persons to contact can be a difficult task and getting the help for somebody that already knows the company can be very valuable.

Disclosing inventions to companies

Is it safe to disclose your invention or will the large company take advantage of your ideas without giving you credit? One way of keeping your ideas safe is to ask the company to sign a non-disclosure agreement (NDA) before presenting the idea. But many companies are reluctant to sign such agreements. The problem for the company is that the inventor might have ideas that are already known to the company. The inventor will not know whether the ideas are new or if they are already known and the company does not want to be accused of stealing ideas.

One strategy to handle this problem is to submit a patent application before approaching the company. The drawback with this strategy is that the invention might not be completely ready and you might want more time to refine a patent application. This can be handled by an NDA where the company only promises to only keep the content of the patent application confidential until it is published. The patent application can then be amended or withdrawn and resubmitted in a more advanced form before it is examined.

The company does not have to take any risks. If it is an invention that they really are interested in, they have can make a deal with the inventor. If the invention is something trivial or uninteresting, they just must keep the knowledge disclosed in the patent application secret until it is published.

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11 Summing up and looking ahead

The scientific research, both fundamental and applied, is expanding. New tools emerge that generate more data and data with higher precision. Many more persons are involved as researchers from all parts of the world and become active in research. The sole domination of the USA and Europe in research is quickly receding. Asia is becoming a major source of research and is already a dominating research force in some areas. As more research is published by more researchers, the competition is increasing.

A problem with all new research is to understand if it is reliable. There is still much research with results that are difficult to reproduce. The lack of reproducibility means that if a new researcher independently repeats the same experiment, the results are different. The pharmaceutical industry has pointed out that this creates major problems when research is transferred from the lab to the clinic and onward to commercial drugs (Leroux 2017). In medicine, these phenomena of non-reproducible results are documented and studied. In other areas, the same problems exist but they are not yet studied and documented as extensively as in the medical field. In a similar manner, technology development is speeding up over time. To keep up with the competition, products that are insufficiently tested or not even developed are launched.

The problems with reproducibility are due to several possible reasons (Sumner et al. 2016; West and Bergstrom 2021). Bad research quality, a review system for research that does not work as intended, and honest mistakes are some of the factors. But there is also deliberate research misconduct. Sometimes, this has terrible effects such as when several patients who had artificial trachea implanted died. This was done based on research that had all the important buzzwords. It was a new application of stem cell technology, artificial organs were created using 3D printing, and it claimed saving patients' lives in life-threating conditions. The problem with this research was that results were partly falsified, animal experiments that should have been done prior to clinical trials were missing, and the ethical review had been bypassed. Patients with the implanted artificial trachea died. Some of this research was published by established scientific journals and have now been withdrawn by the journals (Asplund and Hermerén 2017).

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Similar problems have emerged in the entrepreneurial field. The financing of the innovative ecosystem has grown rapidly in some places. Driven by the fear of missing out on huge opportunity, decisions have been taken on very loose grounds. Huge sums of venture capital have been invested in businesses with very slim futures. The reasons have been that the technology has in the worst case been non-existent or the readiness for market introduction has been hugely exaggerated ('Theranos' n.d.). Pictures of products that are generated by visualisation software is so good that it is difficult for a potential buyer to know if it is a real photo or just a CAD model that is portrayed in a picture.

The pressure to deal with climate-related challenges has led companies to proclaim their products as "green" with "net zero climate impact" or with "climate compensation" and so on. But to be able to make such claims in the future, companies that sell products will have to substantiate the claims. It will be necessary to look at the entire lifecycle of a product and to quantify the actual environmental impact. A life cycle perspective should be included in product development and there is a need to quantify the major factors of environmental impacts.

For the future, it will be much more important to do a due diligence not only of business ideas and board members of start-up companies but also of the technology content and the readiness of the technology that a start-up or spin-off offers. There is also a need for improvement in the review system for scientific literature. The self-correcting process of science works in many cases but is slow and does not to keep up with the increasing speed of development of science.

New ways of collaboration will probably emerge since collaboration is one of the fastest and most efficient ways to speed up innovation. This will increase the demands for research agreements that handle results in a way that is favourable for all partners. It will also be increasingly important to evaluate potential collaboration partners before entering into a collaboration. Scientific work and even more importantly the applicability of the science and technology to the real world need to be evaluated. It is important to know if the technology exists or if it is still only an imagined technology. Very enthusiastic and colourful pitches of new technology are not enough for success with innovation. Time and time again, we find narcissistic leaders who can sell unworkable ideas.

What is needed is a technical due diligence that looks at new products and new investment in development from a viewpoint of technical understanding and not only from a market and economy perspective.

Another big challenge will be to provide adequate and sound leadership for all new researchers and all new enterprises developing new technology. To provide the safety and support, they need to develop their skills and release their creativity. Adequate strategies and leadership are in dire need in a rapidly changing world where new major challenges will have to be met on a global as well as a local scale. On the local scale, a simple strategy such as listening well and showing that it is safe to have a different opinion can make all the difference in the world.

What we know is that creating a safe environment for innovation is crucial for success. This requires a leadership that understands how groups develop and how innovation develops. To be effective, it is often crucial to cooperate across organisations of different types and with different goals. By understanding the role and the interests of each part of the collaboration, we can set up agreements that protect all partners. It is also possible to use Intellectual Property Rights (IPR) to safeguard our innovations and make them easier to exploit.

The road from a first new idea or invention to a functioning new product or process that can be placed on the market is often long and difficult. But as I have tried to show in this book, there is basic knowledge available that can help us to guide persons, groups, and organisations along this road. If you create a safe environment and collaborate with teams with other competences, then new ideas will come in plenty, people will flourish, and you will have lots of fun.

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