

# INTRODUCING BROAD SKILLS IN HIGHER ENGINEERING EDUCATION: THE PATENTS AND STANDARDS COURSES AT EINDHOVEN UNIVERSITY OF TECHNOLOGY

Rudi Bekkers and Gunter Bombaerts

School of Innovation Sciences, Eindhoven University of Technology, Eindhoven, Netherlands

Over the years, the engineering profession has changed and evolved. The expectations that employers and society have of engineers nowadays are different from those of even a few decades ago, and universities have been trying to respond to these changing needs by rethinking and redesigning their courses. This paper describes the large-scale efforts by Eindhoven University of Technology to redesign its entire undergraduate program. More specifically, it elaborates on a series of three courses on patents and standards to illustrate how new academic innovations have been put into practice while also reporting a critical evaluation of these reforms. We conclude that the undergraduate program redesign has led to an almost 50% rise in intake. Additionally, despite confirming our belief that this is a better way to train engineers, the new approach has also been challenging and not always appreciated by students as much as we would like. In regards to the patents and standards courses in particular, the efforts to increase workload while maintaining student satisfaction levels eventually proved to be successful.

**Key words:** Patents education; Bachelor curriculum; Engineering education; University education

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## INTRODUCTION: THE ENGINEER OF THE FUTURE

What employers and society expect from engineers has changed dramatically compared with earlier decades. While deep technical knowledge and problem solving skills remain important, today's engineers also need to know how to operate in diverse environments, often within complex multidisciplinary teams. They are expected to be lifelong learners, understanding and appreciating both the social and the ethical dimensions and implications of their work. Moreover, they are expected to contribute towards solutions to 'grand challenges' in fields such as sustainable energy, health, aging, mobility, environment, and global development.

The above realities have prompted a worldwide debate on the engineer of the future. Technological developments, as well as societal changes, have prompted educational institutes to think critically about education design and the future requirements for engineers. The discussions on curriculum and educational approaches for engineering studies, however, are considerably older. Back in 1949, the Massachusetts Institute of Technology (MIT) was the first engineering university to introduce Humanities, Arts, and Social Sciences (HASS) after the Committee on Educational Survey (1949) had concluded that, in addition to science and engineering fundamentals, there should also be a clear curricular focus on the mastery of problems arising from the impact of science and technology on society (1). Today, the

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Address correspondence to Rudi Bekkers, Eindhoven University of Technology, Room IPO 2.21, P.O. Box 513, 5600MB Eindhoven, the Netherlands.  
Tel: +31 (402) 4756-21. E-mail: [r.n.a.bekkers@tue.nl](mailto:r.n.a.bekkers@tue.nl)

HASS Requirement is still “an indispensable part of every student’s undergraduate education that provides students with a broad understanding of human society, its traditions, and its institutions.” All MIT undergraduate students are required to complete eight HASS subjects, comprising about 25% of their total class time (2). At the same time, MIT was leading in other areas of academic innovation, for instance, by introducing hands-on learning in 1969 in their Undergraduate Research Opportunities Program, which introduced challenging projects such as the Electrical Vehicle, Marine Robotics, and Robotics Football (1). Later, project-based learning was adopted at many more institutes, certainly not only in the field of engineering.

In the early 2000s, the National Academy of Engineering conducted a large project known as “The Engineer of 2020.” It centered on an effort to envision two decades into the future and use this knowledge to predict the roles engineers would play in the future in order to “position engineering education in the United States for what lies ahead, rather than waiting for time to pass and then trying to respond.” The results were published in two reports (3,4). Focusing primarily on undergraduate education, the Academy not only confirms the need for engineering education to produce technically excellent and innovative graduates but also emphasizes the need to enrich and broaden engineering education so that those technically grounded graduates will be better prepared to work in a constantly changing global economy. Apart from a number of recommendations specific to the U.S. educational system, the two main recommendations are:

- “In addition to producing engineers who have been taught the advances in core knowledge and are capable of defining and solving problems in the short term, institutions must teach students how to be lifelong learners.”
- “Engineering educators should introduce interdisciplinary learning in the undergraduate curriculum and explore the use of case studies of engineering successes and failures as a learning tool.”

In fact, these earlier approaches and thoughts are very much in line with the notion that a strong,

disciplinary focus is important but no longer sufficient to address the grand challenges that society is facing today, challenges for which society expects engineers will contribute to finding solutions (5). In addition, in recent years, a number of trends in education in general have emerged: more flexibility and freedom of choice from the perspective of the student, greater focus on assessment and success rate, more focus on student-centered and learner-centered education, and higher standards for curriculum organization (6,7).

This paper reports on large-scale efforts at Eindhoven University of Technology to redesign its entire Bachelor’s program (undergraduate program) and describes in greater detail one of its new courses, on patents and standards, to illustrate how academic innovations have been put into practice. In the second section, we present the context of Eindhoven University of Technology and discuss the process of redeveloping its undergraduate program, thereby summarizing the outcome of an independent assessment performed in early 2015, two and a half years after the new program was adopted. The third section continues by focusing on the patents and standards course, one of the series of courses in this new program, and discusses its positioning, learning objectives, design, and content, whereas the fourth section elaborates on a series of academic innovations implemented in this new course. The fifth section discusses our experiences with this course, based on student feedback, and a pilot program to make specific improvements to the course. The final section offers concluding remarks.

## **THE TOTAL REFORM OF THE UNDERGRADUATE PROGRAM AT EINDHOVEN UNIVERSITY OF TECHNOLOGY**

Eindhoven University of Technology (TU/e) is located in the south of the Netherlands. Founded in 1956, it is a fairly young institute. It currently has over 3,000 staff members (of which, over 2,000 are academic staff) and approximately 6,500 undergraduate students, 4,200 graduate students, and 1,200 Ph.D. students. In terms of education, TU/e offers sixteen undergraduate programs (majors): applied mathematics; applied physics; architecture, urbanism and building sciences; automotive; chemical engineering and chemistry; data science; electrical engineering;

industrial design; psychology & technology; software science; sustainable innovation; web science; biomedical technology; medical sciences and technology; industrial engineering; and mechanical engineering.

TU/e has been a strong performer in research, ranking eighth among European institutes in the 2015 “Shanghai Ranking” of Engineering/Technology and Computer Sciences (8). Situated in the Brainport region, it is in the heart of one of Europe’s prominent high-tech hubs, home to organizations such as Philips Research, chip maker NXP, and chip lithography company ASML (currently the world’s largest supplier of photolithography systems for the semiconductor industry), to name a few. It should, therefore, not come as a surprise that the university has significant, close forms of collaboration with industry (9).

For a variety of reasons, TU/e started discussing radical reforms to its undergraduate teaching programs in late 2010 (10). One reason was that, like other technical schools in the Netherlands, it was suffering from a relatively low, if not insufficient, student intake. From 1994 to 2010, the freshman intake for TU/e was more or less constant at around 1,000 per year but not showing much growth (1). At the same time, industry demand for technical graduates was high and rising, especially in the area of the country in which the university is based. In recent years, several multinational Dutch firms raised the alarm about the insufficient number of technical students graduating from Dutch universities. Already back in 2004, the Dutch government created a national science & technology platform (known as ‘Platform Bèta Techniek’) that was tasked with ensuring the sufficient availability of people with a background in science or technical subjects (11). While this platform has generally proven to be successful, a further increased influx into technical studies is desirable, starting at the undergraduate level.

Another reason for reforming the undergraduate program was the desire to rethink how the university was training its future engineers and seeing if the training matched the changing requirements of the engineering field and society as a whole. The university also wanted to be responsive to progress in terms of didactics and make the best use of educational innovations. In other words, it wanted to redesign its undergraduate studies to train the “engineer of the future.”

The starting point for this reform was a task force established by the rector of the university, who came with a proposal for a redesign and a vision as to how this proposal relates to the institute’s mission and core values (12). The proposals of this task force were widely acclaimed, and, by 2012, a full redesign of the undergraduate program was under way. This redesign required a great deal of negotiating and diplomacy (university departments enjoy a relatively high degree of autonomy), organizational changes, the development and issuance of new sets of institutional rules, and much more. In terms of the structure and content of new educational elements in the humanities and social sciences, they investigated the teaching programs at three institutes: MIT, the California Institute of Technology (Caltech), and Ecole Polytechnique Fédérale de Lausanne, Switzerland (EPFL). TU/e chose these institutes because they had experience introducing humanities and social sciences into their technical curricula (representing 25% of the overall study load at MIT, 20% to 25% at Caltech, and 7% at EPFL).

Different from some of the above institutions, the newly developed humanities and social sciences program of TU/e’s revised Bachelor curriculum is specifically aimed at the context of technological development. It consists of four courses with a total nominal workload of 560 hours, representing 11% of the full Bachelor curriculum. Thus, the program is shorter than those at MIT or Caltech, yet longer than EPFL’s.

In this TU/e program, students study and reflect on the user, society, and entrepreneurial (USE) aspects of their future engineering professions. The USE basic course applies ethics and the history of technology to introduce these subjects. TU/e intentionally starts this USE basic course in the students’ first year in order to underline that USE is an intrinsic part of technology and not a voluntary or non-binding supplement to the students’ major. In their second or third year, students choose one of eleven series of three courses on a particular theme. Examples of these themes are the future of mobility, the secret life of light, decisions under risk and uncertainty, and, finally, patents and standards, which we will focus on in the second part of this paper.

The introduction of the new Bachelor College included a large-scale independent assessment in

early 2015 (6). It was executed by an expert who has also done similar projects for MIT, the Royal Academy of Engineering, and University College London (UCL). The overall evaluation states, “Compared to the majority of educational changes made in engineering across the world, Bachelor College is a genuine curriculum-wide, systemic reform, affecting every course, student and teacher. In this context, what has been achieved by the Bachelor College reform is very impressive.” Nevertheless, the review also identified challenges. In general, curriculum coherence and connectivity should be made more explicit, and students should be offered an active and integrative approach. In particular, the USE courses should provide extra challenges and be more demanding in terms of the time investment required to pass the course (we will return to this final challenge later on). While these are indeed real challenges, the assessment also notes that they are “in line with what might be expected for a change of this magnitude, and should not detract from the quality, ambition and impact of the change overall” (11).

The new Bachelor College also resulted in a considerable growth in intake. After having been stable for more than a decade at around 1,000, student intake numbers started to grow steadily in 2010 up to over 1,900 in 2015 (13). The assessment revealed that the increase came in particular from two groups of prospective students that the Bachelor College had

specifically targeted: ‘career betas’ and ‘generalists’ (see Table 1 for an explanation of these categories).

**A SERIES OF COURSES ON PATENTS AND STANDARDS**

As discussed in the previous section, the series of courses on patents and standards is one of the options for students. It was first offered in autumn 2013 and, since then, has attracted around 90 to 100 students every year. Its development came from a belief that this topic was not receiving the attention it deserved in training engineers, a view also expressed by Garris and Duderstadt (14,15), among others. To explain the relevance of this topic to students, we use the following arguments:

- a. The use of technology in society surely depends on how good that technology is, but also, and perhaps to a much larger degree, on other factors relating to firm strategy (basic starting point being works of authors such as Porter and Teece (16,17)), user adoption (see the seminal work of Rogers (18)), and more. In this context, patents and standards together play a paramount role. Patents have a central position in a firm’s strategy, including their decisions on what research they want to invest in, what technology they use in their product offers, and how they compete vis-à-vis

**Table 1:** Student Population Before and After Introducing the Bachelor College

Student group	Pre-defined statement characterizing this student group	Pre-Bachelor College Students	Bachelor College Students
Intrinsic betas	<i>“I like technology and am keen to know how things work and how things are put together. My degree program must fit in with my interests.”</i>	64%	54%
Career betas	<i>“I like to buy technical gadgets, but I don’t feel the need to tinker with them. I want a career where I can earn lots of money and enjoy a certain status in society.”</i>	4%	9%
Generalists	<i>“I have a social vision for my future and am looking for a job in which I can make a meaningful contribution to society, where I can work together with others and grow personally.”</i>	29%	36%
Non-engineers	<i>“I don’t really like technology and I don’t actually want to take a technology-related degree.”</i>	3%	1%

Based on data reported in (11). Using the Beta Mentality Model (<http://www.betamentality.nl>) to define four different student demographics, students were asked to self-allocate themselves into one of these four groups by identifying which of the following predefined statements most closely correlates with their own perspective.

competitors. Standards play a central role in the many markets where connectivity and interoperability are required—think of DVD standards in consumer electronics, the various mobile telecommunications and WiFi standards, and the Transmission Control Protocol (TCP) and the Internet Protocol (IP) standards, without which the internet could not work. Standards-setting meetings are not about dusty rooms with old-fashioned participants but are actually the places where firms send their very best and brightest people, and where they negotiate and decide what a technology field will look like 10 or 20 years from now. This is where the winners and losers in industries are decided.

- b. As future engineers, knowledge of patents and standards will likely serve students well in their daily work, and the skills they develop in this class enhance their curricula vitae (CV) in a valuable way and may give them a leading edge when applying for jobs. The ability to both know when one of their own inventions has the potential to receive exclusive protection and how to avoid using innovations that others have been able to protect are not merely desirable skills; increasingly, companies will expect engineers to do these competently. Some companies may even see individuals who do not possess such fundamental knowledge as a risk and a business liability. At the same time, while the law can create risks—which should be minimized from a firm’s perspective—it can also offer opportunities to create value (19).
- c. Some graduates go even further; quite a significant number of engineers who graduated from our institute have gone on to make patents and/or standards their main field of expertise. They work as patent attorneys or standardization experts. For instance, Philips Intellectual Property & Standards, the department of that firm responsible for standards and patents and headquartered in Eindhoven, employs no fewer than 245 professionals.
- d. Both patents and standards affect individuals, markets, businesses, and society as a whole, raising many interesting questions. For

instance, patent systems may result in people in developing countries being deprived of much-needed pharmaceutical drugs.”

Note that we deliberately decided to use the word “patents” in the title of the course, not the term “intellectual property (IP).” Although the course also extensively covers copyrights, trademarks, design rights, and other forms of IP, our prospective students may not be acquainted with the term IP.

In terms of set-up, Patents and Standards is a series of three consecutive courses focused on exploration, specialization, and application, respectively. Each of these courses spans one quartile (approximately 11 weeks) and requires a nominal workload of 140 hours (for class attendance, assignments, exam preparation, etc.). For students, the course is well aligned with the underlying philosophy of the USE courses:

- User perspective: Here, we interpret the user as the individual, creative user/innovator/inventor who is aiming to patent their own research or design results, considering other means of protection (e.g., copyright, design right), or considering involvement in standards. The user perspective focuses on the creation of societal, firm, or individual value and the skills to recognize such values. We pay particular attention to the entrepreneur and the role of patents in firm creation, attracting capital, etc.
- Societal perspective: This perspective focuses on both the positive and negative impact of patenting on society as a whole, both in economic and non-economic terms, following recent critical discussions by authors such as Jaffe, Bessen, and Boldrin (20,21). We also address the impact of standardization (and, specifically, the impact of a lack of standardization) and the complex interplay between standards and patents.
- Entrepreneurial perspective: This perspective focuses on how firms adopt patenting and standardization strategies and how that affects the industries in which they are active. It involves multiple firm perspectives, such as start-ups, upstream knowledge firms, large implementing firms, universities and knowledge institutes, and so on. Specific attention will be paid to knowledge-intensive firms,

new technology-based firms, and the creative industry, which is especially relevant in the Dutch context.

- The holistic approach we adopt on IP is in line with recent academic contributions on value articulation, such as the paper by Conley et al. (22).

Other academics have shared their experiences of designing content for educating engineering students in patents (23,24). For teaching patents, there is also a variety of classroom materials and books available, including some specifically aimed at engineering students (25). We use the second edition of the World Intellectual Property Organization handbook on IP as the primary book (26). An advantage to the students is that this book is available without charge. This is complemented by over two dozen specific journal papers, book chapters, and articles on specific topics addressed in the course. Finding suitable materials for the standards part of the course was more difficult. After an extensive stock-take, we could not find a handbook that would suitably align with the scope and depth of our course, and so we use a compilation of materials from different sources.

During the exploration course, students are trained in the basic concepts of IP systems, their history, the ways in which actors use the systems, etc. In the process, we strive to create awareness and understanding of the role and importance of both patents and standards in technology and society. Preferably, we create enthusiasm for the topic. Here, students are continuously challenged, provoked, and interactively involved. They are shown how some companies can only survive if they position themselves properly in a compatibility standards regime, how innovation is positively and negatively affected by patents, how huge numbers of overlapping patents ('patent thickets') impact markets, and how extremely aggressive patent strategies (e.g., patent trolls and privateering) threaten and sometimes kill their prey. We show how patents have developed far beyond their original role (providing a manufacturing monopoly) towards becoming the business assets required to obtain freedom to operate, to defend a company against others, and to strategically block others or extract money from them. Students learn why patents and standards are most relevant in a number

of selected areas, especially those relating to grand challenges such as energy, health, and smart mobility. Students are also stimulated to take a broader view, like thinking about the societal impact of patents on the availability of AIDS medication. Finally, students learn how design rights, copyrights, trademarks, and other Intellectual Property Rights (IPR) are used in conjunction with patents.

During the specialization course, we aim to expand students' knowledge in selected, relevant topics and offer more theoretical depth. More than in the first course, we build on academic work in the fields of law, economics, and management science. The topics include university patenting, quantitative approaches to estimate patent value, the economics of patents and copyright, open-source developments, and the relationship between patents and antitrust/competition law. In a similar vein, we address a number of topics in the field of standards. One specific lecture is dedicated to issues when standards and patents come together; this is the main research interest of the developers of this course (for their work on this topic, see 27 and 28, among others). The specialization course also aims to train students in a specific skill set, enabling them to analyze larger sets of patents such as patent portfolios. This skills training comes in the form of three related group assignments, which are complemented by instruction lectures, tutoring lectures, and feedback on group assignments.

During the application course, students finally get involved in conducting a project of their choice, in which they apply the knowledge and skills they acquired in the previous offerings. They apply this knowledge on a technical topic relating to their own undergraduate program (e.g., electrical engineering, physics, or biomedical technology). To achieve true integration between their technical field and the field of patents and standards, students carry out this project in groups (typically three to five students) and are supervised not only by the course teachers but also by a scientist from their own technical department. The four project options for students are described in Figure 1.

## USING ACADEMIC INNOVATION IN THE PATENTS AND STANDARDS COURSE

While our university has taught intellectual property for a very long time, and has offered dedicated

**Figure 1:** The four types of projects in the application course.

**Patent landscape study:** This is an in-depth study of the global patent situation for a specific technology, application area, or product category. Such studies are usually performed by a firm to determine freedom-to-operate, understand their own licensing position, understand the position of potential acquisition targets, and more. It usually comprises several elements, such as firm ownership of patent portfolios, firms' portfolio value, technology trends, time trends, geographical trends, white spot analysis, and more. Examples of topics chosen by students in recent years are electronic terahertz spectroscopy and imaging, wafer steppers/lithography, and 3D television.

**Patent pool investigation:** An in-depth analysis of a patent pool of choice, usually focused on patents that are essential to implement a specific technological standard. Apart from investigating why the pool was established and how it further developed, this project includes a quantitative analysis, which tries to address whether (and how) patents in the pool differ from other patents also essential to the same technical standard. Such an analysis could reveal, for instance, whether the pooled patents are of higher technological value/merit than those outside the pool by performing a patent citation analysis. Examples of topics chosen by students in recent years are pools dedicated to the ITU H.265/ HVEC standard, the IEEE 802.11 standard, and the ETSI 3G/UMTS standard.

**Analysis of standardization and standards adoption discourse:** Here, students perform a critical investigation of how a standard of choice has developed over time. The typical questions posed in such a project are: How do standardization processes lead to successful standards? How did stakeholders contribute to the standard and, perhaps, 'shape' it in their own direction? When do we have an outbreak of a standards war? Examples of topics chosen by students in recent years are: standards for personal area medical networks, for wireless charging, for digital video interconnect, and for TCP/IP.

**Patent your own invention:** Some of our creative or inventive students may come up with their own unique solutions for problems. In these projects, such a student (together with other group members) can investigate whether their invention is patentable and whether it is advisable to do so. Elements of such a project are a prior-art search, claims drafting, and a consideration of the commercial opportunities of an eventual patent. Students also consider whether another form of protection (copyright, design right, trademark) may be more effective. In the spirit of patents, a non-disclosure agreement can be signed by students, supervisors, and other involved staff. Examples of topics chosen by students in recent years are rain tires, millimeter-wave anechoic chambers, interactive light control, elementary method to replace SF6 in power grid circuit breakers, and tidal energy generation.

courses on this topic for over a decade, the development of this new course prompted considerable challenges. Primarily, the new course was aimed at a much wider audience (undergraduate students from many different engineering sciences) than the previous courses (usually innovation scholars). Secondly, the Bachelor College was seen as being of utmost strategic importance for our university. We took this opportunity to try to include interactive learning and blended learning (29), as well as several other academic innovations, in order to meet the high expectations. Thanks to the support of education experts at our institute, we integrated the following elements into the course.

**a. Classroom response system:** This is a system whereby we offer students each week, throughout the course, the opportunity to test their knowledge and see whether they are well on their way to preparing

for the final assessment. Each student in the course is equipped with a small response device, also known as a 'clicker,' which is uniquely linked to the student's ID in the administrative system. At the start of every classroom meeting, there is a 10-minute period in which three to four test questions are projected on the screen. Students have 30 seconds to select the appropriate answer. Immediately after that, the right answer is displayed, plus live statistics on how the students answered that question. If necessary (i.e., if many students give incorrect answers), the teacher elaborates on the question.

**b. Guest lecturers:** There are few things students appreciate more than hearing from people in the field, and, as developers of this course, we could not agree more. For that reason, we have guest lecturers on an almost weekly basis, complementing and illustrating the materials and regular lectures, talking about their

own work, and sharing their own ideas. Covering almost all the main topics of the course, we have patent attorneys, patent lawyers, a European Patent Office examiner, academic inventors, participants in standardization, managers of large firms (including Philips and Volkswagen), as well as external academics in the fields of competition law and open source. Student evaluations clearly express appreciation for this aspect of the course.

**c. Assignments with progressive feedback:** As indicated above, the second part of the course ('specialization') includes a series of group assignments that train students in patent search and analysis skills. All three group assignments are in the same technological area, which can be selected by the students themselves. After an instructional lecture, students start carrying out their task and are given the opportunity to attend tutor meetings for individual help. After submitting the first report, the student group receives detailed feedback on their work. During the next round, they not only work on the second assignment but can also improve their report on the first assignment based on the feedback. The second assignment is such that it builds on the first assignment. Then, there is another round of submission, feedback, and a third assignment. The group's final report contains the work on all three assignments, having benefited from several opportunities for feedback and improvement.

**d. Peer review:** For the third part of the course, when students conduct their in-depth projects, we designed a peer-reviewing process in which individual students assess a number of reports written by other student groups. The reviewing rubric is quite detailed and extensive, ensuring that not only the content is evaluated but also general skills in terms of report structure, language and writing style, referencing, and so on. The peer evaluation is not only one of the elements for the final grade but is also used by groups to improve their report based on the received feedback. Students in the early years of the course expressed little appreciation for peer reviewing as a method, and some even protested, seeing it as way for teachers to outsource their work to others. We discovered that spending more time explaining the benefits of peer reviewing changed that attitude completely. We now explain that, in their later careers, many students

will be using peer reviewing in one way or another (especially if they go into science), and it might be useful to gain experience with this mechanism as well as benefiting from the opportunities it offers to learn and improve.

**e. Role-playing game:** For both patents and standards, firms' strategic behavior plays an important role. Sometimes firms decide to compete, sometimes they decide to collaborate. Here, we believe that role-playing games (also known as 'serious games') offer interesting opportunities for interactive learning. To this end, we include a game in which five different organizations—all consisting of student participants—are given the task to negotiate a future standard (in our case, to regulate flying cars). Some organizations are product manufacturers or regulators, while others represent end users or safety interests. For each of the parties, some of the interests and positions are publicly known (to all the other groups), whereas other interests or negotiation goals are only known to the party in question. The game is also designed in such a way that some of the participating organizations' goals are conflicting, so, necessarily, some will win and others will lose. During multiple negotiation phases, the students themselves learn to negotiate and protect their interests. After the game is over, the outcomes are discussed with all the students, and we ask them to explain the outcome and what they would do differently next time.

**f. Collaboration with technical departments:** Because the Bachelor College aspires to integrate social science insights with technological knowledge, we opted for full involvement of the academics from the technical departments within our university. In this way, students work on actual, real-life issues, and they have to justify that their work is also technologically sound.

**g. Collaboration with patent attorney firms:** Especially for students who conduct a 'patent your own invention' project, we have set up a collaboration with three patent attorney firms based in the Eindhoven region. Under that collaboration, students are offered the opportunity to present a nearly-finished patent proposal to a patent attorney specialized in the field and compare their own assessment of patentability with that of the expert. Some student groups have used this opportunity in recent years.



**h. Essays:** In the first part of the course, students are also challenged to think about the ethical and moral considerations relating to patents. In fact, several of the lectures present a rather critical view of the state of the patent system, its effectiveness, and its societal consequences. Students are required to write a short essay on an ethical or moral question of choice and present this to an audience. A typical topic would be the concern that an IPR system may drive the price of pharmaceuticals above a level that people in developing countries can afford.

We have found the above new elements to be worthwhile didactic innovations and believe that they are important for achieving success in satisfying a relatively diverse and sometimes challenging audience. Having said that, we see them as complementary to classical teaching in a motivating and inspiring way and not as a way to replace classical teaching.

### **EVALUATING AND IMPROVING THE PATENTS AND STANDARDS COURSE**

The TU/e has a policy whereby each course is monitored on an annual basis using student feedback. A core element of this quality monitoring is a non-obligatory survey among all participating students. For this course, the survey included almost forty five-point Likert scale questions, including organization, teacher's performance, quality of teaching materials, the different educational methods (lectures, assignments, role-playing games), preparation for assessment, actual assessment (exams, clickers, grades of assignments), actual time spent, etc. There were also questions allowing students to share their views on the extent to which learning goals have been achieved, whether the course was useful, whether they enjoyed it, and whether they believe they will use what they learned in their future profession. (See Table 2 for a list of relevant questions.) In a series of open questions, students can comment on what they liked and what they believed should be improved. Such surveys are not perfect. There is a risk of self-selection in terms of response that can lead to bias (although our response rate of 40% is quite satisfactory and mitigates extreme risks) (30). In some groups of students, there is also a known attitude to be critical of everything, right or wrong.

Despite such limitations, we believe these surveys are instructive for teaching staff and enable us to make targeted improvements.

The main results of the student surveys in 2013, 2014, and 2015 are summarized in Table 3. Overall scores and satisfaction levels are quite good. When we look to the exploratory course that is central to this article, it scores the highest of all 10 exploratory USE courses offered at our institute. Our overall course evaluation score is 3.8 on a scale of 5 (average of the ten courses is 3.4, ranging from 2.9 to 3.8). The satisfaction level of our course is 4.0 on a scale of 5 (average of the ten courses is 3.4, ranging from 2.7 to 4.0). One aspect that caught our attention was that students pass our course relatively easily (i.e., the pass rate was above average for our institute), yet the effort they self-reported putting into a course, in terms of hours spent, was lower than the defined workload. This, in fact, illustrates one of the previously discussed challenges identified by the independent assessment of the Bachelor College. At this point, we decided to use the series of patents and standards courses for a pilot study in order to explore how students' study load could be increased while, critically, not reducing the level of student satisfaction. The pilot study also received financial support from the Dutch 4TU.Centre for Engineering Education and the TU/e Innovation Fund.

The pilot had three main elements. Firstly, we reviewed and improved the final exam. Using a matrix, we ensured the right mix of knowledge questions based on multiple dimensions: topic (covering the seven main topics of the course), learning goal (knowledge, reasoning, or application), and difficulty (easy, moderate, and hard). We also adopted a model in which each of the seven topics was covered by three different types of questions. The model had three multiple-choice questions per topic and one open question. It also had one one-line question per topic in which students are only allowed to use up to 10 words for their answer, testing whether students can produce the right terminology or explanation, without seeing these already stated as in a multiple choice question. Secondly, the pilot reviewed and improved the classroom response system ('clicker') tests, bringing them in line with the more challenging final exam. Consequently, students got a better feel

for the level of difficulty and the required study effort. Finally, we distributed a representative test exam and organized a session in which students, pairwise, could assess each other's exam papers (based on the correct answers and assessment grid we supplied). This exercise would allow them to test not only their own knowledge but also see how different types of answers would give different results when using the assessment grid. To our own surprise and disappointment, only one student turned up for this session even though the students themselves had asked for more opportunities to test for the exam. This illustrates that making successful improvements is not always a task you can easily predict.

As part of the pilot, we analyzed the effect of the course redesign with qualitative data from student surveys as well as two focus group interviews. In general, the results show a positive development between 2014 (before the pilot) and 2015 (once the pilot was implemented). The positive evaluation of the course remains virtually at the same level, as well as the degree to which students say they enjoy the course (Table 4). But the students report that the work load increased from 2.4 to 2.7, where a score of 3 indicates that the workload is perceived exactly equal to the aim of 140 hours (a lower score indicates it is easier, a higher score indicates it is more demanding). We also observed that the pass rate dropped from 94%

**Table 2:** Selected, Relevant Questions from the Student Questionnaire Used in Our Regression Analysis

Variable	Full question
Course setup	Are you satisfied with the substantive setup of the course (for example, structure, teaching approach, nature of assignments and tests, and opportunities for contact)?
Course organization	Are you satisfied with the organization of the course (for example, study guide, availability of lecturers and material, provision of information, scheduling, and planning)?
Teacher B	Are you satisfied with teacher B (for example, explanation, pace, enthusiasm, and willingness to help)?
Lectures	Are you satisfied with the lectures (for example, structure, content, level, and coherence)?
Study materials	Are you satisfied with the study materials for the course (for example, books, readers/lecture notes, websites, and video lectures)?
Study guide	Are you able to use the study guide?
Sufficient exercises	Do you feel there were sufficient exercises available?
Use clickers	Are you satisfied with the use of clickers during this course?
Course materials	Have the course materials, practice opportunities, and interim tests/assessments contributed to the learning process/ability to pass the module?
Role-playing game	Are you satisfied with the role-play about the flying car?
Time attended contact moments	Which percentage of the teaching sessions for this course have you attended this quartile?
Time self-study	On average, how many hours of self-study (outside of the teaching sessions) have you spent on this course per week in this quartile?
Time final test	Excluding the teaching sessions, how many hours have you spent in preparation for the final test?
Work rigor	Do you feel that the number of credits (5 ECTS = 140 hours) for this course (including teaching sessions, self-study, interim tests, and final test) corresponds to the effort you have applied?
Work spread	Do you feel that the study load for this course is distributed equally throughout the quartile?
Enjoyment	Have you enjoyed taking this course?
Relevance	The course contributes to my development as an engineer.
Course evaluation	On a scale from 1 to 10, how would you rate this course?

**Table 3:** Student Evaluation Results for the Series of Courses on Patents and Standards

Survey question	Exploration course	Specialization course	Project course	Total set of courses
“How would you rate this course?”	3.8	3.4	3.7	
“Have you enjoyed taking this course?”	4.0	3.2	4.0	
“I feel that in this project I have been engaged in an authentic example of engineering practice.”				4.6
“Do you think this package of courses is relevant for your discipline?”				4.2
“How would you rate the series of courses as a whole?”				3.6
“This package of courses has contributed to my development as an engineer.”				3.6

Note: Numbers are based on our calculations using the official student evaluation results. Results shown are the averages of the evaluation outcomes of the first three years the course was offered (2013, 2014 and 2015), and are shown on a five point Likert scale. They are based on a total number of 112 student responses, equivalent to a response rate of approx. 40%. The “total set of courses” is based on a single evaluation survey (these questions were introduced only with the most recent version of the survey).

**Table 4:** Selected, Relevant Questions Used in the Student Questionnaire

Variable	Full question	Average score 2014 (N=46)	Average score 2015 (N=36)
Overall course evaluation	“On a scale from 1 to 10, how would you rate this course?”	7.0 (sd 1.9)	7.1 (sd 1.5)
Enjoyment	“Have you enjoyed taking this course?” (five point Likert scale)	4.0 (sd 1.2)	4.0 (sd 1.2)
Work rigor	“Do you feel that the number of credits (5 ECTS = 140 hours) for this course (including teaching sessions, self-study, interim tests, and final test) corresponds to the effort you have applied?” (five point Likert scale)	2.4 (sd 0.8)	2.7 (sd 0.6)
Pass rate	[percentage of students that passes the first time they sit the exam]	94%	84%

**Table 5:** Selected Stepwise Regression Analysis for Course Evaluation

Model Course Evaluation	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	0.321	0.532		0.602	0.549
Enjoyment	0.946	0.112	0.616	8.477	0.000
Work spread	0.491	0.093	0.313	5.267	0.000
Work rigor	0.408	0.113	0.176	3.606	0.001
Teacher B	0.333	0.114	0.223	2.921	0.005
Study Guide	-0.314	0.118	-0.155	-2.658	0.010

to 84%. In other questions (not shown), students also reported spending more time both on preparation for the final exam as well as weekly self-study. These numbers indicate that the pilot achieved its objective: a higher workload but not at the expense of satisfaction levels.

Having completed this exercise and collected a wide range of data, we also decided to explore whether we could discover which elements of a course could be defined as determinants of the students' overall course evaluation. We did so by conducting a stepwise multiple regression, in which a range of aspects of the course served as predictors (see Table 2 for the exact questions) and the course evaluation as the dependent variable.

A stepwise multiple-regression was conducted to evaluate how the different predictors could explain the course evaluation. In Table 5, we show the most interesting findings. Of the seventeen predictors we tested, five were significant predictors of overall satisfaction. These five are "enjoyment," "work spread," "work rigor," "teacher B," and "study guide." Together, they predict no less than 85% of the variance in the variable representing overall satisfaction. The twelve other predictors did not enter into the equation ( $p > .05$ ). The findings from this quantitative analysis were in line with those of the two focus group interviews: Enjoying the course played a high role in the total evaluation, as did having the work well spread out over time and having an appropriate level of rigor (i.e., sufficiently challenging the students and not giving them exams that are too easy). We also observe from both the data and the interviews that the performance of specific teachers had a significant impact on overall satisfaction. One outcome of the analysis, however, is puzzling: The higher the students scored the quality of the study guide, the lower they scored overall satisfaction. This is a counterintuitive outcome, and the students in the focus group interviews were not able to shed further light on what might be happening here.

The role-playing game created some fascinating findings. Whereas the distribution of answers to almost all the questions in our survey resembles a Bell curve, the answers about satisfaction with the role-playing game are extremely polarized. In total, 15 students are (very) unsatisfied, 1 student is neutral,

and 20 students are (very) satisfied. We speculate that this particular activity brings some (engineering-oriented) students quite far out of their comfort zone, whereas other students enjoy having their social and negotiation skills tested.

We ourselves found it remarkable that the classroom response system ('clickers') did not turn out to be a predictor of overall satisfaction. Whereas our data does not support a conclusion that clickers help to improve overall satisfaction, we do believe clickers are useful, providing opportunities for testing knowledge as well as inserting more interactive moments into lectures.

It is important to mention that this course adds to the larger programmatic learning goals of the TU/e and its Bachelor College (Figure 2). In brief, this course makes students "aware of the significance of other disciplines," and it increases their ability to "communicate their results of their learning, thinking, acts and decision-making processes." After the course, students increased the "intellectual skills that enable them to reflect critically, reason and form opinions under supervision." They are "aware of the societal contexts of science and technology (comprehension and analysis)." And, finally, in addition to a recognizable domain-specific profile, students "possess a sufficiently broad basis to be able to work in an interdisciplinary and multidisciplinary context."

The course contributes to the formation of 21<sup>st</sup> century engineers, who should be capable of critical thinking, as reiterated by the TU/e's educational vision: "Engineers of the future must be professionals capable of thinking critically and independently [...] they must be able to contribute to solving societal problems [...] They must have an inquiring and creative attitude, a high degree of creativity and societal responsibility" (13). We believe the methods used in our course engage students in this broader engineering profile.

## CONCLUDING REMARKS

Views on education, technology, and society have been subject to huge changes in recent decades, and engineering studies have been challenged to respond to these developments. In an attempt to rethink its education program—in order to train 'engineers for the 21<sup>st</sup> century' who are skilled and prepared for the

**Figure 2:** Overview of the overall learning goals of the Bachelor of Science graduates at Eindhoven University of technology.

Bachelor of Science graduates:

- a. are qualified to degree level within the domain of engineering science and technology,
- b. are competent in the relevant domain-specific discipline(s) at the level of a Bachelor of Science [...]
- c. are able to conduct research and design under supervision,
- d. are aware of the significance of other disciplines (interdisciplinary work),
- e. take a scientific approach to non-complex problems and ideas, based on current knowledge,
- f. possess intellectual skills that enable them to reflect critically, reason and form opinions under supervision,
- g. are good at communicating the results of their learning, thinking, acts and decision-making processes,
- h. can plan and implement their activities,
- i. are aware of the temporal and societal contexts of science and technology (comprehension and analysis),
- j. in addition to a recognizable domain-specific profile, possess a sufficiently broad basis to be able to work in an interdisciplinary and multidisciplinary context. Here, multidisciplinary means focusing on other relevant disciplines needed to solve the design or research problem in question.

challenges of their profession in the future—Eindhoven University of Technology has developed a new and novel Bachelor College curriculum. This new curriculum can be considered a success. An in-depth, independent assessment showed that numerous goals were well achieved, including attracting new students with broader profiles. The assessment talks of ‘systemic reform’ and ‘impressive achievements.’ Yet, several significant challenges remain, both in terms of furthering the coherence and integration of technical and non-technical elements in the curriculum as well as in making non-technical elements more challenging and demanding for students.

This paper discusses the experiences with one specific course in the new curriculum, Patents and Standards. Starting out from the notion that any engineer will benefit from a basic understanding of the role of both patents and standards in business and society, the course implements academic innovations in order to achieve its learning goals; these include but are not limited to a classroom response system, practitioner and industry involvement (guest lecturers, patent attorneys’ assistance), role-play, and peer reviews. In further attempts to make this specific course more challenging and demanding while, critically, avoiding a negative impact on overall enjoyment or satisfaction, we conducted a pilot study. From this pilot, we conclude that design improvements in final exams and in weekly testing via the classroom

response system do, indeed, help to achieve that goal. The data collected also shows that overall student satisfaction is mostly determined by how much the students enjoy the course, how well the workload is spread out over time, whether that workload is sufficiently heavy, and the perceived performance of the teachers involved.

We believe that our experiences in the redesign of the entire curriculum for our technical undergraduate program, and the development of the series of courses on patents and standards specifically, can help other institutes to further develop and improve their teaching programs, and we hope that this article will inspire them to do so. We would like to offer them the following recommendations:

1. Do not be afraid to take a step back and think in an open and unrestrained way about what knowledge and skills future graduates should master. While such a step takes courage, and may challenge vested interests, we think it is the best way to ensure a teaching program that meets the changing demands and requirements of the future employers of these students and of the needs of society.
2. Take the opportunity to explore academic innovations such as interactive learning and blended learning (see Section 4 for specific innovations that we implemented in our own new course). They provide opportunities for

more effective learning and more intrinsic motivation in the longer term. In-house or external educational experts may help in this process.

3. Be patient. Most often, undergraduates did not choose a technical study only to be told within their first year that they also need to develop non-technical skills in order to be a successful engineer or to be attractive to future employers. This makes them a challenging audience, which can be reflected in critical mid-term student evaluations. In our experience, however, students are much more positive after they finish the full series of courses. Then, they much better recognize the value and rationale. While we advise taking student evaluations very seriously and using them to improve courses, we also advise not letting them discourage you too much.
4. Also, other staff who have been involved in more technical courses for a long time may be hesitant or may resist changes in teaching programs. However, here as well, we noticed increased appreciation among technical colleagues over time, especially those who are actively involved in the new program.

We are aware that some of our experiences, findings, and results may be context specific. We hope that others, operating in different contexts, will share their ideas and experiences as well and thus will help and inspire teachers worldwide to train our engineers of the future.

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