Turning Technology into Business Using University Patents

Dap Hartmann

> *I hear, I know.*
> *I see, I remember.*
> *I do, I understand.*
>
> Confucius (551–479 BC)
> Philosopher

We present an education paradigm that stimulates innovation and entrepreneurship through a master's-level university course: "Turning Technology into Business". The course was specifically designed to connect technological research with education using patented technologies developed at the research faculties of a technical university in the Netherlands. We outline the structure and the main content of the course and explain the selection process of both the patents used in the course and the students admitted to the course. This program was initiated at Delft University of Technology in 2003 and has resulted in 10 startups that have commercialized new technologies and at least two additional dozen startups that are indirect spinoffs. To illustrate the potential of this approach, we describe the case of Holland Container Innovations, a company founded by students who developed a foldable sea container during the course.

Introduction

New technologies that might provide solutions to practical problems are constantly being developed at technical universities worldwide. In most cases, the researchers involved report their findings in international scientific journals to share them with their colleagues in the field. Occasionally, these technologies are patented, thereby protecting the intellectual property rights. The question is: what happens next? Generally, the researchers move on to new projects and the university's technology transfer office is then responsible for finding interested parties to whom the university can license these patented technologies. Over the years, this approach has proven to be very difficult to execute because there is a large gap between the laboratory proof of principle that gave rise to the patent and a marketable application that utilizes the patented technology. For this reason most patents merely remain "solutions looking for a problem".

To bridge this gap and to overcome the deadlock, we designed the course "Turning Technology into Business". This elective course is aimed at Master's-level students, PhD students, and employees (researchers) of a technical university. For the sake of brevity, we will refer to all participants as *students*, even though about 10% of them are PhD students and employees. The course brings together diverse students; they come from different faculties and have different cultural and family backgrounds. The students work in interdisciplinary teams of four or five people so that their individual skills and competencies may complement each other. The synergy between, for example, Aerospace Engineering students, Industrial Design Engineering students, and students from the Business School is often very fertile because it combines the specific insights and tools from each discipline. Moreover, such diverse teams create opportunities for cross-over: solutions developed in one domain may solve problems experienced in another domain. Each multidisciplinary team investigates the commercial potential of a patented new technology developed at the Delft University of Technology (TU Delft; tudelft.nl/en/). The aim is to understand what the new technology enables users to do, why this is useful, which problem it solves, who is in needs of this solution, what they are willing to pay for that solution, and what alternative solutions already exists in the market today.

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Patents and Technologies

The core of the "Turning Technology into Business" course consists of new technologies developed at TU Delft. In most cases, these technologies are patented, but not necessarily so. For the sake of clarity, conciseness, and consistency, we will refer to all technologies used in the course as *patents*, even though some of the technologies are not (yet) patented.

In the early editions of this course, we mined the TU Delft patent portfolio in search of useful patents. But, after a few years, researchers became familiar with the concept of the course and started contacting us directly, offering new technologies they had developed or even technologies that were still in the process of being developed. It was clear to these researchers that a thorough investigation of the commercial potential of their new technology could provide useful guidance to the direction of further research and development. Rather than perfecting the technology before looking for marketable applications, it became clear that the technological capabilities should be matched with the societal needs in a cyclical feedback loop. Market needs should guide the technological development in the right direction. A "perfect solution" is not so much perfect in the technology as it is perfect in filling a need in the market.

The patents used in the course are selected on the basis of three criteria:

1. *Creative potential:* the technology offers sufficient creative possibilities for innovative applications

2. *Inventor involvement:* the inventor agrees to be involved in the early stages of the project

3. *Business potential:* the patent is available for commercialization.

Criterion 1: Creative potential
We prefer patents that have a broad applicability in a wide range of fields. For example, a patent for a mechanical balancing mechanism or patent for a device that actively compensates for unwanted motion is sufficiently versatile to enable finding innovative applications in different industries. In contrast, a patent for a highly specialized process for manufacturing one particular substance (ammonia, for example) leaves no room for creativity. Although there might be business opportunities related to this new process (when it is safer, or cheaper, or uses different raw materials) there is little creative challenge in what the patent will be used for (producing ammonia).

Criterion 2: Inventor involvement
The involvement of the inventor (i.e., the university researcher) is of paramount importance in the early stages of the project. The inventor knows much more about the technology than what is codified in the patent. Many patents do not contain specific parameters that may be crucial to the proper implementation of the technology. For example, a TU Delft patent for a sludge drier consists of two large transport screws in which hot steel balls are mixed with the sludge to evaporate the moisture and hence dry the sludge. But, the patent contains no information on the dimensions of the screws, the size of the compartments, or the rotational velocity (i.e., the transport speed) of the screw, nor on the size, the amount, or the temperature of the steel balls. In some cases, the ideal parameters are unknown to the inventor; in other cases, they may have been determined but are kept secret.

The inventor can answer questions regarding the technology and its applications. Is there a prototype? Which alternative similar technologies exist? Why was this technology developed? Which likely markets may benefit from this solution? What additional information is available that is not part of the patent? After providing the students with all relevant information, the inventor is kindly requested not to be involved anymore until the final presentations. Asking the inventor to step back from the process at this stage avoids the risk of "tunnel vision". In many cases, the technology was developed with a specific application in mind. We do not want the students to focus too much on that particular application. For example, students working on a patent describing a fibre-braiding technology developed at the faculty of Aerospace Engineering came up with a business idea to produce risers for the offshore oil industry. Originally, this technology was developed for braiding airplane fuselages. The students who developed the risers had no aerospace background and started a company called Straw Rising Technologies, which was later renamed Taniq (taniq.com).

Criterion 3: Business potential
It is rather pointless to name a course "Turning Technology into Business" if there is no possibility of the students starting a company to commercialize the technology they study in the course. Although the chances that this actually happens are modest, over the

past 12 years 10 companies have been founded as a direct result of the course. Therefore, it is important that the patents studied in the course are available for commercial use. It would demotivate the students who put a lot of effort into their project and want to start a company to discover that the patent cannot be licensed. There are a few TU Delft patents that have been licensed exclusively to third parties, and these patents obviously are not suitable for use in the course.

Team Selection and Patent Assignment

The course participants are master's-level students and PhD students from all eight faculties of TU Delft. Occasionally, researchers (employees) enrol in the course and bring their own technology to explore its potential business opportunities. The choice to focus on graduate students is motivated by two considerations. First, experience shows that these students possess the necessary scientific backgrounds and skills pertaining to their fields of expertise. For example, we consider a fifth-year mechanical engineering student to be a mechanical engineer, whereas a third-year student is merely a high school student who took courses in mathematics, physics, and mechanical engineering for two years but still needs to develop sophisticated mechanical engineering skills. Second, these students are close to graduation and are contemplating what to do next. One career option is to become an entrepreneur. Even though there is no guarantee that a viable business opportunity will emerge from the course, there is always a chance that this option will present itself. Third-year students would then be faced with the dilemma whether to continue their education (which would take another three years on average) or quit their studies to pursue this business opportunity as entrepreneurs. We strongly encourage students to finish their MSc degrees first, because obtaining a university degree is generally a one-shot deal. In our experience, very few students have successfully completed their degrees after interrupting their education to pursue business ideas that later failed. However, we generally find that technology entrepreneurship requires much more than casual attention, and admittance to the Yes!Delft incubator requires a full-time commitment. This entrepreneurship dilemma is less prevalent for advanced master's-level students who are close to graduation.

Every year, more than 100 students register for the "Turning Technology into Business" course. We limit admittance to a maximum of 75 students (which breaks down into 15 groups of five students) for two reasons. First, this number just about fills the auditorium at the Yes!Delft incubator (yesdelft.nl) where we teach the course. Second, and more important, we consider teaching entrepreneurship as a hands-on practice that requires a lot of personal attention and coaching. It is not a mass-market enterprise that can be managed from a distance. In our approach, we adhere to the famous saying by Confucius (551–479 BC): *"I hear, I know. I see, I remember. I do, I understand."*, which is appropriately rephrased in the Chinese proverb *"Tell me and I'll forget; show me and I may remember; involve me and I'll understand"*.

The course involves students and staff in a three-month-long intensive exploration of potential business opportunities offered by new technologies developed at TU Delft. Every student who registers for the course is required to complete a number of pre-course assignments, the most important of which is a letter of motivation in which the student explains why they want to take this course and what they hope to get out of it. Only the most motivated, fully committed students are admitted to the course. Apart from the obvious reason that it is very rewarding to work with highly motivated students, there is another important reason: we ask researchers from the technical faculties to make available their latest inventions and to invest their valuable time by helping students in the early stage of their projects. The least we can do in return is to try and prevent dropouts and mediocre work. Without new technologies and the support of the inventors, there would be no course.

In the course, work is done in teams of four or five students – no more, no less. We have not studied the literature on the ideal group size; we are merely guided by our experience that four or five students to a group works best. During the first lecture, the students must form groups, and every group must select a patent. It is entirely up to the students how they achieve these requirements. There are two general approaches to this problem. The first approach is for a student to form a group with fellow students who feel comfortable working together, and then find consensus over which patent the group wants to work on. The second approach is to form a group with students who are interested in the same patent, and hope that this group will prove to be a good team to work with. There is only one rule that all groups must adhere to: the composition of the team must be as diverse as possible. Ideally, that means five students from five different faculties, but because that is not always feasible, we allow a maximum of two students from the same faculty per team. This diversity requirement is crucial because different disciplines equip the students with different tools and skill sets, which we encourage the students to apply (when appropriate, of course) in their analyses. Furthermore, students from one faculty may be aware of specific problems and related solutions that are not familiar to students from other faculties. One of the main goals of the course is to benefit from this collective intelligence.

The patents are assigned to the groups using a tiebreaker methodology that involves commitment and intelligent gambling. During the first lecture, all patents are presented and a tentative inventory is made of the popularity of each patent using an informal poll (i.e., a show of hands). Using this information, together with the particular preferences of the team members, each group must hand in its top-three choices of the available patents. Each group is given ten points to distribute over their three choices, with the restriction that each choice must be assigned at least one point. This approach provides a psychological challenge: should a group put all its eggs in one basket or take a more conservative approach? If a group gives the maximum eight points to its favourite patent, it will certainly be assigned that patent if none of the other groups did the same. However, if other groups waged eight points on that patent, the second and third choices are indistinguishable (one point each). Despite all these challenges, risks, and pitfalls, this way of assigning the patents works quite well: most groups obtain their number one choice and virtually no group "gets stuck" with its third choice. Generally, two different groups are allowed to work on the same patent. Only in special cases (such as when the inventor is a participant in the course) is a patent limited to one group. Usually, all the patents entered into the course are assigned to at least one group, which motivates the inventors to put forward their patents and assist during the early stages of the project. The message, "unfortunately, your patent was not chosen this year" rather stifles the enthusiasm of an inventor and may discourage other inventors from coming forward for future editions of the course.

Course Structure and Content

The course includes seven four-hour sessions that combine lectures, participant-centred case studies, classroom exercises, real-life case studies, and trial presentations. Attendance is mandatory but we expect full commitment and active participation rather than merely presence. Moreover, because this course is a highly interactive elective that is heavily oversubscribed – so only the best-motivated 70% of the applicants can be admitted – we observe that students actually feel bad when they have to miss a lecture. The advantage of working in groups is that the other team members can later bring the absent student up to date on what they missed. They are also strongly encouraged to do the classroom assignments and exercises because, as stated earlier while referring to Confucius, only by actively doing the work (i.e., involvement) will they obtain the understanding.

Because we are dealing with technology, it is relevant to ask the question "what is technology?" However, instead of elaborate definitions such as “The collection of tools, including machinery, modifications, arrangements and procedures used by humans” (Wikipedia, 2014), “The purposeful application of information in the design, production, and utilization of goods and services, and in the organization of human activities” (Business Dictionary, 2014), or “The application of scientific knowledge for practical purposes, especially in industry” (Oxford Dictionaries, 2014), we use a more practical and useful definition. During the course, we express, or define, any particular technology by completing the phrase “We know how to…”. Specifically, the technology described in the patent should be rephrased in this way. For example, “We know how reduce the volume of a rectangular box by 75% using a mechanical folding mechanism”, or “We know how create axisymmetric tubes that are very strong and lightweight, using fibre braiding that positions the fibres along the minimal path”.

The lectures consist of concepts, tools, theories, and methods culled from the literature and augmented with case studies, anecdotes, and lessons learned from experience. The only requirement for any of these notions to be part of the lectures is an affirmative answer to the question, "Is this practically useful to the art of commercializing a new technology?" Conceptual frameworks, abstract theories, psychological speculations, philosophical musings, and most quantitative social studies are not practically useful and, for that reason, have no place in this course. Among of the notions that we do use are technology unbundling and the technology tree (Floyd, 1997), the lead user concept (Urban & von Hippel, 1988; von Hippel, 1995), the theory of inventive problem solving (Altshuller, 1996), diffusion of innovations (Rogers, 2003), crossing the chasm (Moore, 2014), and a framework identifying the central drivers of start-up commercialization strategy (Gans & Stern, 2000). Each of these concepts is first presented in a general way together with practical applications. Next, the teams must apply it to their own cases. For example, technology unbundling and the technology tree are discussed and applied to the Philips Living Colors luminaire (livingcolors.philips.com), a consumer LED lamp for creating coloured "mood lighting". We start with the top-level description of the (combined) technologies that make up this product: “We know how to create 16 million colours of light that can be modified in hue and intensity using a remote control”. That meta-technology is the root of the technology tree, which is created by disassembling the product into specific technology blocks for the basic functionalities of the device. This process is called technology unbundling and it is of prime importance because, no matter which technology your patent describes, it is virtually useless without complementary technologies that together make up an application. Given that it is unlikely that the business also owns these other technologies, it must decide how to acquire them and combine them with its own (patented) technology. In the case of the Living Colors luminaire, four main branches emerge from the root of the technology tree: “We know how to i) supply power to the light source; ii) select colour and intensity; iii) emit coloured light; iv) design a light to suit a home interior”. These four main branches can be further refined until the leaf nodes represent very specific technologies. Each of these technologies is assessed in two dimensions: technology maturity (e.g., embryonic, growing, mature, aging) and competitive position (e.g., base, key, pacing, emerging). Positioning each technology in a two-dimensional matrix shows the strategic technology landscape that can be used to determine the best strategy to build the application.

Results

The first edition of "Turning Technology into Business" took place in 2003. We used seven patents distributed between nine teams. One team developed a marketable application for a boundary-layer suction technology and pursued this idea in the follow-up course "Writing a Business Plan" (in 2010 renamed "Ready to Startup!"). In 2005, two of the students founded Actiflow (actiflow.nl), a company that developed an active flow control system for vehicles. Later, Actiflow also offered engineering and design services for other industries. Actiflow specializes in combining aerodynamics and product design for a wide range of markets, and the company conducts aerodynamic studies on a consultancy basis.

Since 2003, there have been 11 successive editions of "Turning Technology into Business", hosting a total of 95 patents analyzed by 138 teams. Ten companies were founded as a direct spinoff from this course, meaning that the idea developed in the course was actually turned into a business (as the name of the course suggests). All these companies are still in business today, and the most successful spinoff to date, Ampelmann (ampelmann.nl) has well over 250 employees. In addition to these 10 first-line startups, at least another two dozen technology-based companies were started by students who participated in the course but did not manage to find an application to commercialize the patent they were analyzing. Instead, they later applied the course tools and methods to another technology for which they did develop a marketable application.

All of the companies that came out of the pipeline of the two courses ("Turning Technology into Business" and the follow-up course "Ready to Startup!") were incubated in the Yes!Delft high-tech entrepreneurs centre, which is partnership between TU Delft, the City of Delft and the Netherlands Organisation for Applied Scientific Research (TNO). Yes!Delft focuses on companies with a technological, innovative, and scalable product or process, and has a clear mission: "Building Tomorrow’s Leading Firms". Since its foundation in 2005, Yes!Delft has accommodated 142 startups, the majority of which have outgrown (and moved out of) the incubator to make room for new startups.

Case Study: Holland Container Innovations

In the 2005 edition of the "Turning Technology into Business" course, we used a Dutch patent (NL1017159) for a foldable sea container that had been dormant at the university's technology transfer office for some time. Although the patent specifically describes a foldable cargo container, the assignment was broadened to look for commercially interesting applications of any type of foldable rectangular box. The box could be as large as a 40-foot maritime container and made of steel, or as small as a shoebox and made of wood. The main questions were: Who needs foldable rectangular boxes? What problem does it solve? and What is that solution worth to them? After analyzing many possible applications (including a foldable raised workspace, a foldable cupboard, a foldable bar, and foldable temporary housing), the most promising market remained that of foldable sea containers. As a next step, the students entered this idea in the follow-up course, which was then named "Writing a Business Plan", where they transformed this concept into a viable business plan. In 2008, they founded the company Holland Container Innovations (HCI; hcinnovations.nl), which has since developed the first 40-foot foldable cargo container that meets all industry requirements, including certification from the International Organization for Standardization (ISO) and compliance with the International Convention for Safe Containers (CSC). HCI is convinced that this innovation will revolutionize the strained logistics of the world transport system by reducing the excessive costs of storage and repositioning of empty containers.

One particularly interesting aspect of this case is that HCI does not use the original patent. The way in which the container was folded in that patent was not reliable enough and it took too much time to make it practically useful. This dilemma is frequently encountered when trying to implement a new technology in the real world; we refer to as the "university–market gap". A technology that works perfectly well in the laboratory at the university does not automatically fill the real needs in the market. Exploring various applications of this technology had led the students to the market of cargo containers and the potential benefits of foldable containers. Although the market expressed a need for foldable containers, it also had requirements that could not be fulfilled by the folding technology described in the original Dutch patent. At such a moment, there are two options: i) quit the business because, apparently, you cannot deliver what the market wants, or ii) come up with a better solution that solves the problem the way the market dictates. HCI decided to do the latter and, together with the faculty of Mechanical, Maritime and Materials Engineering (3mE), they redesigned the foldable container in such a way that it complied with the market demands. This new technology was subsequently patented by TU Delft. The new patent (WO2009034142) lists both the mechanical engineer from the faculty of 3mE and the CEO of HCI as inventors. This example also illustrates how technology-based startups provide interesting engineering challenges for researchers at the host university. The new foldable-container technology contains a spring system that stores the potential energy from the long side walls (which each weigh approximately 600 kg) when they are folded inward. This energy is reused when the container is unfolded again, thus minimizing the effort. This spring system is protected by the same patent.

The 4FOLD foldable container is currently being tested in a pilot project in collaboration with CARU Containers (carucontainers.com), one of the largest traders of new and used shipping containers in the world. HCI is one of CARU's preferred suppliers, and CARU owns 5% of its stock. In May 2014, HCI won the prestigious Promising Innovation in Transport Award at the 2014 International Transport Forum for its 4FOLD ISO-certified foldable container (youtube.com/watch?v=UYOMhjbpuil).

Lessons Learned

The "Turning Technology into Business" course has proven to be a successful methodology to overcome the university–market gap. What works well in the laboratory is usually not quite ready for the market. The reason may be technological immaturity, for example, when a new process is successfully demonstrated in batch mode on a laboratory scale but the market requires a continuous process on a much larger scale. More often, there is simply no good match between the real market needs (i.e., what the customers want) and early applications of the new technology. What is still needed is the repeating process that Blank (2013) and Ries (2011) call "pivoting": the iterative improvement of the product–customer fit. Researchers at TU Delft do not have the time or the incentives to pursue that process. And, on the opposite side of the gap, incumbent companies are generally unwilling to acquire new technologies that are barely out of the experimental phase. Startup companies are a great way to break the gridlock and bridge that gap. When successful, the startup – which according to Blank (2013) is merely a temporary organization in search of a profitable, repeatable, and scalable business model – has matured into a real company. Not surprisingly, these young companies are sometimes acquired by incumbents, as was the case for Yes!Delft alumni Epyon and Ephicas.

Students have discovered that the course is an excellent hands-on way to learn how to commercialize a new technology. Even when the patent they worked with during the course did not lend itself to commercially interesting applications, they still acquired the tools and the skills that could be applied to another technology. And, researchers have discovered that the course offers a unique opportunity to analyze the commercial potential of a new technology that they have developed. Increasingly, the policy of the university is requiring researchers to "valorize" the results of their research, meaning that it should somehow generate money to fund future research. Although some researchers at TU Delft have a good track record in this endeavour, many of their colleagues are less successful, not in the least because they do not like to be distracted from what they love doing best: scientific and technological research. For these researchers, the "Turning Technology into Business" methodology offers a welcome alternative.

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Conclusion

The "Turning Technology into Business" course concept has been implemented at TU Delft, where it is organized once a year for a maximum of 75 master's-level students, PhD students, and university researchers. Given the rate of success as witnessed by the innovative technology-based companies that were started as a direct result of this course, we believe this method is the ideal way to bridge the gap between a proof of principle for a new technology and a marketable application. It stimulates students to start technology-based companies that generate valuable spinoff effects. First and foremost, it shows students that there is a third career opportunity for engineering graduates: entrepreneurship. Starting your own company and being your own boss is a serious alternative to the "traditional" career choices: academia (researcher) or industry (employee). Second, it provides an important way for new technology to find its way to the market. This benefit is particularly relevant for technologies that have not generated immediate interest from industry. Although the "Turning Technology into Business" approach is a clear example of technology push, its successes prove that finding the right balance between technological competencies and societal needs does pay off. Third, the companies started as spinoffs from TU Delft motivate the next generation of students to do the same thing. Bringing back alumni who started their own companies following the course methodology gives current students first-hand proof that "it can be done". Moreover, it preys on the Dutch sentiment that "if *they* can do it, then *I* can do it too!" And, fourth, it generates good publicity for the university. Technology-based startups are considered to be "cool" and, more importantly, they are regarded as important drivers of innovation and economic growth.

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