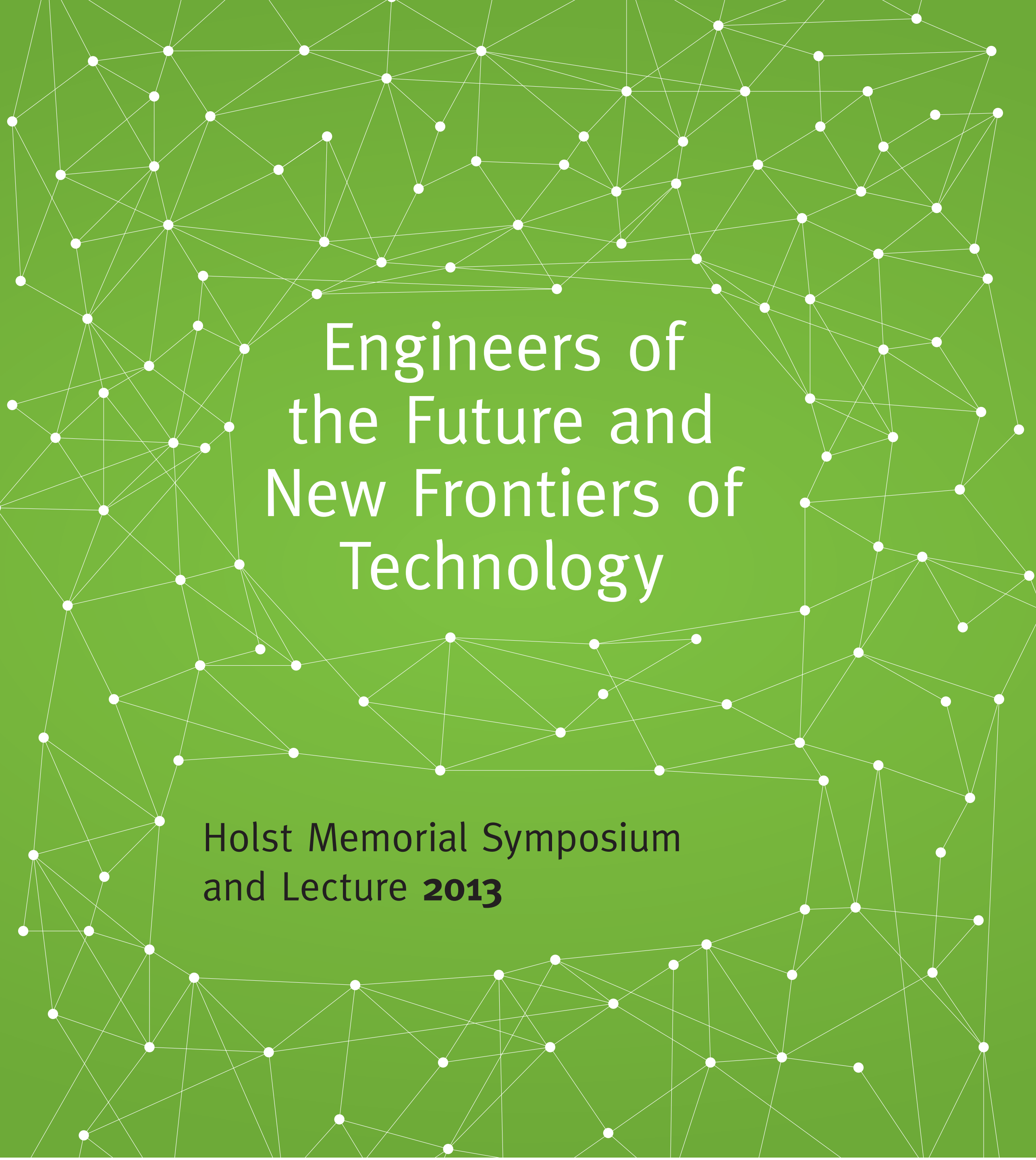

Engineers of the Future and New Frontiers of Technology

Holst Memorial Symposium and Lecture **2013**

TU/e Technische Universiteit
Eindhoven
University of Technology

PHILIPS

Engineers of the Future and New Frontiers of Technology

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Foreword

The 2013 Holst Symposium and Holst Memorial Lecture in Eindhoven proved to be an inspiring event that brought together scientists, students and professionals from Philips, TU/e and other institutions. The theme for the day targeted various aspects of the challenges facing academia (and industry) when it comes to educating the 'engineers of the future'.

The landscape is changing rapidly. The rise of smart machines, a globally connected world, superstructured organizations and emerging new technologies all have their influence on higher education in general and engineering education in particular. Engineers of the future need to be able to make connections with ever expanding frontiers of science and technology and different fields of expertise, and use this knowledge and these insights in their work. This holds for aspects like behavioral influence and social cohesion, but also for what we can learn from nature.

The 2013 Holst Memorial Lecture was given by Prof. Cherry A. Murray, dean of Harvard University's School of Engineering and Applied Sciences. Four invited symposium speakers from both the academic and industrial research communities presented their views on the theme. On the same day, TU/e published its vision on the future of engineering education in the form of an essay titled 'Engineers for the Future'. Students representing the student associations of TU/e were challenged to present their ideas on this theme as well, which resulted in a series of posters.

Content

Prof. Cherry A. Murray, Ph.D, Dean, Harvard School of Engineering and Applied Sciences, USA

Engineering For All: How the Newest School in America's Oldest University is Transforming Undergraduate Engineering Education

Cherry A. Murray, who has led some of the USA's most brilliant scientists and engineers as an executive at Bell Laboratories and the Lawrence Livermore National Laboratory, was appointed dean of Harvard University's School of Engineering and Applied Sciences in 2009. She holds the John A. and Elizabeth S. Armstrong Professorship of Engineering and Applied Sciences at that university. Her research interests include nanophotonics, soft condensed matter and surface and interface sciences. She holds a BSc and a Ph.D, both in physics, from the Massachusetts Institute of Technology and is a former President of the American Physical Society. She has served on more than 80 national and international scientific advisory committees, governing boards and National Research Council panels.

A self-professed non-academic, it was her love of solving problems that brought Prof. Murray to engineering. Prof. Murray believes this is a prerequisite for any budding engineer. Young people today are eager to tackle society's problems. The resulting influx of students who want to be able to generate solutions need engineering, or a grounding in engineering principles, to do this. This is the philosophy that guides

Harvard University's School of Engineering and Applied Sciences in creating learning that is driven by practical experience, teamwork, and applicability.

Understanding Harvard: the oldest university in the U.S.A.

Harvard by numbers

Established
1636, by the Massachusetts Bay Colony

Faculty
About 2,100 faculty members and more than 10,000 academic appointments in affiliated teaching hospitals

Students
- Harvard College – About 6,700 undergraduates
- Graduate and professional students – About 14,500
- MBA students – About 900 (the biggest business school in world)

Courses
- Over 3500 courses
- 48 undergraduate 'concentrations' (majors)

Harvard is possibly one of the most misunderstood universities in the world. This is due to a unique culture, rooted in its history, which makes it different from other universities for many reasons. It has a complex organization, with its own terminology (students have 'concentrations', rather than 'majors', for example), and lots of internal inconsistencies. Each of Harvard's schools has a lot of autonomy, which starts with historically separate calendars and independent control of their own funds and business models. Some schools are funded mostly through research; some by endowment; and others, like the business school, are funded mostly through their press. The end result is twelve faculties, each with different attitudes, and different approaches to education.

While this is the reason for complexity, the autonomy also frees the schools to focus on competing with their peers in other universities, without having to compromise to overarching organizational goals. Currently, every school at Harvard, with the exception of engineering, founded in 2007, is among the top three schools in their field nationally. And collectively, over the last 10 to 15 years, the university has been evolving to maintain its position as arguably the number one research university in the world. Over the last decade the independent schools have begun to partner in a tremendous amount of interdisciplinary education and research, and have all adopted the same calendar.

Tuition and admission

It is a common misconception that Harvard is an expensive college. Tuition is US$ 50,000 a year, but this is paid only by students coming from families earning over $200,000 a year. Over 60% of students are below this threshold and eligible for financial aid – some pay no tuition at all. The result is a spectrum of students with backgrounds ranging from poverty, to the children of billionaires, and coming from around the world – international students make up roughly 20% of the total attendees.

Harvard College students are not admitted by faculty, but by the Dean of Admissions, based on their leadership aptitudes and their breadth of abilities, as well as their academic records. Harvard admits less than 6% of applicants, but has a very high yield, with eighty per cent of the admitted applicants matriculating – the highest rate of any university in the U.S.A.

Engineering at Harvard

Harvard's historical focus has been on the liberal arts, humanities, and social sciences – with a growing interest in science developing in the last 100 years. The accompanying attitude towards applied fields was historically negative, although this has turned around recently. This created the opportunity for the School of Engineering and Applied Sciences (SEAS), as part of the Faculty of Arts and Sciences (FAS). It is the newest school, at the oldest university in the USA.

Engineering at Harvard can be traced back to two donations. Firstly, Abbott Lawrence (founder of the town of Lawrence, Massachusetts, where he ran his textile mills) made a donation to start a school of applied science in 1874. This became the Lawrence School, Harvard's first graduate school. The school was not popular among Harvard faculty and those presidents that disdained applied learning. On various occasions, they even tried transferring it to the nearby Massachusetts Institute of Technology (M.I.T.) – itself founded as a reaction to the focus on liberal arts, humanities, and social sciences in Harvard.

The second donation came from Gordon McKay, the inventor of machinery to sew the soles onto boots and a pioneer of machine leasing. He bequeathed his entire fortune to Harvard to found an engineering school. With this money, the Lawrence School faculty was merged with the Harvard College faculty to create the Faculty of Arts and Sciences, which also includes the Graduate School of Arts and Sciences. The endowments are not enough on their own to finance the growth of the SEAS, so Prof. Murray has launched a fundraising campaign within a broader Harvard University campaign, and successfully convinced Harvard that SEAS has the need and potential for growth.

Becoming a world leader

When Prof. Murray became dean in 2009, she went back to first principles, to look at why Harvard founded SEAS. To a large extent, it is because of the extent to which engineering and technology influence life today. Any top, modern university requires a strong engineering and applied sciences program. This is shown by the trajectories of the top schools in the country. Schools that have invested in engineering, such as M.I.T., Caltech and Stanford, have risen rapidly; while schools which had actively rejected engineering, such as the University of Chicago, plummeted – in the case of Chicago from number one 150 years ago to outside the top ten today.

The second reason is that in a liberal arts college like Harvard, the role of engineering is also to arm the leaders of tomorrow, even those studying humanities, divinity or economics, with understanding and literacy in technology. Because engineering and technology are so pervasive, you cannot be a top school today without offering engineering.

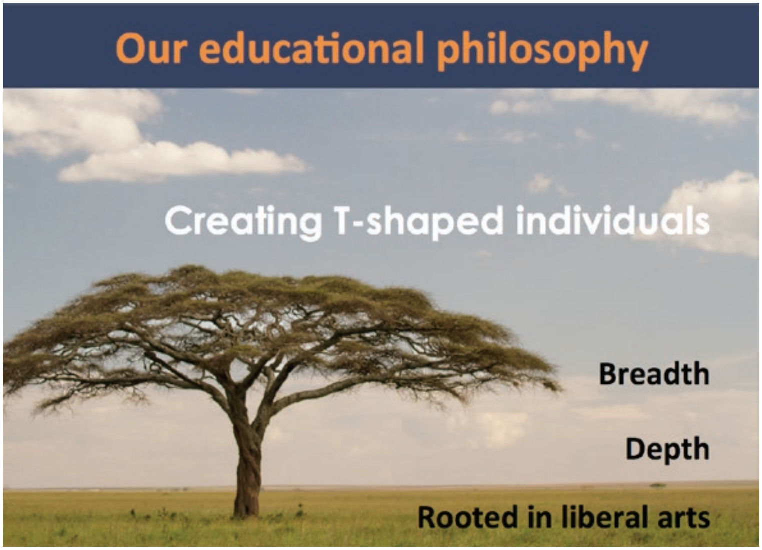
As she started to analyze SEAS, she noticed that it had a very heavy research bias, compared to the focus on the school's curriculum, and particularly on the undergraduate curriculum. Prof. Murray's attention quickly turned to strengthening teaching and advising at the undergraduate level, as well as building the masters program – which is very important for industry.

In 2009, the school had one of the lowest student ratings at Harvard, with very little coherence between undergraduate courses, due to the independence of each faculty member in selecting their own subject material. To change this, Prof. Murray organised a strategic planning exercise to identify the disciplines in which SEAS could become a world leader. This resulted in a cohesive plan of continuous curricular improvement (and a lot of debate over courses), which addresses what is taught at SEAS, how it is taught, and how success in measured.

Teaching areas

As a liberal arts university, Harvard students must take writing and a large number of liberal arts courses. This way, students are immersed in arts, humanities, social science, life science, the science of the physical universe (where engineering fits in), and at least one language other than their native language. After they have taken these courses they choose what they want to concentrate in. This is a flexible structure, and courses cannot necessarily build on each other. So the curriculum needs to allow courses to be taken in almost any order.

The curriculum of the School of Engineering and Applied Sciences developed out of applied physics, which was a successful graduate program, with two Nobel Prize winners among its former faculty. Originally SEAS focused on just applied math and engineering sciences, but today it has grown to cover biomedical engineering, electrical engineering, environmental science, mechanical engineering, and applied computational sciences. It is testimony to the relevance of engineering that the program's first graduate data science course attracted over 300 students, for example, with a large number from many of the other schools of Harvard. Engineering is the catalyst, bringing together students from schools as diverse as law, goverment, business, design and arts and sciences. This has also driven courses in other faculties, such as courses in Internet law.



Our educational philosophy

Creating T-shaped individuals

Breadth

Depth

Rooted in liberal arts

The SEAS believes in creating individuals with the breadth to work across boundaries, and the depth of an expert.

Experience and design

Without any legacy departments, Prof. Murray could devise the curriculum for Harvard students from first principles. For engineering, this means immersion in laboratory and experiential learning, as well as design work. The curriculum incorporates design, for example, into as many courses as possible, to ensure undergraduate students at the school have significant design experiences. This includes a foundation mechanical engineering course to design a miniature car – competing against other teams in the course – or a foundation electrical engineering course that adds controls to that car.

The school also goes to lengths to embed the learning in social responsibility and practical application. This means internships, but also service learning in community work and teaching in prisons, for example. Or project work, such as the medical device design course, which works on problems brought by clinicians at the research hospitals affiliated to Harvard. One such project produced a tool, requested by neurosurgeons, that will drill through the skull without damaging the membrane of the brain. This project is even being taken up by industry, and turned into a product.

The overall approach to education in SEAS is not about packing the students with knowledge, but instead to leave them room to flourish creatively, and to teach them to think. This involves developing an understanding that failure is a learning opportunity, which can be hard for students who have excelled through all of their preceding schooling. And it involves learning to rely on others, which can be hard for those who have made it this far through their independent attitude and are now faced with the peer reviews that are now part of their education.

SEAS is also pioneering peer instruction techniques. This complements the top-down teaching in cases where a teacher may not always be able to understand the difficulties a student has in grasping topics that are so obvious to the teacher. In this model, other students become the ‘teachers’, and the faculty member takes more of a coaching role.

The challenge for the school in all of these novel approaches to education is to measure how well they are doing, because many of the ways they are defining success are not easy to grade, or do not become obvious until after the student has left the school.

One effect of raising the benchmark for engineering education, is that SEAS is helping elevate standards throughout Harvard in the constant interfaculty rivalry for students interest. Prof. Murray’s goal is for every Harvard undergraduate student to take an engineering, computer science or applied math course (at the moment it is around three quarters). For those in the School of Engineering and Applied Sciences, her goal is for every student to be involved in a research project, working alongside a faculty member to prepare them for a research career or for work in industry. The majority of SEAS undergraduate students go to work after graduation. Only 20% go to graduate school straight after graduation. Approximately 10% start their own companies, including not-for-profit organizations. And among the graduate entrepreneurs, many return to Harvard after a while to attend the law or business school.

Real work, for real applications

Two examples of successful businesses which were founded during SEAS courses are Mark43 and the Bicyclean.

Mark43

The junior design course is comprised of 15 students per section, who form a consulting team for a customer. In 2012, the customer was the police force of Springfield, Massachusetts, who were having drug and gang trouble. Over a term, the SEAS team developed algorithms and software to integrate and analyze all the available data streams. The result was the discovery of two drug-dealing warehouses the police had been unaware of. This made front page news in The New York Times. At the end of term, the students ended up presenting their project to an auditorium packed with police chiefs and mayors. They won the Harvard President's social entrepreneurship challenge, and have since been awarded around 5 million dollars of venture funding for Mark43, the company they founded after graduating.

The Bicyclean

During Rachel Field's international experience in Ghana she discovered people were melting down cellphones and old electronic equipment, to recover valuable materials. Apart from the environmental issues, many of the resulting fumes are poisonous. Field's invention is based on a bicycle, and breaks up the electronics mechanically as the user pedals, so the components can be better separated before melting them down more safely. Field has started an NGO to distribute her invention to developing countries.

Rachel Field, a graduate of the senior design course created an appropriate technology for use in disadvantaged communities.

School of Engineering and Applied Sciences in numbers

- Currently there are 84 faculty, 70 of whom are full-time equivalent staff through joint-appointments with other schools. Almost a third of the faculty have industry experience – which makes for a very collegial atmosphere.
- In addition, SEAS has around 435 post-doctoral researchers, and several technicians.
- There are also 400 graduate students, each provided with a fellowship.
- Since SEAS was launched in 2007, the number of undergraduate applicants interested in engineering or computer science has gone up by about 50%. The Dean of Admission says these people who apply to Harvard are the strongest candidates.
- The number of concentrators has increased by 2.5 since 2008.
  - This represents an increasing share of Harvard students for SEAS now at around 16%, as the overall number of Harvard students stays constant.
- The Bachelor of Science in Engineering students have gone up by a factor of three.
- The ratio of students switching concentration is also informative:
  - 97% of computer science students stay in the concentration
  - The 20% of students who switch out of engineering either switch to computer science, or are Bachelor of Arts in Engineering students taking on four more courses to switch up to Bachelor of Science in Engineering.
- The number of female concentrators has more than doubled, rising from 15% to 34%.
- Of those who graduated with a degree in computer science, around two-thirds had initially intended to study humanities, social science, or science and engineering.

Tim Salimans, Ph.D, Co Founder and Data Scientist at Algoritmica, Utrecht, the Netherlands

Data Science: Turning Big Data into Big Value

Tim Salimans is a founding partner and data scientist at predictive analytics consulting firm Algoritmica, where he helps innovative companies build predictive models for marketing, customer engagement, risk, fraud, supply chains, maintenance, and more. He holds a Ph.D in Econometrics from Erasmus University Rotterdam, and studied Machine Learning research at Microsoft Research Cambridge. Tim is the winner of several predictive modeling competitions on Kaggle.com, and he also received a top lecturer award from the Erasmus School of Economics for bringing these competitions to the classroom.

Data science is the art of structuring and analysing large amounts of data, and using the findings to add business value. Given the massive amounts of data generated every day by people and systems, data science has the potential to significantly change the future of everything, from education to business to engineering.

Today, practically all engineered products, from clocks to thermostats, running shoes to large scale industrial applications, can produce data. This data is a rich source of potential added value, if it can be appropriately structured and analysed.

This is where the data scientist comes in. Tracing its origins to 1998, data science describes a holistic approach to the challenges presented by the massive explosion in data that has occurred in recent years. This involves managing and structuring data into a workable form to extract information, often in real time. This information can then be analysed to ultimately extract value, by turning the data into actionable results.

The job of data scientists is to create and communicate such value, and its implications for business directions. Outcomes can range from the development of products or decision making tools, to the modelling of social processes or business issues. Put simply, data science is the art and science of deriving value from data.

Why now?

The main impetus behind the field of data science is the sheer amount of data being generated. So much so that 90% of data existing today has been created in the last 2 years. Additional drivers include a host of web-related phenomena, such as e-commerce, social media, the quantified-self movement, and the concept of the Internet of Things, whereby increasing amounts of data are continually generated by objects and individuals.

Analysing data is now also cheaper and easier than ever, thanks to the decrease in storage costs, and the development of free, open source software. Supercomputers, for example, previously only available to government agencies and large corporations, can now be rented by the hour to provide small companies and researchers with previously unheard of processing power. These tools however, are not enough by themselves. They are only of use in the hands of people with the right skill-set and mind-set.

Data scientists require a unique combination of skills, encompassing statistics, a “hacking” approach to problem-solving, and a business understanding of how their insights can be used to make decisions and develop products and processes. That is, a data scientist knows how to identify what is of value to a business and how it can be used to implement practical solutions.

Putting theory into practice

The power of data science is well illustrated by large scale engineering applications. In these high-cost ventures even incremental savings can amount to significant sums of money, and more than justify the cost of data science. Algoritmica is a Dutch company that works with health, web and engineering related data to providing predictive models for marketing, risk and maintenance.

They have used data science approaches to bring added value to the wind energy industry, for example. Wind turbines are complex, expensive, maintenance-intensive machines that are susceptible to failure. They also generate huge amounts of data. By identifying patterns in the data collected by the turbines, failure can be predicted to instigate proactive maintenance.

To validate their approach, data scientists at Algoritmica used data collected by turbines over five years to refine a method of identifying anomalies in the data that correlate with imminent mechanical failure. This can pre-empt the need for expensive component replacements. In practice, data science could even identify compromised components before the manufacturer's warranty expired, that would otherwise have gone unnoticed.

Algoritmica developed a similar approach to identify tell-tale signatures in the data that indicate the build-up of ice on the turbine blades, which can lead to system failure. This method has proved to be as reliable as a costly, mechanical ice-detection system. This is a good example of the potential of data science to provide cost-effective and reliable alternatives, and underscores the importance of a basic understanding of data science for tomorrow's engineers.

The motivation of competition

A thriving community of companies and researchers participate in predictive modelling and analytics competitions. These are organized by companies like Kaggle, who provide competition hosts with a crowdsourcing platform to identify the best strategies to solve a given problem. Participants get access to the first of three parts of a given data set, from which they are required to predict the second and third parts. Participants experiment with different techniques to compete against each other to produce the best models. Submissions are scored based on predictive accuracy. The progress of each participant is displayed on a live leader board.

One such competition, sponsored by the analytics provider Deloitte, sought to develop a more accurate chess rating system and challenged participants to develop predictive models that could forecast the results of chess games. Dr Salimans based his submission on Trueskill. Trueskill is a system developed by Microsoft to rate individual players of an online video game. He tweaked this to create the winning technique, using his own insights, and by adapting the algorithm to incorporate information on player pairings.

Kaggle have also applied this competitive learning approach to the classroom though their *Kaggle in Class* program. This allows educators to incorporate competitions into coursework. This offers just an inkling of how data science can be applied to educational settings, for instance to provide a more personalized form of education. By monitoring student progress, the information obtained can be used to adjust course content or to provide extra material to students with specific needs.

The perspective in engineering education

The increasing demand for data scientists is in no way matched by supply, with an estimated 1.5 million data scientists needed in the US alone in the coming years. While several online courses in data science are available, few comparable programs are offered by bricks and mortar learning institutions. Moreover, pure statistics departments have disappeared from most universities, and general interest in studying statistics has waned. Training students in the diverse skills necessary for a career in data science therefore poses a challenge to universities and research institutions. University departments thus have to cooperate to develop quality programs that provide students with a solid theoretical foundation in data science as well as the necessary problem-solving skills and a clear understanding of the real-world applications of the discipline.

Already, there are signs that educational institutions are stepping up to this challenge, with data science now offered as a module within other programs or as a stand-alone course in several Dutch institutions, for example.

Physics and Biology Merging into Nanobiology

Cees Dekker (1959) is known for his research on carbon nanotubes and molecular biophysics. He has more than 200 publications, including more than 20 papers in Nature and Science. Four of his group publications have been cited more than 1000 times, 25 papers have been cited more than 100 times, and in 2001, his group work was selected as "breakthrough of the year" by the journal Science. In recognition of his achievements, Dekker has been elected Member of the Royal Netherlands Academy of Arts and Sciences and Fellow to the American Physical Society and the Institute of Physics. He was awarded a number of national and international prizes, including the 2001 Agilent Europhysics Prize and the 2003 Spinozapremie. He was also granted an honorary doctorate from Hasselt University, Belgium.

Nanobiology, also referred to as bionanoscience or synthetic biology, is an emerging area of science that combines, physics, biology, chemistry, and engineering. Nanobiology takes the study of biology from the macroscopic and microscopic level to the nanoscopic scale. Although nanobiology is currently a buzzword, is also very appropriate, as biology itself is ultimately organized at the nano scale: all the particular components and structures of the cell (DNA, RNA, proteins) work at this level.

The toolbox of nanotechnology

However, nanobiology would not be possible without the proper tools and instruments that allow the study of these tiny components and structures in real, living systems. It is only through advances in nanotechnology (such as scanning probe microscopes) that different phenomena in living cells can be studied. Nanotechnology makes it possible to pick up a single strand of DNA, to rotate, pull and measure it, and thus to study its interactions with proteins.

A good example of applied nanobiology comes from Prof. Dekker's recent work. Driven by the question "How do molecules organize themselves in space and time to create what we call life?" Prof. Dekker's latest research has focused on pattern formation and physical properties of molecules in bacterial cell division.

During bacterial cell division certain proteins oscillate to and fro, between the poles of the cell. To analyze the limits of this oscillation, Prof. Dekker and his team modified the shape of the otherwise rod-shaped E.coli bacteria – that is, nanobiology is not only used to study and describe biology at the nano scale level, but can also be used to create new, tiny structures. In this case, they grew the cells in rectangular, square, round, and triangular cells. Then they studied the different oscillations of the proteins in the new shapes, to increase their understanding of the mechanisms involved.

Synthetic biology

Synthetic biology is an emerging field at the interface of biology and (nano) engineering. It takes the classical study of biology one step closer to the engineering of biology. Taking biology as a source of inspiration and applying engineering principles to it, synthetic biology enables the design and development of synthetic systems that imitate biological structures and processes. With this, synthetic biology has the potential to dramatically change our life as we know it. Just as the advent of computers and the internet have changed the way we communicate, new discoveries and developments in synthetic biology could very well change the way we eat or get energy.

New products or applications developed using synthetic biology could impact real life areas, such as
- health (synthetic versions of drugs, personalized drugs, biosensors)
- energy (more efficient biofuels)
- climate (CO_2 reduction) or
- optimized food production

Synthetic biology is a truly multidisciplinary field that combines different disciplines, such as biology, physics, chemistry, mathematics, and engineering, as well as different technologies, including from information technology, genomics, and nanotechnology.

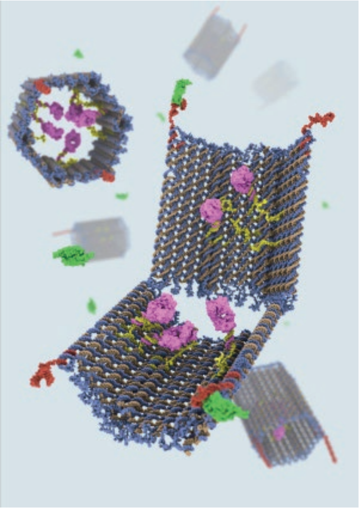
Synthetic biology uses two main approaches: the top-down approach and the bottom-up approach.
- In the top-down approach researchers engineer an existing cell (typically a live bacteria), by adding or removing elements. The best example of this top-down synthetic biology was produced by Craig Venter. He not only succeeded in sequencing the human genome, but also created the first cell with a synthetic genome, by removing the normal DNA of a living bacteria and replacing it with synthetic DNA.

- In the bottom-up approach researchers aim to build synthetic cells and biological systems from scratch, by adding components together, with the ultimate goal of creating biological functionality.

Both of these approaches can be combined with other methods such as established in-vivo or in-vitro approaches.

- In the in-vivo approach the DNA of living bacteria is engineered by adding some kind of circuitry. The most famous example of this approach is the production of artemisinic acid in engineered yeast by Prof. Jay Kaesling. By combining genes from different organisms Prof. Kaesling succeeded in creating artemisinic acid, a precursor for the antimalarial drug artemisin. The successful development of this method would allow a large-scale industrial production of a synthetic version of artemisin, which could help to reduce malaria worldwide.
  Other areas in which the in-vivo approach of synthetic biology could be applied are recombinant drugs, “green” chemistry, biosensors as well as medicine and human treatment.
- The in-vitro method in synthetic biology is component-based and driven by nanotechnology and super molecular chemistry. Potential applications could be controlled drug delivery and functionalized new materials. However, the ultimate dream of the in-vitro approach is the synthesis of biological functionality, the synthesis of an artificial cell.

Examples of component-based, bottom-up synthetic biology include DNA sequencing, and using DNA as building material.



© Image created by Campbell Strong, Shawn Douglas, & Gaël McGill using Molecular Maya & cadnano

DNA nanorobots can target cancer cells and deliver an antibody payload (purple).

DNA sequencing, or the “reading” of DNA, is done at the single molecular level. In one example a strand of DNA is moved through a tiny pore, allowing researchers to detect it and to read off the sequence. Using DNA as building material applies the ability of DNA to act as a kind of programmable glue, where bonds form between complementary DNA elements. This employs DNA purely as a structural material, independent of its normal role as carrier of genetic information. This technique is a good example of how biology can be used as an inspiration, to build something from the nanoscale up. A possible application could be in a nanoscale drug delivery system, where the drug delivery “box” attaches itself to specific cells (for example, cancer cells), and only delivers the drug at this particular site.

“What I cannot create, I do not understand”

What theoretical physicist Richard Feynman claimed “What I cannot create, I do not understand”, has a direct reference to the bottom-up approach of synthetic biology. Researchers are trying to build biological functionality from scratch to gain a deeper understanding, to discover new underlying principles, or through encountering unforeseen problems, to increase the knowledge and understanding of a given system.

Although scientists dream about building artificial cells from components – and have already made quite some progress in this respect – it is still not trivial. In fact researchers encounter lots of challenges such as unknown or ill-defined parts, context-dependent parts, unpredictable circuits as well as an enormous complexity (even minimal life already needs hundreds of genes).

Synthetic biology is driven by a fundamental science perspective, that is, a thorough understanding of the field at the nanoscale. However it is also driven by a strong application perspective, where the knowledge is used to create solutions that will help to address major challenges such as climate change, energy security, and serious diseases.

Although synthetic biology is clearly a scientific endeavor it also raises philosophical questions such as: What is life? What is nature? What is natural versus artificial? It also prompts rethinking of the metaphors used. Referring to proteins as “machines” evokes a different image and ideas than, for example, characterizing a cell as a “symbiotic community of molecules”. Since an ultimate goal of synthetic biology is the creation of novel living cells, ethical (and legal) questions arise as well. And, of course, this powerful new technology also triggers questions about biosecurity, specifically bioterrorism and biohacking.

Synthetic biology or biology as an engineering discipline

The new developments and advances in technology have shifted the classical field of biology from a discipline that studies and describes, to an engineering discipline. This is particularly visible in the new multidisciplinary field of synthetic biology. Synthetic biology not only requires a thorough knowledge of the complexities of biological systems, but also a deep understanding of engineering. In fact, applying engineering principles is essential in this new field in order to produce new biological devices and systems. Since the quantitative treatment of data plays an important role in this “new” biology, a thorough grounding in mathematics and physics is also required.

Since its early stages, synthetic biology has generated new education initiatives, such as the international Genetically Engineered Machine competition (iGEM). Undergraduate teams from around the world strive to design and build functional biological devices. The competition takes place in two phases. The first phase is a design and build period in which the students have the freedom to develop whatever they like. The second phase is a jamboree where the competing teams meet to vie for a trophy. The rapid growth of this competition in recent years has effectively raised the profile of synthetic biology. The creative applications developed by the participants also highlight the wealth of potential applications that could be realized using synthetic biology.

Prof.Dr. Thomas Speck, Chair of Botany, Morphology and Bionics, University of Freiburg, Germany

Biomimetics: Future Engineering Inspired by Nature

Thomas Speck studied biology at the University of Freiburg, finished his Ph.D in 1990 and received his habilitation and venia legendi for botany and biophysics in 1996. After a visiting professorship at the University of Vienna, Thomas Speck received offers for professorships at the Humboldt-University in Berlin and at the University of Freiburg. From 2002 until 2006 he was associate professor for botany at the University of Freiburg and director of the Botanic Garden. In 2006 he received an offer for a full professorship at the Freie University Berlin combined with the general directorship of the Botanic Garden & Museum Berlin-Dahlem. He decided to stay as director of the Botanic Garden in Freiburg, where he has held the chair for Botany: Functional Morphology and Biomimetics since October, 2006.

Biomimetics or “learning from nature” deals with the transfer of knowledge from basic biological research into innovative technical products and processes. There are different approaches to biomimetics. The top-down-approach starts with a concise technical problem, which might be solved by structures and principles found in nature. In contrast, the bottom-up-approach begins with a finding in biology (such as, that insects can’t walk on certain surfaces), which is then used as a concept generator for technical innovation (for example, new anti-adhesive surfaces). Reverse biomimetics comes into play when engineering techniques such as advanced modeling and simulation techniques, originally used during the biomimetic transfer process, help to better understand biological processes.

Differences between engineering and biology

Although the physical boundary conditions are the same in biological and technical constructions, there are a number of distinct differences between the two fields. Engineers and material scientists typically construct with a special goal, and technical constructions are usually optimized for one or two functions. In contrast biological structures originate from random evolutionary processes, and are often multifunctionally adapted. Due to this random process ('filtered' by selection), biological solutions often differ from engineering ones, which usually rely on linear thinking.

The biological production process

A main characteristic of the biological production process is self-organization. Self-organization occurs when the forming, constitutive, restrictive influences originate from the system itself. The system is thus complex, self-referencing, redundant, and autonomous. In biology this is visible in the spontaneous building of complex patterns in non-linear, dynamic systems, such as schools of fish or flocks of birds, which originate and organize in a very complex manner in space and time. This self-organization can also be witnessed in biological materials such as macromolecules, membranes, and tissues, where under suitable environmental conditions complex structures form spontaneously.

The biological production process can be described as a genetically-controlled self-assembly, which works from small to big, that is, from molecule through cell, to tissue and organ, and ultimately to a living being. But there is not only an increase in complexity in this hierarchical progression, there are also functionalized surfaces and interfaces between all these different hierarchical levels. Biological production uses just a few, lightweight, easily-accessible elements, which are brought together in low-energy processes, at ambient temperatures (ranging from –20 to +40 degrees Celsius), and at around one bar of pressure. The resulting biological materials are typically damage-tolerant, adaptive, and multifunctional, with a high potential for self-repair, self-cleaning or self-organization.

The technical production process

The traditional technical production process, by contrast, typically progresses from large to small, with no hierarchical, internally-functionalized product structure. It usually starts with a blank item made of one material, which is then processed until the final product is achieved. The production process is generally dominated by heavy elements, brought together in a high-energy process, requiring high temperatures and high pressures. It is these elements, and the processes involved in this approach to production which result in technical products usually being less sustainable than their biological counterparts.

On the other hand, all biological organisms suffer from the “evolutionary burden”, which defines their form-structure-function relationships. Thus biological structures are not “newly-made”, but are more or less built on their precursors in evolution. This also explains why some biological structures, such as the knees of biped organisms (like humans), are often not considered very useful from an engineering perspective.

Biomimetic engineering in practice

Biomimetic engineering tries to analyse and to abstract hierachical biological structures and the concommitant functions, and to transfer them for technical products. Some examples include

- Fiber reinforced branched and unbranched composites using different kinds of fiber and matrix polymers
- Self-healing structures
- Impact-damping and puncture-resistant materials
- Anti-adhesive surfaces
- Façade shading systems for buildings

Fiber reinforced branched and unbranched composites using different kinds of fiber and matrix polymers

The main objective of this project was to produce structurally optimized, highly damping lightweight fiber-reinforced, composite materials. The result has excellent vibration and bending characteristics, a long-lasting, high dynamic load capacity, and a benign fracture behaviour.

Among others, bamboo and giant reed were used as biological models for this biomimetic product. These plants can fine-tune their mechanical properties on at least five different hierarchical levels. Due to their specific construction, the structures of these plants are highly damping, lightweight, with high strength and stiffness, and a benign fracture behavior.

Another plant used as inspiration is the horsetail. Since the horsetail typically grows in muddy environments its stem is equipped with hollow tubes that are used for the transport of oxygen. These “hollow

© Plant Biomechanics Group Freiburg

The inspiration and the result: giant reed and horsetail plants, and the “Technical plant stem”, a biomimetic fiber-reinforced composite structure

tubes” were incorporated in the new technical product as functional channels, which can be employed for adding sensors and actuators, or as transporting tubes for fluids.

The dragon tree was used as a model for the branched technical compound structure. Due to its flange-mounted design at the branching regions and the internal fiber arrangement these plants can stand high bending and torsional loads at their branchings.

The new biomimetic fibrous composite material is produced using a 3-D braiding-pultrusion technique, in which a computer-controlled machine braids fibers and fiber bundles in pre-defined arrangements.

Due to its inherent characteristics the new material is suitable for use in aviation and aerospace, automotive engineering, sports equipment, medical technology (e.g. artificial limbs), and architecture.

Self-healing coatings for pneumatic structures

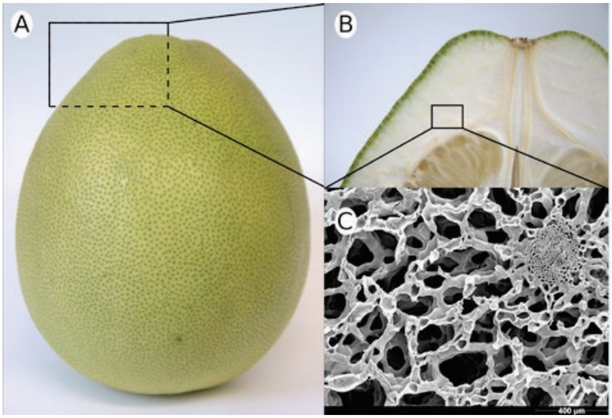
The principal idea of this project was to develop a biomimetic coating that repairs fissures in pneumatic structures quickly and efficiently. As a model, this uses the “Dutchman’s pipe” liana, a plant that quickly seals and repairs any fissures that originate during the growth processes. Since these fissures in the liana would provide entrance points for fungus spores or bacteria, there is a high selective pressure for the fissures to be sealed quickly.

Using closed-cell polyurethane foam, the team developed a biomimetic coating that abstracts and transfers the healing principle of the liana, where specific cells relax and swell, thus sealing the fissure. This biomimetic self-healing coating could be used in all sorts of pneumatic air and watercrafts, for pneumatic seats, in membrane structures for containers and hulls.

Impact damping and puncture-resistant materials

There is a strong need for impact-damping and puncture-resistant materials for use in protective wear, or in crash protection for vehicles. The peels of citrus fruits, as well as nut shells provided the inspiration for this new biomimetic product. The pomelo fruit, one of the heaviest citrus fruits, is particularly interesting in this respect, since it survives a free fall from heights of 15 meters virtually undamaged. Upon impacting almost the entire impact energy is dissipated by the fruit peel. The pomelo peel consists of a hierarchical, open porous structure built up of a graded system of foams. This graded foam structure is stabilized by a three dimensional network of vascular bundles. It is this network that quickly adapts during an impact, transferring the strain of the impact to nearly the entire peel.

Combining the energy-dissipating and impact-damping principles found in the pomelo peel with the puncture-resistant elements of the macadamia nutshell, a new, graded metal foam was produced. This new material can be used for transporting hazardous goods or for impact protection in cars.



©Plant Biomechanics Group Freiburg

Pomelo peel, with its porous structure and network of vascular bundles

Anti-adhesive structures inspired by plant leaves

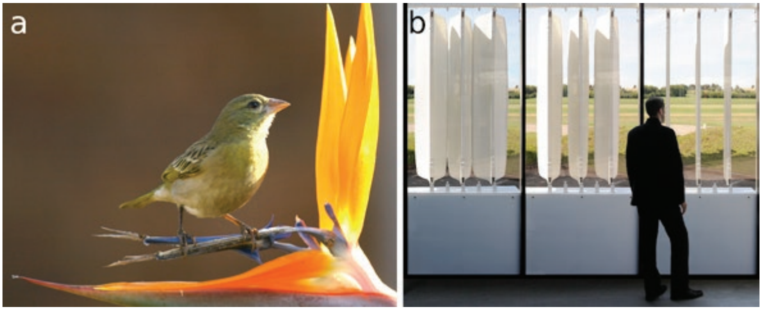
This project started with the observation that insects can walk easily on some plant surfaces, but cannot get any traction at all on others. These differences are due to selective pressure for a plant to keep plant eaters off, while welcoming visits from pollinating insects. But this does not explain the underlying mechanical effect.

Adhesion experiments with the Colorado potato beetle on particular leaves showed that it is the microstructure of the thin layer covering the epidermis of the leaf, the so-called cuticle, that prevents the beetles from walking on certain surfaces. Detailed examination revealed that a medium-sized fold in the cuticular layer rejected the tiny hairs on the beetle's leg. These are too stiff to dig into this particular fold, leading to the insect sliding off. This was replicated using synthetic epoxy resins, to create surfaces on which the insects again could not gain traction for walking.

A possible application for this new anti-adhesive surface could be a special foil or tape that protects food or medicine (in cupboards or storage rooms) from harmful, crawling insects.

Flectofin®, a bio inspired façade shading system

Since hinges are often the weakest part of a technical construction, the main goal of this project was to develop a hinge-less, mechanism for a façade shading systems. In this case the source of inspiration was the reversible elastic deformation that takes place during the pollination of the bird-of-paradise flower (Strelitzia reginae) by the weaver bird. When the bird lands on a protruding perch of two blue petals, its weight causes the perch to bend down, thus exposing the previously enclosed stamens with the pollen. When the bird flies away with pollen on its feet, the now unburdened perch encloses the pollen again.



© Rouslou Corts (A) B. Miklautsch, University of Stuttgart (B)

The opening of the bird of paradise flower for pollination (A) inspired the development of the Flectofin, a hingeless façade shading system, (B) model of the double Flectofin

The bending is here enabled by torsional buckling, something that is familiar to engineers, but is perceived as undesirable and thus to be avoided. In this case however it highlights how nature has “cleverly” solved the problem of a reversible elastic deformation. After creating physical models and performing digital simulations (FEM) Flectofin® was produced and patented. The bending in Flectofin® can be initiated by hydraulic bending, small electro motors, or by incorporating and heating small metal wires into a ‘backbone’ with two layers of fiber-reinforced material with different thermal coefficients. Adding flexible photovoltaic systems would allow the Flectofin® system to run on solar energy, making it independent from other energy sources. The first building with a façade shading system that was produced based on the principles of the Flectofin® mechanism, was the thematic pavilion at the WorldExpo 2012 in Yeosu South Korea. The Flectofin® principle is suitable for a wide range of applications from small-scale shading systems to large-scale architectural building components.

Future vision of biomimetics

Although the idea of using nature as a source of inspiration is not new, recent developments have led to what may be called a “golden era of biomimetics”. In particular advances in analytical, simulation, and production technologies are helping to analyze and understand biology much better, and to produce biomimetic products with reasonable efforts and budgets.

Trying to envision, develop and to produce new innovative products requires strong interdisciplinary thinking. For all those involved in the field of biomimetics this often means going beyond traditional boundaries and drawing upon all conceivable sources of knowledge and experience.

But biomimetics is not only an interdisciplinary field, it is also future-proof, as nature’s treasure trove offers an almost unlimited supply of models. From the roughly 10 million species that live on our planet only several hundred have been analyzed with regard to their potential for biomimetics.

Prof.Dr.Ir Peter-Paul Verbeek, Chair of Philosophy of Technology, University of Twente, the Netherlands

Enhancing the Human Body and Brain

Peter-Paul Verbeek (1970) is professor of philosophy of technology and chair of the Department of Philosophy at the University of Twente. He is president of the Society for Philosophy and Technology and a member of the Dutch Council for the Humanities. Between April 2011 and April 2013, he was chairman of the 'Young Academy', which is part of the Royal Netherlands Academy of Arts and Sciences. Among his publications are Moralizing Technology: Understanding and Designing the Morality of Things (University of Chicago Press 2011), De Grens van de Mens: over techniek, ethiek en de menselijke natuur (Lemniscaat, 2011) and What Things Do: Philosophical Reflections on Technology, Agency, and Design (Penn State University Press 2005).

Broadly speaking, "human enhancement" using technology encompasses any endeavor to temporarily or permanently overcome the limitations of our bodies through artificial means. One familiar and early example is Icarus, the figure from Greek mythology who attempted to fly with feather-and-wax wings. Millenia later, humans are still at it – enhancing our bodies and environments through technology. And the debate continues in the philosophy and ethics of technology: How do we and how can we improve human beings? Have we moved beyond the boundary between improving a person in terms of recovering from illness and boosting performance? Technological developments, such as the increased use of Ritalin or "labs, on a chip" to assess sperm, allow us to engage in activities and make *decisions in the short term without fully considering their long-term implications. Technology now affects the human body so profoundly that it's changing what it means to be human. The question we face is "how" to interact with technology instead of "should we or shouldn't we." It's an ethical discussion that calls for a deeper exploration of the interplay of human development and technological development – and what lessons today's engineering students should learn.*

Should we or shouldn't we? The ethics of human enhancement

While Icarus is admired for his ingenuity and daring, Nietzsche's übermensch lurks in our collective conscious. Many people are still frightened by the concept's association with the Nazi regime. Habermas answers the question, "Should we make a better version of ourselves?" with a resounding "no." He posits this is the worst idea humanity ever had. Designing our children's DNA, for example, would spell the end of ethics. Our ethical framework is founded on the belief that each one of us is the author of our own life, and as such, we have the power to decide how we wish to live that life.

This ethical framework shapes how many people regard the role of technology in human life and development. One school of thought argues that human enhancement through technology creates two groups of people: the ones who design, and the ones who are designed. This division would disrupt our natural and current state of equality – which would be unacceptable and ultimately undermine all ethics. Human beings, then, should stay as they are, drawing clear boundaries around technology in the human sphere.

The other school of thought argues that no one has the right to decide how, when, or if at all technologies are used. In fact, we have a moral obligation to one another to use this technology to improve people's lives (by, for example, enabling us to run faster and live longer). If we are the product of evolution, this argument continues, it would make no sense for millions of years of progress to stop simply because someone said it needed to. Technology represents a new stage in the development of mankind; humans have always used technology to interfere in their environment, and in the future, humans would use it to interfere with themselves.

Technology and what it means to be human

Both arguments fail to see how deeply interwoven human beings and technology have always been. As a result, the ensuing discussion ignores a central issue: How is human life unfolding and advancing with the technology we have today and will have in the years to come?

Stelarc, a contemporary Australian artist, illustrates this point in his experiments with the boundaries between humans and technology – and asks where technology will lead us. In writing the word “evolution,” for example, he juxtaposes the act of writing with the unsettling presence of the third hand. We’re acutely aware of that technology, yet writing feels natural to us today. Was it always so? Plato was fiercely opposed to writing, claiming it would misrepresent his ideas. It would sound culture’s death knell. By our modern standards, writing is regarded as the beginning of culture – the point at which humans moved beyond their oral traditions of transmitting ideas.

As the boundaries of technology expand, they expand our own human boundaries and ultimately transform us. And technology will not stop advancing, and it certainly won’t disappear. Given this reality, the question shifts from whether or not we should engage with technology, to how to engage with technology. This must be the starting point for our ethical considerations. In adopting this stance, we must first deepen our understanding of the relationship between human life and technology.

Central to that relationship is a differentiated view of technology. Many of us can cite examples of technology that acts, in Ihde's terms, as a medium for human existence. MRI scanners and telescopes, for instance, are seen as a medium for human existence, not a threat to it. These scientific instruments help us see things our naked eye cannot. But what about technology that is more integral and immersive – technology that is within us or part of us in some way, that can't be unpacked and packed up when we need it? People living with Parkinson's disease can have electrodes inserted in their brains, triggering chemicals to restore mobility and motor functions. A visit to your doctor's office might bring you face to face with a "smart mirror," a device linked to your medical file and capable of showing what you'll look like years from now based on your habits today. These kinds of technologies require us to interact with them in new ways, ushering a fundamental change in understanding what it means to be human.

Technology touches four aspects of the human condition:

- We have a body. But by attaching prosthetics, implanting teeth, and inserting pacemakers, the way in which we differentiate robots and humans is changing.
- We are all born. But by focusing on our babies' DNA and sex, the way in which we are born is changing.
- We all die. But by re-engineering organs, growing human tissue from stem cells, and extending longevity, the way in which we die is changing.
- We are all free to choose how we live. But by influencing how we think using electrodes, we're influencing how we exercise that freedom.

Freedom and the sense of autonomy in the human condition are particularly noteworthy. Generally speaking, we accept technology when we can maintain a sense of autonomy. When we suspect it begins to alter our thinking, or to operate independently of us, we lose that sense of autonomy. The result: fear.

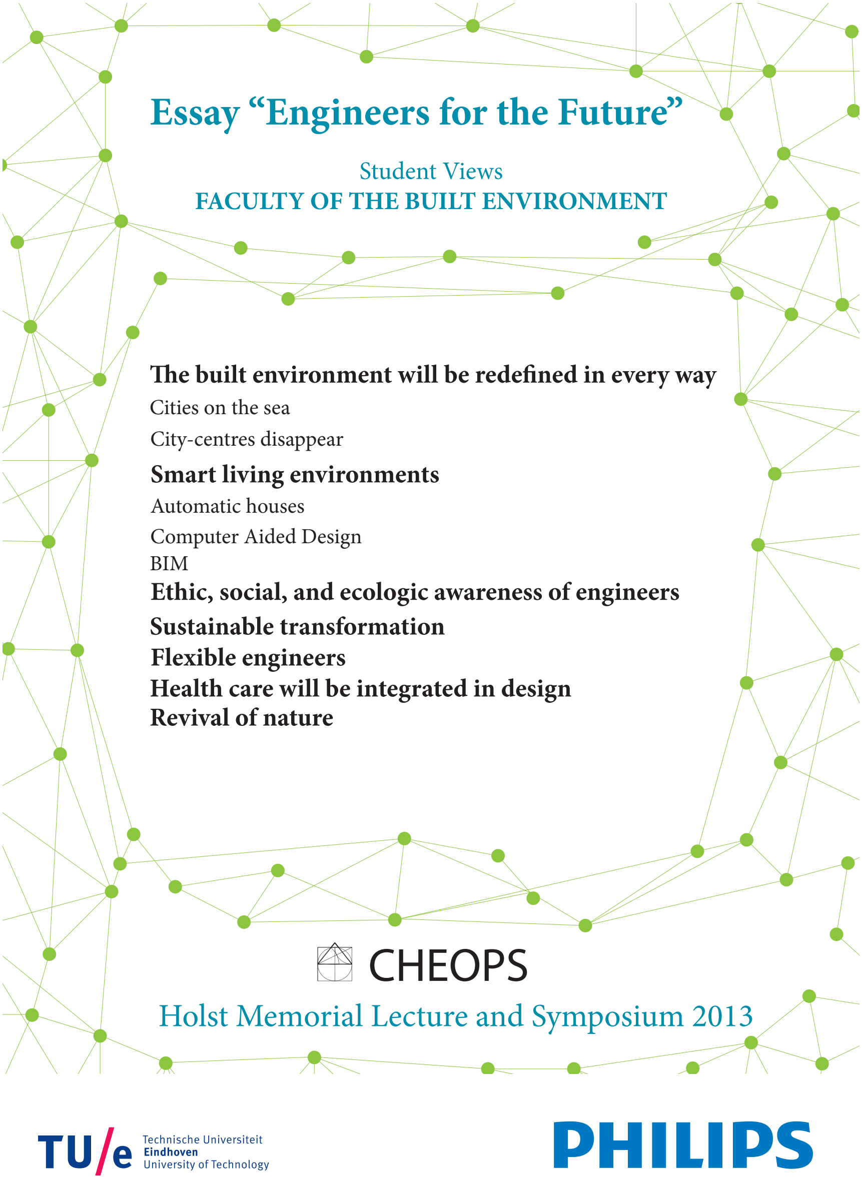
Fear of technology isn’t a new phenomenon. But it is unfounded. Technology is not an otherworldly power forcing its way into mankind at discrete points. It’s our constant companion. As such, it continues to provide us with challenges to redesign ourselves and, at the very least, opportunities to explore what it means to be human. A case in point is the birth control pill. It contributed enormously to the women’s liberation movement while changing the perception of homosexuals in society. Decoupling reproduction from sexuality introduced alternative ways of thinking about family planning, relationships, and sexual and social norms. Although the pill was never designed to change our moral views, it most certainly had an impact. Our moral views, then, develop within a larger context, and it’s essential for us to place the role of technology in that context.

Designing technology is designing what it means to be human

Boundaries between humans and technology will continue. Are we fated to become passive recipients of technological advances? No – not if we question how we can live with that technology. We can also encourage more ethical reflection in areas where this technology originates. Engineers must be able to see the bigger picture of their work and what’s at stake.

In place of post-development assessment, engineering curricula can promote ethical accompaniment. While technologies are still in development, students and researchers pose ethical questions on how and where the impact will be felt. Shifting the focus from function, such practices lead to a richer idea of what the technology can accomplish and how it could be used. At the same time, this method would help us grasp how it might reorganize our relationship with the world and our normative frameworks. A definitive blueprint is impossible, but ethical considerations can shed light on different scenarios.

Icarus's story holds an ethical lesson for engineers. Flying too high (focusing on the next great gadget) and flying too low (shying away from new technology) both lead to destruction. Daedalus wisely cautioned his son to keep to the middle. What is the middle in human enhancement? Rather than advancing or hindering technology at any price, students must try to anticipate the mediating effects of technology, training their moral imagination in what technologies will do beyond their intended function. Technology will transform us into new humans with new moral choices, and that transformation can unfold in a more systematic, structured way. "Value-sensitive design," for example, can assist students and engineers to keep to the middle in thinking about multiple desirable outcomes for society.



Essay “Engineers for the Future”

Student Views
FACULTY OF THE BUILT ENVIRONMENT

The built environment will be redefined in every way
Cities on the sea
City-centres disappear
Smart living environments
Automatic houses
Computer Aided Design
BIM
Ethic, social, and ecologic awareness of engineers
Sustainable transformation
Flexible engineers
Health care will be integrated in design
Revival of nature

CHEOPS
Holst Memorial Lecture and Symposium 2013

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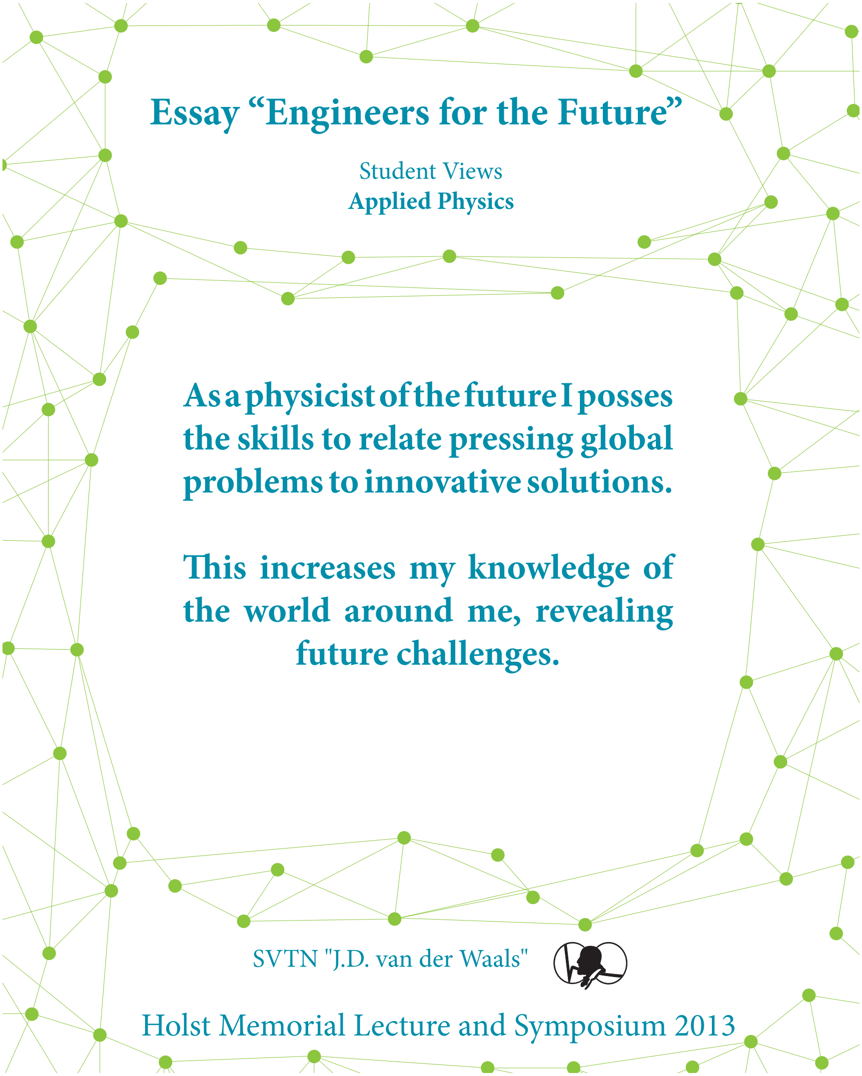

Essay "Engineers for the Future"

Student Views
Applied Physics

As a physicist of the future I posses the skills to relate pressing global problems to innovative solutions.

This increases my knowledge of the world around me, revealing future challenges.

SVTN "J.D. van der Waals"

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Essay “Engineers for the Future”

Student Views
Mechanical Engineering

Keep it personal
  Why grow?
  Small scale with lots of interaction

Digitalisation
  Do MOOC's jeopardise excellence?

Netherlands versus international

W.S.V. Simon Stevin

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Essay "Engineers for the Future"

Student Views

Sander Hochstenbach (ST)

Education: Didactic Approach

- International and increased diversity of students
- Interdisciplinary courses
- Increased use of ICT: Libary of video lectures, MOOC's, open weblectures
- Learn to learn / lifelong learning

Chemical Engineering: Future Prospect

- Energy sector: posibillities to CO_2 reduced processes, exploitation of other recourses
- Increased importance of biology and biochemistry: biotechnology, bio-energy, bio-materials,
- Nanotechnology: microelectronics, nano-mimetic scaffolds
- Process modeling: predicting molecular and system properties for system optimisation, smart manufactoring

T.S.V. 'Jan Pieter Minckelers'

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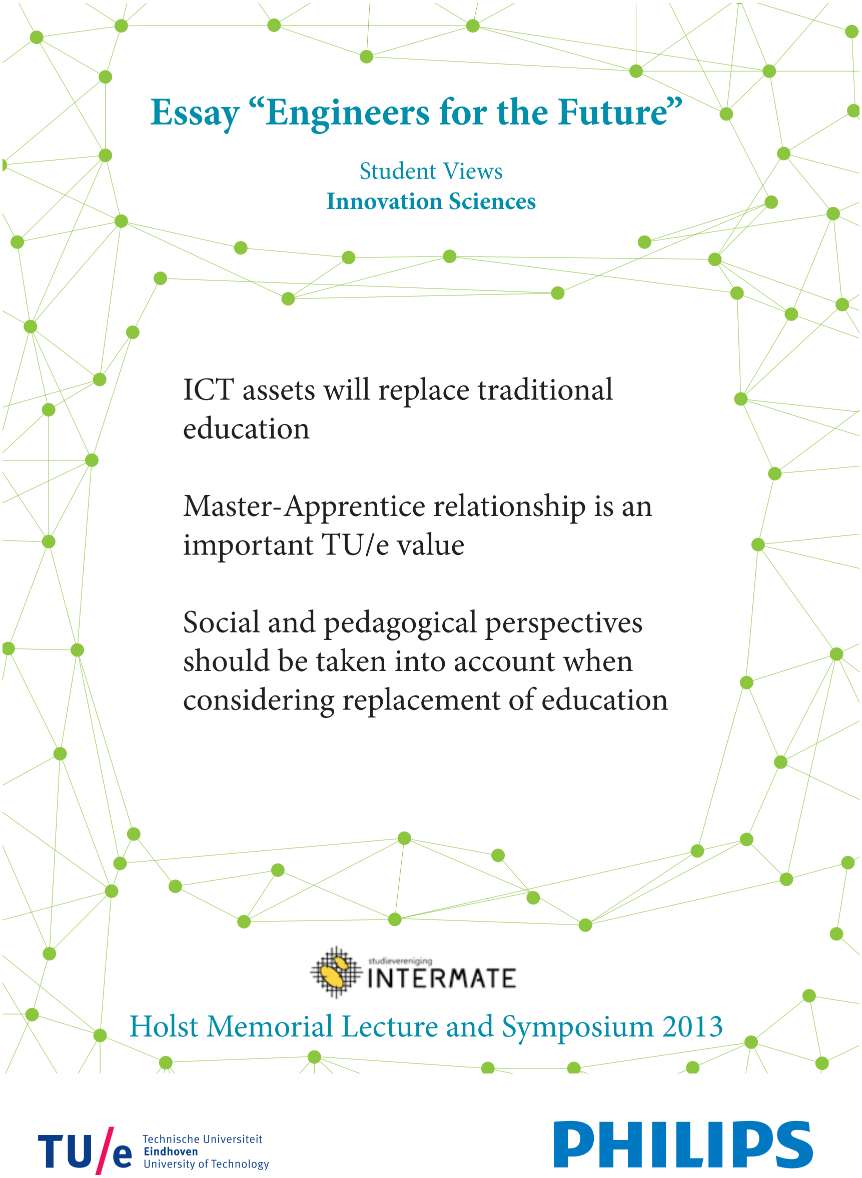

Essay "Engineers for the Future"

Student Views
Innovation Sciences

ICT assets will replace traditional education

Master-Apprentice relationship is an important TU/e value

Social and pedagogical perspectives should be taken into account when considering replacement of education

studievereniging
INTERMATE

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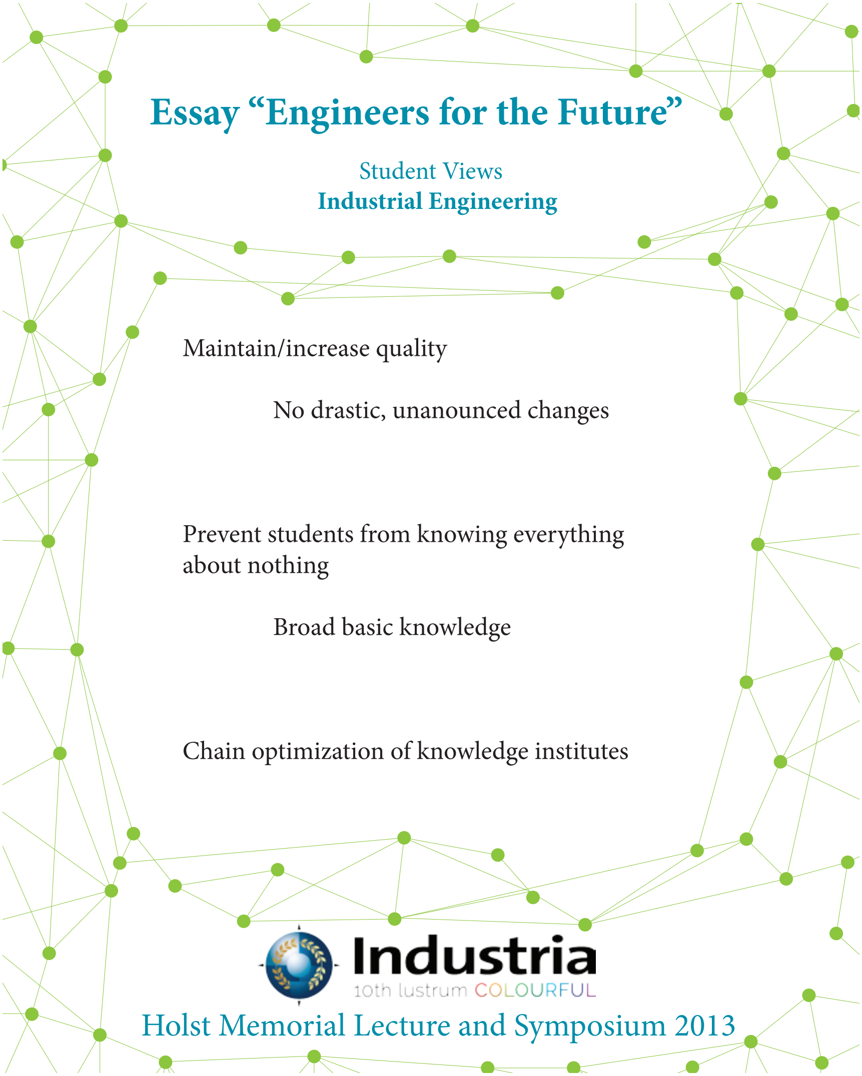

Essay "Engineers for the Future"

Student Views
Industrial Engineering

Maintain/increase quality

No drastic, unanounced changes

Prevent students from knowing everything about nothing

Broad basic knowledge

Chain optimization of knowledge institutes

Industria
10th lustrum COLOURFUL

Holst Memorial Lecture and Symposium 2013

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Eindhoven
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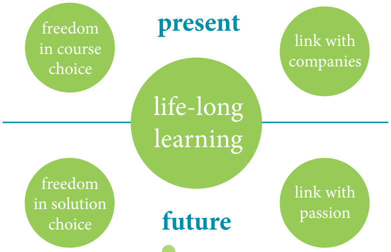
PHILIPS

Essay “Engineers for the Future”

Student Views
Industrial Design

Life-long learning is an important aspect of the current vision of the engineers for the future, and very much relates to the educational model of Industrial Design. It is currently integrated within the educational program by creating freedom in course choice (Bachelor College) and by creating a link with companies.

However, these two aspects can go a step further to raise the level of life-long learning. First of all, by creating freedom within the courses where students should look for their own solutions for the related tasks. And secondly, by creating a link with one's passion. This creates an incentive for life-long learning.



freedom in course choice

present

link with companies

life-long learning

freedom in solution choice

future

link with passion

lucid study association industrial design

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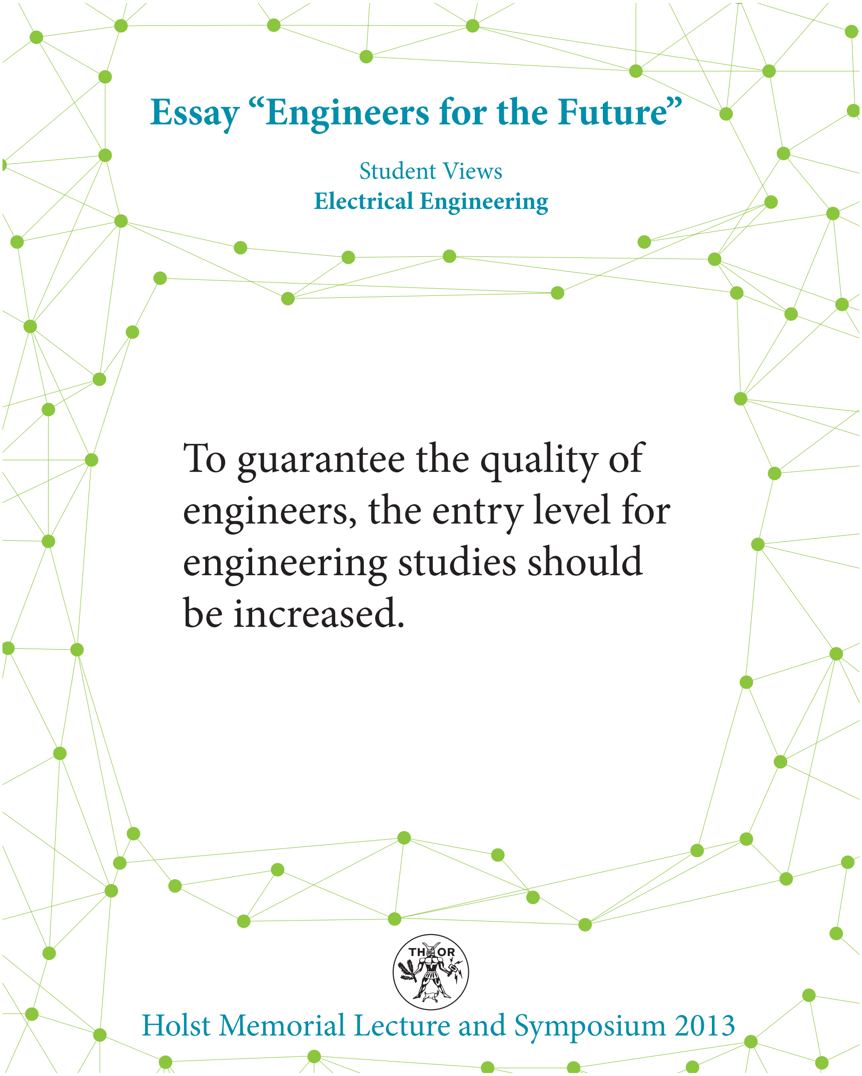

Essay “Engineers for the Future”

Student Views
Electrical Engineering

To guarantee the quality of engineers, the entry level for engineering studies should be increased.

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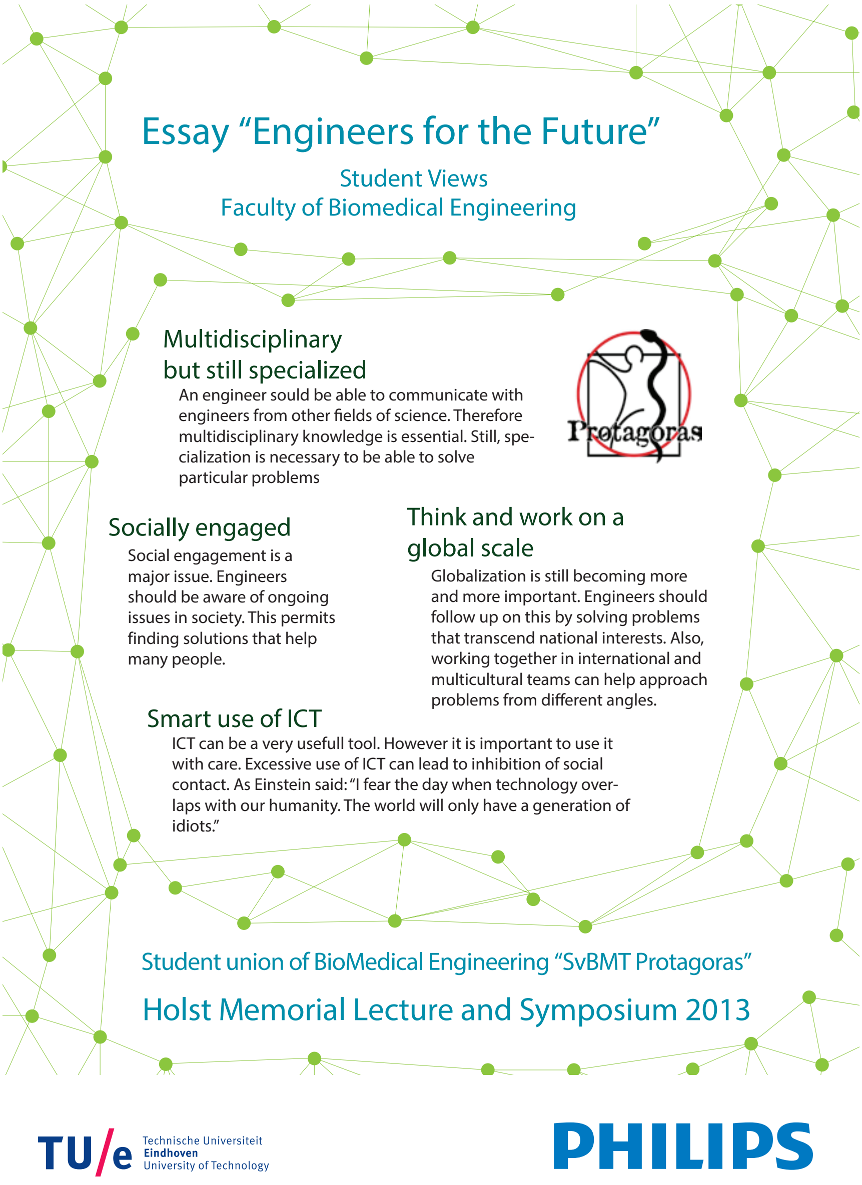

Essay “Engineers for the Future”

Student Views
Faculty of Biomedical Engineering

Multidisciplinary but still specialized

An engineer sould be able to communicate with engineers from other fields of science. Therefore multidisciplinary knowledge is essential. Still, specialization is necessary to be able to solve particular problems

Socially engaged

Social engagement is a major issue. Engineers should be aware of ongoing issues in society. This permits finding solutions that help many people.

Think and work on a global scale

Globalization is still becoming more and more important. Engineers should follow up on this by solving problems that transcend national interests. Also, working together in international and multicultural teams can help approach problems from different angles.

Smart use of ICT

ICT can be a very usefull tool. However it is important to use it with care. Excessive use of ICT can lead to inhibition of social contact. As Einstein said: “I fear the day when technology overlaps with our humanity. The world will only have a generation of idiots.”

Student union of BioMedical Engineering “SvBMT Protagoras”

Holst Memorial Lecture and Symposium 2013

TU/e Technische Universiteit **Eindhoven** University of Technology

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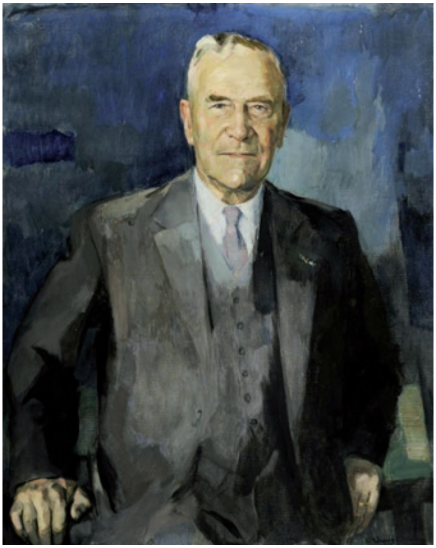
History of the Holst Memorial Lecture and Award

The Holst Memorial Lecture is held each year at the University of Technology in Eindhoven (TU/e), the Netherlands, with support from Philips Research.

The theme reflects an important contribution to the development of research and technology, in line with the idea advocated by Dr. Gilles Holst concerning the development of applied sciences, particularly mathematics and the natural sciences, for the benefit of industry on the one side and their implications for society on the other.

The Holst Lecture is given by an eminent scientist in a selected field of research. Candidates for the lecture and the associated Award are selected by a committee consisting of representatives of both Royal Philips Electronics and the University, under the chairmanship of the Rector Magnificus of the TU/e and the CEO of Philips Research.



Gilles Holst

The audience is made up of university staff and students, representatives from industry, and other guests with a general interest in science and technology. To honour the guest speaker, a symposium with invited speakers precedes the Memorial Lecture.

After the Lecture, the Rector Magnificus presents the Guest Speaker with the Holst Memorial Lecture Award, a special bronze medal designed by Dutch sculptor Jos Reniers.

Gilles Holst (1886-1968)

As an academic, Gilles Holst is best known for the essential part he played at the University of Leiden, the Netherlands, in the discovery of superconductivity by Nobel Laureate H. Kamerlingh Onnes.

However, Holst is first and foremost remembered as the founding director of the famous ‘Nat Lab’, the Philips Physics Laboratory in Eindhoven, where he worked between 1914 and 1946. Gilles Holst was also chairman of two committees that were instrumental in establishing the University of Technology in Eindhoven in 1956.

List of Holst Memorial Lecture Award Recipients

The first Holst Memorial Lecture was given in 1977 to commemorate the 21st anniversary of the founding of University of Technology. Since then the speakers have included:

1977 **Dr. Alexander King**, Director OECD, Paris, ‘The role of the engineer and the engineering sciences in future society’.

1978 **Prof. Dr. Cristopher Freeman**, University of Sussex, Brighton, UK, ‘Technology and employment: long waves in technical change and economic development’.

1979 **Prof. Dr. Carl Friedrich Von Weizsäcker**, Max Planck Institute, Starnberg, Germany, ‘Langfristige Energiepolitik als Beispiel technischer Zukunftplanung’.

1980 **Prof. Kevin Lynch**, MIT, Cambridge, USA, ‘What is a good city? General theory of good city form; a new try at an old subject’.

1981 **Prof. Dr. Hendrik B. Casimir**, Philips N.V., Eindhoven, the Netherlands, ‘Gilles Holst, pionier van het industrieel onderzoek in Nederland’.

1982 **Dr. Michiyuki Uenohara**, Nippon Electric Co, Kawasaki, Japan, ‘The Japanese social system for technological development; its merits and demerits’.

1983 **Prof. Dr. Joseph Weizenbaum**, MIT, Cambridge, USA, ‘The place of the computer in our world’.

1984 **Prof. John M. Ziman**, F.R.S., Imperial College London, UK, ‘Doing my own work: the individual in collectivized science’.

1985 **Prof. Ilya Prigogine**, Nobel Laureate, The Solvay Institute, Brussels, Belgium, ‘Exploring complexity from the intemporal world of dynamics to the temporal world of entropy’.

1986 **Prof. Sir Hermann Bondi**, F.R.S., Churchill College, Cambridge UK, ‘The application of satellites in connection with the environment’.

1987 **Prof. Dr. Dick Swaab**, Dutch Institute for Brain Research, Amsterdam, the Netherlands, ‘De klok in onze hersens’.

1988 **Prof. Dr. Abraham Pais**, Rockefeller University, New York, USA, ‘Einstein’s influence (the impact of Einstein’s relativity theory)’.

1989 **Sir John Maddox**, Nature Magazine, London, UK, ‘How true is the promise of science?’.

1990 **Prof. Dr. Cornelis M. Braams**, FOM-Institute Plasma Physics, Nieuwegein, the Netherlands, ‘Kernfusie in historisch perspectief’.

1991 **Prof. Dr. Philippe G. de Gennes**, Nobel Laureate, ESPCI, Paris, France, ‘Bubbles, foams and other fragile objects’.

1992 **Dr. Arno A. Penzias**, Nobel Laureate, AT&T Bell Laboratories, Holmdel, USA, ‘The future of knowledge intensive industries’.

1993 **Prof. Dr. Henk C. van de Hulst**, University of Leiden, the Netherlands, ‘Het astronomisch spectrum’.

1994 **Prof. Dr. Donald P. Greenberg**, Cornell University, Ithaca, New York, USA, ‘Imaging and the electronic age’.

1995 **Prof. Dr. Hubert Curien**, Université Pierre et Marie Curie, Paris, France, ‘Big instruments and big programmes for research; where is the limit?’.

1996 **Prof. Dr. Serguei P. Kapitza**, Russian Academy of Sciences, Moscow, Russia, ‘World population growth and technology’.

1997 **Prof. Dr. Nicholas Negroponte**, MIT, Cambridge, USA, ‘Why Europe is so unwired’.

1998 **Prof. Dr. Alan J. Heeger**, Nobel Laureate, University of California, Santa Barbara, USA, ‘20 years of research into conducting and semiconducting polymers; is it worth the effort?’.

1999 **Prof. Dr. H. Koenraad Hemker**, University of Maastricht, the Netherlands, ‘Een bloedstollende geschiedenis’.

2000 **Dr. Rod C. Alferness**, Lucent Technologies, Holmdel, USA, ‘Optical networks, enabler of the communication revolution’.

2001 **Dr. John L. Hennessy**, Stanford University, Stanford, USA, ‘Directions and challenges in microprocessor architecture’.

2002 **Dr. Harold G. Craighead**, Cornell University, Ithaca, USA, ‘Nanostructures for mechanical and biological applications’.

2003 **Dr. Sanjiv Sam Gambhir**, Stanford University, Stanford USA, ‘Imaging diseases with molecular detectives’.

2004 **Sir Richard Friend**, FRS, University of Cambridge, UK, ‘Plastic Electronics: new science, new technology, new products and new markets’

2005 **Dr. J. Craig Venter**, the Venter Institute, Rockville MD USA, ‘From the Human Genome to Environmental Metagenomics’

2006 **Prof. Dr. Peter Carmeliet**, KU Leuven en VIB, Belgium, ‘The neurovascular link of A. Vesalius revisited’

2007 **Prof. Dr. Henk van der Vorst**, RU Utrecht, the Netherlands, ‘Men and Computers: an Upward Spiral’

2008 **Prof. Dr. Shuji Nakamura,** University of California Santa Barbara USA, ‘Current and Future Status of Sold State Lighting’

2009 **Prof. Dr. Rutger A. van Santen,** Royal Academy of Arts and Sciences professor at TU/e, ‘Energy, Catalysis and Society’

2010 **Dr. Denis Le Bihan,** Neurospin, Gif-Sur-Yvette, France ‘Water: from Brownian Motion to the Mind’

2011 **Prof.Donald E. Ingber** MD, PhD, The Wyss Institute, Harvard University, USA. ‘From Cellular Mechotransduction to Biologically Inspired Engineering’

2012 **Russel Foster, Bsc, PhD, FRS,** The Nuffield Laboratory of Ophtalmology, Oxford University, UK, “Light and the Rhythm of Life’

2013 **Cherry A. Murray, PhD,** Dean Harvard School of Engineering and Applied Sciences, ‘Engineering for All’

Imprint

Holst Committee
Candidates for the Holst Memorial Lecture 2013 were selected by the Holst Committee under the joint chairmanship of Hans van Duijn, rector magnificus Technische Universiteit Eindhoven (TU/e) and Henk van Houten, General Manager Philips Research.
Secretary to the Committee: Joep Huiskamp (TU/e).

Members of the Scientific Organizing Committee 2013
Mariëlle Langerak (Philips Research), Carel-Jan van Driel (Philips Research),
Anthonie Meijers (TU/e), Secretary to the Committee: Joep Huiskamp (TU/e).

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www.holstmemoriallecture.nl