Highlights 2014

TU Delft

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Delft University of Technology

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Foreword

I am very pleased to present the TU Delft Highlights 2014. In this edition, you can read inspiring examples of how we at TU Delft build on what we have been good at for so long so that generation after generation of students and researchers can be inspired to make the most of their abilities.

Karel Luyben, Dirk Jan van den Berg, Anka Mulder, Executive Board of Delft University of Technology

A discussion is currently taking place in the Netherlands on the 'Wetenschapsvisie 2025: keuzes voor de toekomst', the cabinet's vision document that is intended to form the basis for a broad-based scientific agenda. The scientific vision document is unequivocal about the starting position of the Netherlands on the international playing field - it is unquestionably good. Priority is also given to factors that we at TU Delft consider important, such as societal impact, solidarity with society, and collaboration with the business sector. At the same time, there is recognition of the fact that science is always a quest for the unknown.
In my view, it is good that this subject is so high on the political agenda. Additionally, the scientific vision document is a reaffirmation of what we actually already know - that Dutch universities are performing excellently. We at TU Delft also regard it as outstanding recognition of the work we do here.
Moreover, the vision considers the importance of the career development of young talented individuals. Our university is of course a breeding ground of this type of young talent. This Highlights too includes a number of prominent examples. The quest for the unknown is perhaps best reflected in the story of Professor Ronald Hanson, who this year, with his research group, received widespread media coverage with a historic teleportation experiment.
Other young talented individuals to feature in this Highlights include some who are working on improving teaching. Teacher of the Year Alexandru Iosup has a unique way of fascinating his students by combining his lectures with elements from the world of gaming. Former students Ewoud de Kok and Siem Kok have made the move towards entrepreneurship. With their plug-in software, they have given online teaching systems unprecedented possibilities for feedback and interaction between teachers and their students. It is very pleasing to see how our core business, education, at which we have traditionally been very strong, can be taken forward by and for new generations, through innovation.
As a university, it is one of our responsibilities to create the conditions that will allow those with talent to achieve their full potential. A significant aspect of these conditions is the facilities on the campus at Delft. With more than 20,000 students and academic and support staff, the campus is a world in itself - a community with a broad-based international composition and a high level of knowledge. In order to ensure that the campus can offer optimum space for this community, which is involved with world-class research and teaching, we have embarked on a far-reaching programme of redevelopment of the grounds of the university.
The purpose of this operation is to make the campus a lively and future-proof hub where top-level teaching and research can be performed in a sustainable environment that is in keeping with such modern-day teaching methods as blended learning and flipped classrooms, and equipped with state-of-the-art amenities. A campus where high-tech facilities go hand in hand with respect for tradition. After all, a university that has been in existence for 173 years in 2015 is uniquely placed to do this - retaining the good parts and combining them with discovering the new.

Drs. Dirk Jan van den Berg
President of the Executive Board
Delft University of Technology

Arjan van Timmeren

Sustainable building blocks for intelligent cities

Arjan van Timmeren is Professor of Environmental Technology & Design at the Faculty of Architecture and the Built Environment's Department of Urbanism. He specialises in the integration of renewable technologies into the built environment. 'If I had to sum it up, my work involves engineering, design and integration, with users and people as a further aspect,' says Van Timmeren. On 9 January 2015, he delivered the Dies Natalis lecture at the event held to mark TU Delft's 173rd anniversary.

Professor Arjan van Timmerman's field of work is full of urgent problems. 'How can we speed up our search for effective solutions in the areas of urbanization, the environment, viability and resilience in relation to climate change, for example? These are problems that aren't really visible on an everyday level, until that one flood event comes along and sweeps everything away.' The solution involves making technical systems and infrastructure more sustainable, but there are social aspects too, such as whether all humans have a fundamental right to certain facilities. Because while we in the West are already talking about 'smart cities', in much of the world they have not yet met people's basic needs for sanitation and clean drinking water.

The perspective of the user is crucial to Van Timmeren's research. 'What we need to watch out for is this: although we are using technology to find solutions for everything, we often don't seem to think about whether and how people will embrace these solutions,' he says. Look at what happened in the Nieuwland area of Amersfoort, for example. Part of the neighbourhood was made energy-neutral using solar panels. But it turned out that residents in that part of the city started consuming more energy, meaning that the neighbourhood did not stay energy-neutral for very long. 'Apparently people thought: now that I live in an energy-neutral neighbourhood, I can consume as much energy as I want. People adapt their behaviour, and that can have either positive or negative consequences.' So the involvement of users is essential, but scale is another important factor in the success of this kind of project, as Van Timmeren discovered during his doctorate in 2006. 'I found that two levels of scale are essential. The first is the scale of the neighbourhood or local area, and the second is that of the urban area of the city with its hinterland, which I talked about in my inaugural lecture, which was entitled 'ReciproCities'.

Hinterland

But with ever-increasing urbanisation, the reality is that in many places in the world, we are building ever higher, and urban areas are becoming more and more dense. According to Van Timmeren, the city is too often viewed uniquely from an urban perspective, while anything outside it is seen as rural. 'But the city cannot exist without the countryside, and very often it is dependent on peri-urban areas too. Take Hong Kong, for example, a city that requires no less than 2,200 times its own surface area in order to sustain itself,' he says. 'Not all of those needs are satisfied within the city's hinterland; that is done all around the whole world. But even so, you still need to take account of the mutual dependency between the city and its hinterland.' That hinterland is home to nature's essential 'reserve systems'. So cities do not stand alone; they are connected with their hinterland. That reciprocal relationship exists between technology and humanity, between the city and the hinterland, and also between different systems such as energy and water.

Resilience

Van Timmeren believes that the design of these mutually dependent elements should be built to accommodate continuous change - also known as resilience. But why is that so important? 'When you try to find solutions for urban areas, on the one hand you are dealing with what are known as 'double-complex systems' which have both technical and social aspects, and on the other hand you are talking about a usage timespan of several decades. It involves a process of continuous change, and that makes it difficult to predict. But people are unpredictable too - sometimes they fail to adapt or they exhibit herd behaviour. In any case they rarely behave as they are predicted to behave. This complexity, in combination

‘We are living ever closer together and that requires us to make much more efficient use of space and facilities’

with the long time frames involved, means that you need to think in terms of systems that can be adapted, systems that you can change in real time and change over the long term, and - where possible - systems that can actually anticipate change. Resilience is a prerequisite for achieving sustainability, while the capacity to change in real time implies being able to use and respond to data - so-called ‘smart systems’.’
Making our urban areas more sustainable is a matter of some urgency. ‘That is particularly evident in places where urbanization is at its most extreme. That is mainly in Asia, but in the Netherlands we face similar problems, such as air pollution by particulate matter and urban flooding,’ says Van Timmeren. But in fact, here in the Netherlands we face a harder task than many other places in the world. ‘Here, we need to modify what already exists, while in other countries the pace of growth is such that completely new eco-cities are being built on the basis of the ‘smart city’ concept, often close to existing cities, such as Tianjin near Singapore or Songdo near Seoul.

Kiruna

Another factor that we need to take into account here in our own country is what we might call democratic considerations. That complicates matters, but it is often a cause for innovation too.’ That talent for innovation is what helps us to export Dutch knowledge to other countries. One example of this is Van Timmeren’s involvement in research into how to improve the construction of the ‘hidroanel’ project in São Paulo. The aim of the project is to construct a metropolitan waterway ring around the massive Brazilian metropolis of over 22 million inhabitants. It will have to meet the city’s essential water requirements, in addition to transporting all waste away from the city. ‘The ring encloses an area about half the size of the Netherlands. As a small country, we are quite good when it comes to extrapolating our ideas in order to tackle the world’s large-scale problems.’
There are also major challenges in Kiruna in northern Sweden, which is 150 kilometres north of the Arctic Circle. The city is at risk from landslides. This is because Kiruna is home to the world’s largest iron mine, where every day enough iron is extracted to build six Eiffel Towers. The mine is now one mile deep and over time has expanded right underneath the city. Kiruna is now being moved three kilometres eastwards. The process is happening in phases but is a matter of some urgency. Relocating practically the entire city also represents an opportunity, however. Kiruna is one of the ‘Urban Living Labs’ of the European research project Green/Blue Infrastructure for Sustainable, Attractive Cities. The aim of the research is to create an urban water system that is climate-resistant. Van Timmeren: ‘We are working on the construction of hybrid systems in the city, which means combining traditional grey systems, such as sewers, with green-blue systems.’ Green-blue systems make use of natural elements as a back-up to make urban areas more secure, more resilient, more liveable and more economically attractive. It’s a way of building with nature. That sounds attractive, but in Kiruna, there are limits to what is possible. ‘We can’t build the perfect city. Every year another section of the city needs to be moved as the subsidence from the mine spreads further, growing in size and getting ever closer to the city centre. The railway station has already been relocated, and the town hall is going to follow next. The hotel where I stayed recently, won’t be there any more in a year from now. So we are constantly working on adapting the city’s technical systems and looking at how we can make our short-term goals coincide with our long-term goals.’
As a project it is absolutely unique. ‘You’re dealing with a complete paradigm shift, a fundamental redesign of the city’s infrastructure. There are fewer than twenty cities in the world where that has happened,’ says Van Timmeren. ‘But some of the solutions that we’re devising in Kiruna will subsequently be applicable in other places in the world. For example, if we learn how you can make cities better able to cope with extreme rainfall and in addition save a considerable amount of the money we spend on sewers by laying them out differently, we could save a lot of money elsewhere in the world.’ Building up and disseminating new knowledge is an important process because people are experiencing the same urgent issues all over the world. ‘As a single research group, you can’t take on the whole world, but you can make some strategic choices about which projects might lead to a new approach that could be applied elsewhere. It is as if we are developing building blocks that we can use to help develop more radical sustainable solutions in other places.’

Missmatch

Technology can certainly be deployed to help to make our cities more resilient. ‘We are living ever closer together and that requires us to make much more efficient use of space and facilities,’ explains Van Timmeren. ‘That means making the ‘flows’ of mobility, water, energy and raw materials more sustainable by changing the linear patterns that they follow into circular patterns, and making the transition from simple to integrated. Sometimes we use the analogy of an urban metabolism.’ Recently Van Timmeren and his colleagues completed a project at

Rotterdam Stadshavens that built on earlier research carried out on behalf of Schiphol. The work involved looking at the potential of using electric vehicles as a means of storing energy and as a link between renewable sources (which generate variable levels of energy) and energy use in buildings (which also fluctuates). 'There is actually an almost continuous mismatch between the renewable energy that is generated and the demand for it. That means that if we want to use renewable sources of energy, we either have to build more capacity or use the central electricity grid as a buffer. The sun shines just at the times when we are consuming the least energy. If we could store that surplus and exchange it over a smart grid using batteries, including those in electric cars, you could match up the supply and demand from both transport and buildings in a smart way. Ultimately, this will enhance efficiency and save money, but it will also introduce greater flexibility because as the proportion of energy generated from renewable sources increases, there will be less need to connect to the central power grid.'

The right question

Integrating systems also means working together in integrated research teams. 'I very often work with people from other faculties and disciplines within the university and beyond. You see that out in the field too. So-called smart coalitions are forming that can tackle projects together. And in fact that's the only way to tackle them, because we are talking about complex, large-scale issues that are interlinked and occur over a long time frame. This means that all the different aspects are dependent on each other and the risks are difficult to contain in one area. Those dependencies are currently another focus for our research. This is a very relevant aspect of resilience engineering - the design approach that focuses on resilience.'

Van Timmeren likes to quote architect Cedric Price, who once said 'Technology is the answer, but what is the question?'. Technology is not always automatically the best solution; we still need to stop and think. 'A well-known example is the automobile. We could use a lot of technology to make cars more sustainable and efficient. But you could also say: hang on a minute, couldn't we solve the mobility problem by sharing our sustainable cars with our neighbours or a group of people? In terms of environmental impact, that would be an improvement many times bigger, and in cities it would save between six and twelve parking spaces per shared car, it has been calculated. And that would not involve extra technology at all, but it would free up more space to improve the quality of life in our cities. In many cases, you simply need to be brave enough to ask the right question to start with.'

Intelligent Cities

Professor Arjan van Timmeren was closely involved in the creation of the Amsterdam Institute for Advanced Metropolitan Solutions (AMS), a partnership between the City of Amsterdam, TU Delft, Wageningen University and the MIT in the US. Using the Amsterdam metropolitan area as its 'Living Lab', the institute wants to carry out research into urban issues in the fields of traffic, water, energy, waste and health. This will be done using data obtained through smart systems, a technique known as 'sensing the city'. 'You can monitor certain things using sensors and then respond to changes,' explains Van Timmeren. It is a way to get closer to achieving adaptable systems, even though actually it does not go far enough. 'At the moment it's still about monitoring, identifying and responding. There is no room for creativity in smart systems yet. We are still thinking in terms of reactive systems.'

Van Timmeren prefers to speak about 'intelligent cities', and sometimes even uses the term 'illuminated cities', which go a step further still than 'smart cities', a term we often hear now. 'With 'intelligent cities', you try to incorporate learning and creative thinking into the process.' He has a clear vision of how that should be done. 'You shouldn't place responsibility for decision-making and the transparency of the data with governments or companies, but with each individual user, or in organized groups. In people, basically. Intelligence comes through continuous learning and creativity, not through passivity.' He also sees a major role in this for knowledge institutions. 'The AMS Institute or TU Delft could manage the data in partnership with bottom-up initiatives by city residents and businesses. That kind of triangular relationship can work very well. As a university, or group of universities, we could be a key player in that, because developing knowledge and learning systems is something we are very much at home with. And one of our central aims is working towards a sustainable future.'

Jouke Verlinden

Combining the physical world with the digital world

Dr Jouke Verlinden is assistant professor of Innovative Design Support at the Faculty of Industrial Design Engineering. On 17 October 2014, he was awarded a doctorate for his research on digital prototypes - prototypes that combine the physical world with the digital world. ‘It’s a combination that works very well, especially when you are working with non-designers,’ says Verlinden.

While I was studying...
in the USA I began by conducting research into Virtual Reality. It was fantastic. Using VR, you can do things that would never be possible in reality - like playing with gravity, for example. But at the same time I would say to myself, ‘This is all very nice but it’s a dream world. What about the real world?’ What really interested me was how to combine the two worlds. You can enrich that physical reality using digital data, and you can also make it interactive. And that’s what I worked on during my doctorate. Designers can already do an awful lot in the digital realm using computer-aided design. But at the same time there is a fine tradition of model making. I set out to find better ways to create prototypes by bringing these two worlds together.

Projections...
play a major role in this. You can project all kinds of digital information onto physical models, such as colours or textures. And you can also make them interactive. For example, if you have a 3D-print or a styrofoam model of a mobile phone, you can project a screen onto it and operate it as if it were a real smartphone. This enables you to test out the tactile elements of the model together with the digital aspects - because you need to look at both these aspects together. That works especially well if you are working with non-designers. Designers generally know what you mean if you talk about a particular type of material or functionality.

My dissertation...
looked at various different fields of design. That included interior design, among other things - and more specifically, the interiors of museums. In the interior design of a museum, many people are involved who have never designed anything in their lives and most probably never will - people like museum curators or directors. That’s when an interactive prototype really comes into its own. It’s not about the colour of walls, so much as how the place operates - for example how visitors will move around the exhibits. If you changed the layout of the museum fixtures - which we represented using small blocks or Lego - the simulation would adapt itself to the new situation so that you could see the effects on the flow of visitors immediately. Of course, you can always run a simulation like that on a screen, but if you make it into something tactile, it becomes much more accessible. Everyone starts moving the blocks around and people really start playing and experimenting.

There was also a spin-off...
from this project. Two students founded a company for 3D projection techniques. Their first major client was a company that converts large aircraft into luxury jets for VIP customers. An aircraft has a particular type of geometry: it is a tube. On a normal 2D plan you don’t see that, but you can when you use a simulation. You can put people in there and look at the interior from their perspective. Furthermore, you can see what happens to the weight distribution within the aircraft when you move the furniture around. You start to realise that a safety specialist will look at an aircraft in a totally different way to a businessman.

My quest...
for better ways to make prototypes coincided very nicely with the advent of 3D printing. When I started in 2000, that was still very much a niche area. Design agencies would only make a 3D print during the very last phase of the design process - to check whether the moulds would work, for example. It was very expensive; an object the size of a mobile phone would cost thousands of euros. It was called rapid prototyping, even though it wasn’t particularly rapid. Five years ago, such a printer would have cost around €60,000 or more. Now you can buy one for €2000. That is down to the development of open source software and the expiration of several major patents. In the space of just a few years, 3D printing has become commonplace; it is also increasingly common in the things I do.

The Faculty...
of Industrial Design Engineering really

benefits from that. Now there are students who make prototypes for design agencies as part of their projects, and students who explore things that you can do with a 3D printer that you could never do using other techniques. Some very interesting things come out of it. One of the most wonderful creations was a knitting machine that the students made. It's an industrial, double-bed knitting machine, which would normally cost a couple of thousand euros. But you can download the design for all the components from the internet and then print them or laser cut them. The software you need to run the machine is also available on the internet. And that's how you can build a knitting machine for €200 in two weeks. There's no big company behind it, just someone in Japan who writes the software and someone in Spain who was trying to make the first machine. Then our students made some improvements to it and they made the thing easier to use. Those improvements will also be shared with the rest of the world over the internet.

Developments like these...
are not driven by commerce. New people now have access to the means of production and the development of new production methods. The role of industrial designers is also changing. Designers used to work for or be commissioned by industrial companies. The strength of designers is still that they look at ergonomics or aesthetics. What is changing is the market. Industrial design is now increasingly about innovation and entrepreneurship, about inventing concepts and bringing them onto the market. This is being made possible by the principles of open source and crowdfunding. You see that many 3D projects find launching customers via platforms like IndieGoGo and Kickstarter. These customers put their confidence into this kind of initiative even before a single product has been made. That's the kind of confidence that big companies are not getting at the moment.

Making products personal...
and human-product interaction are important principles in industrial design. A good example of this is the mouthpiece of a saxophone. About 80% of the sound of a saxophone depends on the mouthpiece, but there's quite a lot of mystery surrounding it. We don't actually know much about what makes a good or a bad mouthpiece. We decided to look into that and now we are one of the three or four places in the world where research is being carried out into woodwind instruments. We have scanned rare, irreplaceable mouthpieces and printed out copies in all kinds of exotic materials, such as alumina. That's a kind of ceramic which is harder than steel.

At the moment...
those mouthpieces are hand-made by

Sailing Simulator

Jouke Verlinden also works at InnoSportLab in The Hague, where he is helping to develop a sailing simulator, another combination of the physical and the virtual, or 'augmented matter in context', as he also refers to his work. The device is designed to allow athletes to train even when the weather conditions are unsuitable. The hope is that Dutch sailors will win even more medals in the future with this simulator, which is the best in the world. 'If there's a storm raging outside, you can still use this to do hanging exercises, for example,' says Verlinden. The current version is still a test set-up, because it's not easy to make a sailing simulator. 'When you're sailing, you're pulling a rope and the rope will also pull back; it's the feedback that makes it difficult to create a sailing simulator. It's much more difficult than a flight simulator or a driving simulator.' The simulator may have applications in amateur sports. 'Sailing schools in the Netherlands tend to depend very much on volunteers, but it's different in other countries. It may be possible to produce and market the simulator abroad,' says Verlinden. Another idea that is being explored is whether the sailing simulator could be used by disabled athletes. 'If someone with a disability wants to exercise for a day, that involves a lot of work by a lot of people. This could make exercising a lot simpler.'

‘Designers can already do an awful lot in the digital realm using computer-aided design. But at the same time there is a fine tradition of model making’

specialist craftsmen. But if they started using 3D printing, those craftsmen could do something other than just sitting behind a lathe all day. They would be able to focus more on designing and testing. Often a fraction of a millimetre is what makes the difference but that is very difficult to achieve by hand. So there is something to be said for a mechanical production method, and as a player you also know what you can expect. Some world-famous saxophonists are already using our mouthpieces, including the soprano saxophonist Dave Liebman. We have also been in touch with Candy Dulfer. We are currently looking at how the unique mouthpiece that she has at the moment can be preserved.

The Museum Boijmans Van Beuningen…
has a large collection of historic crockery and glassware dating back centuries. We have scanned some of those pieces using medical CT equipment. We worked with the ceramics specialist Maaike Rozenburg to do that. Moulds were made from the scans that she used to make porcelain casts. Such a replica is significant in a whole different way to the original, and so in a way we are actually creating new heritage. One of the copies that we made actually cost more to produce than the insurance value of the original cup. It’s a strange experience when you hold it in your hands. What if the copy got broken? When does something become real? When does it acquire meaning? These are very interesting questions to me.

Heritage…
- what is it actually? For me it’s more than just what you find in museums. I’m also a member of a committee that looks at special musical instruments, like Stradivariuses and Bösendorfers. Of course, it’s very important that these are preserved properly; but at the same time, they also need to be played and to be a part of our society. With wind instruments you can change the materials used, but if you’re talking about sound boxes, that’s a completely different story. But scanning and printing technology also plays a major role in this. For example, a number of years ago, a well-known Stradivarius was scanned and printed in Germany. If you can do that, you can also start doing all sorts of calculations relating to sound and resonance. Then the 3D print is no longer a product, but something that you can use to carry out research.

Those 3D scanners…
used to cost between €70,000 and €80,000, and now they cost just €100. There are already mobile telephones that have them built in. Until recently, 3D scanning was reserved for people who had completed a special course. So it all seems to be getting much easier, but the digital tools we use these days still require a lot of craftsmanship. A scan involves an awful lot of work before you can print anything out; that involves some careful work. The model needs to be finished off properly and the transition between the materials must be neat. 3D printing is more than just pressing a button. Developments are happening very quickly.

As a faculty, we try to look ahead and have the latest technology in-house for our students to work with. At the same time we realise that what we know now will probably have changed by tomorrow.

In which other ways…
could we link the digital world with the physical world? 3D prints are still just pieces of plastic or steel. If you could make them move, or incorporate electronic components into them, then you’d have smart 3D prints. If you look at the gripper arm of a robot or a prosthesis, you’ll see that it includes spring elements and sensors. One day it may be possible to produce all this in a single process. There is already a famous prosthetic hand that costs just 50 dollars. That is not an industrial product; it came from work done by volunteers. People who have a specific problem that they want to solve, but who don’t have to deal with things like deadlines or go/no-go decisions. For them it’s a bit like a hobby, but if they put their work online, others can take it further. I think it’s this world of amateur developers that will generate the majority of our innovations in future.

Caspar Chorus

‘Not all the choices people make are selfish’

On 5 November 2014, Professor Caspar Chorus gave his inaugural address entitled: ‘Choice Behaviour Modelling’. The regret minimisation model he has developed was quickly incorporated within the most important econometrics software as an alternative for the widely used utility maximisation model. This is not a competition between the two, but rather an enrichment of the specialist area, believes Chorus: ‘My aim is to encourage people to look differently at the same material.’

Caspar Chorus’ specialist area is choice modelling. If you analyse the choices people make retrospectively, you can identify the underlying preferences and decisive factors. If you then incorporate these within a statistical model, you can use it to predict future choice behaviour. These choice models can be of interest to manufacturers who wish to discover the potential market share of a new product, as well as for policymakers who have to make decisions about major infrastructural projects. This means they are used in numerous different sectors, although Chorus himself focuses particularly on the transport and mobility sector. The electric car is a good example. ‘As long as companies have no clear idea of market demand, development cannot progress,’ argues Chorus. ‘We calculate that market demand. Our colleagues then set to work developing potential policy to provide incentives for electric driving. Should tax relief and subsidies be applied, should the rules on emissions be tightened or just large numbers of charging points installed? These questions involve a great deal of money and some major interests.’

So how can a choice model help with this? ‘Imagine that you have an enormous amount of data about choice of types of car. By making a choice like this, a person reveals how he or she decides what to spend, based on such aspects as cargo space, engine capacity, acceleration and so on. From this, you can extrapolate the average preferences, for example that on average people will be prepared to spend twenty euros for each additional horsepower. Of course, there is a chance that someone made the choice purely based on colour, but that uncertainty is also incorporated within the model.’ The main factor with electric transport is people’s ‘range anxiety’: they worry that they may be left stranded because they run out of power. ‘For manufacturers, it is invaluable to know how much people are willing to spend for each kilometre of additional range.’

Utility maximisation

Let’s start with some history. Choice theory was pioneered by Daniel McFadden, who developed an econometric model in the 1970s based on the idea that people are rational and therefore always make choices based on utility maximisation, in other words, they will try to achieve the greatest possible satisfaction of need. He was awarded the Nobel Prize for Economics in 2000 for this. Caspar Chorus also likes using the utility maximisation model. ‘Utility maximisation is a great rule for decision-making,’ he opines. Despite this, he started to wonder whether an alternative was possible. ‘It fascinated me. Everyone else was modelling based on utility and I have a tendency to go against the grain.’

It was during his doctoral research into travel information systems. The government aims to use travel information to encourage people to use public transport, for example, or to take routes that result in reduced congestion. ‘The question was what influence that travel information has on the choice behaviour of travellers,’ explains Chorus. ‘When I started thinking about it, I quickly came upon the idea of the concept of regret. People use travel information to reduce uncertainty, by checking out how long the journey takes and what it costs, etc. in advance. They often do this in order to prevent making a choice they would later regret.’ This is an example of regret minimisation, a concept well-known in psychology, but largely ignored in econometrics. Based on this, Chorus developed his regret model, a choice model based on a different rule for decision-making: that people do not so much make choices based on the greatest utility, but in order to prevent later regret.

‘For someone who always takes the car, it may actually matter that there is good public transport available for other groups’

This makes them more likely to opt for a compromise than an extreme choice. They therefore prefer to avoid taking a route where the travel time is on average very short but which is also very unreliable, if there is an alternative route that scores reasonably for both of these criteria. It is also easier to explain a compromise to others. Psychological studies have shown that people find it important to be able to explain things, especially when making difficult and important choices.

What makes the regret model so special, according to Chorus, is that you can gain a different perspective with exactly the same data. ‘Take a change in taxation, for example, designed to encourage electric driving. If you look at it using the utility model, the result will, for example, be that in five years’ time 8% of cars in the Netherlands will be electric. Using the same data, the regret model suggests that the figure is 12%. This means you already know more than you would with just a single value,’ says Chorus. It is a very valuable scientific idea to have two models for looking at the same material.’ The regret model is now becoming increasingly popular and was recently also included in leading econometric software packages. ‘That gives me a real buzz: the idea that someone on the other side of the world can use my model at the touch of a button.’

Altruism

Chorus already has the next challenge in his sights. Economics is based on two key assumptions: that people are rational and that they are selfish. ‘It is relatively easy to model an economic system based on these two principles. We already knew that a century ago,’ he explains. ‘It is interesting to note that these two principles have been unquestioningly adopted by all kinds of different subdisciplines in economics.’ That also includes econometrics, of which the choice models are a part. With the regret model, he offers an alternative to the rational idea of utility maximisation. He now wishes to focus on the principle that suggests people always make selfish choices. ‘I intend to focus on modelling altruism.’

An example: imagine that someone would need to travel an additional 30 minutes every day for a new job. This also has repercussions for the rest of the family. But in this case, the classic choice model would assume a decision based on the job applicant’s preferences alone, in other words, weighing up the level of salary against the additional travel time. ‘That is a very one-sided assumption,’ says Chorus. ‘I do not know anyone who arrives home and says: I have a new job, darling, so you will have to rearrange the childcare.’ Even more interestingly, in Chorus’ specialist area, this would be presented as a power struggle: if the choices made are closer to the man’s preferences, the man must have been more powerful. ‘But that’s not how things work in a relationship, is it? This is the economists’ perspective that has been based on a rational, selfish view of people for decades. As if it were two companies fighting for control of the market.’ By ignoring altruism in our models, there is a risk that the predictions they generate are incorrect. The only problem is how you can model these selfless considerations. ‘I do not yet know how to effectively express that mathematically. The aim is to take account in the choice of how that person experiences the partner’s interests, but how can you find out about that? You will probably also need other data.’

Cost-benefit analysis

However, Chorus is convinced of the need for some kind of alternative model. As an example, he cites the social cost-benefit analysis, which is compulsory for major infrastructural projects in the Netherlands. For the construction of a new public transport system or a new motorway, the benefits are estimated based on the time gain achieved, in other words, how much less people need to travel. ‘For public transport, these benefits are often quite negligible,’ he argues. ‘Relatively few people make use of them and on average they also have less to spend, as a result of which they are willing to pay less for each minute of time gained. This means that the estimated benefits often turn out to be lower than the costs.’

The problem with this analysis, in his view, is that it only takes into account the travellers themselves. ‘For someone who always takes the car, it may actually matter that there is good public transport available for other groups and he or she, as a taxpayer, may be willing to fund it. It is a question of how we want our society to be. If you take the benefits based on altruism or a sense of society into account, you will probably end up with a much higher amount people are willing to invest in public transport.’

According to Chorus, it is clear that cost-

benefit analyses need to change. ‘My research group includes some of the best cost-benefit analysts in Europe and they agree. How can we improve these analyses in such a way that they do not only take account of people as consumers?’ The existing social cost-benefit analysis methods are based on classical econometric models. For this reason, Chorus aims to develop a choice model that takes account of factors such as altruism, a sense of justice and social responsibility. The consequences for society would not be insignificant. ‘It involves sums in the region of tens of billions. The bulk of the budget of the Ministry of Infrastructure and the Environment is allocated on the basis of cost-benefit analyses. These are currently based on a far too limited view of human nature.’

This gets to the heart of what the faculty of Technology, Policy and Management is all about. ‘Technology does not take place in a vacuum: there is quite literally a world around it. A nuclear power plant, nanotechnology, infrastructure – absolutely everything we do at a university of technology has a social side,’ asserts Chorus. He welcomes the fact that TU Delft is being bold enough to move in the direction of the social sciences. ‘At TPM, we think about technology in relationship to society. You can accelerate technological developments – or slow them down or put a stop to them if necessary – if you have a better understanding of the social context.’ This is not policy engineering for the sake of it, but a combination of an understanding of society and a thorough knowledge of such areas as energy, water, ICT, or in Chorus’ case, transport and mobility. ‘We work in very close cooperation with the scientists and academics in the other faculties, where there is a great deal of technological and infrastructural expertise. Our contribution is the knowledge we have on top of that, for example: a new motorway affects patterns of mobility, environmental pollution and regional accessibility. We can increase our understanding of these effects by using quantitative models, such as choice models.’ This is a message that he believes is being listened to in the circles that matter, in government and in public institutions. It is also a specialist area in which he very much feels at home. ‘I love doing this kind of research at a university of technology in particular, also because many other people are not doing it, which is what makes it so valuable and unique.’

Big data, major issues

Big data is the dream of every econometrist, or perhaps not? ‘Often, datasets are so large that you can easily identify significant correlations,’ argues Professor Caspar Chorus. But as every scientist knows, a correlation is not a causal relationship. A good example of this is Google Flu Trends, that aimed to monitor the spread of the influenza virus by analysing searches for flu symptoms and medication. For a few winters, it worked effectively and then suddenly stopped working. Chorus feels that this is precisely the problem with big data. ‘It is based on so little theory that it is easy to get lost in the fog. I believe that real understanding only comes if you think in advance about what you can expect.’ Chorus wants to bring big data and the theory of choice models closer together. ‘But the issue of how you can obtain something useful from big data using models not only involves econometrics, but also ethics. For example, you can make people buy things that they do not want because you know that they are vulnerable to a specific temptation at that time. How far do we want to allow ourselves to be manipulated?’

This is exactly the type of subject that belongs in the faculty of TPM. ‘We have a group focusing on the philosophical and ethical aspects of new technology. I think the combination of this with econometrics makes great science. The idea that you are not only thinking about what is possible in terms of econometrics, but also what we as a society are willing to tolerate. That is just what our faculty is all about: carefully considering the repercussions of a new technological development like big data from the very outset, because we ourselves want to remain in control.’

Josien Kruizinga and Tim Jonathan

True to the concept

During the 2014 Solar Decathlon, the Olympic Games of sustainable construction, the Prêt-à-Loger student team proved a resounding success in Versailles with their concept for making existing residential constructions energy-neutral.Design Manager Josien Kruizinga and Construction Manager Tim Jonathan are proud of their performance, but they would like to see the concept be applied in practice: 'It is time to put that enthusiasm into action.'

At the heart of the Delft campus, there is a typically Dutch house, complete with through-room, bicycles by the door and a sandpit in the garden. In the open kitchen inside, the coffee is on and the interior looks cosy and lived-in. But nobody actually lives there. In fact, the house is now in its third location in the space of just a year. What may seem a mystery is actually the TU Delft entry for the 2014 Solar Decathlon, a worldwide competition in which student teams compete to design the best energy-neutral home.

The house, or pavilion to use the competition term, is a recreated terraced house. It features an additional building envelope, like a second skin, running from the ridge of the roof to increase and insulate the living space whilst also generating energy via the integrated solar panels. The idea originally came from a group of five Architecture students under the supervision of Professor of Sustainable Construction Andy van den Dobbelsteen. Josien Kruizinga and Tim Jonathan became involved in the project in its early stages two years ago. The team then grew to include 55 students from various study programmes, including Architecture and the Built Environment, Electrical Engineering, Civil Engineering, Industrial Design Engineering and Sustainable Energy Technology. 'We eventually built up so much name recognition that everyone felt it an honour to be able to take part,' says Josien Kruizinga. But where does the name Prêt-à-Loger come from? 'It means 'ready to live in', because residents can stay in their house during the renovation,' she explains.

Ready to live in

However, a great deal of work was required before the project really was ready to live in. In addition to a full design and enough students to assist with construction, sponsors were needed most. 'That was quite difficult at the outset. When you visit businesses as a student, there is a certain level of distrust,' explains Tim Jonathan. 'But when one or two have already pledged support, it gets easier.' Fortunately, the name Andy van den Dobbelsteen opened quite a few doors. 'Andy really did provide some intensive help,' says Kruizinga. She also spent a lot of time on the road with Jonathan. 'The two of us criss-crossed half of the Netherlands in Tim's car giving presentations.'

The design process ran parallel with sponsorship recruitment, but it did not always go smoothly. 'The solar panel specialist based his calculations on the very best panels,' says Kruizinga. 'But with this kind of renovation, there are at least ten other aspects to take account of, so you continually have to consult and discuss things. It was a great learning experience for everyone. Obviously, an engineer wants to use the very best technology, but the best solar panels are not necessarily the best in the context of the design.' In the end, everything had to come together. 'You need to know what sponsorship you need right down to the washing machine.'

Deadline

By February 2014, the sponsorship and design processes had been completed. 'We sat down with the sponsors and the whole team to discuss the design. It was important to know what kinds of products the sponsors had and how it would all come together,' explains Jonathan. After that, the information needed to be included in the architectural drawings. It was a very tight deadline, because construction needed to start by late March. 'In the weeks in February and March, we became a real team,' says Kruizinga.

By then, Prêt-à-Loger had been allocated space in the D:Dream Hall, the official workplace where the TU Delft 'dream teams' prepare for competitions. The team worked right through weekends, sometimes making an awful lot of noise. 'We had a very international team. All of our engineers were from Greece; they are quite expressive, so there was a lot of passion and raised voices,' says Kruizinga. 'The next day, other student teams in the hall asked us what we had been arguing about.' Although there were actually no arguments, there were times when Kruizinga needed to step in. 'It is extremely frustrating getting up early on Saturday and then having to wait an hour because your colleagues from India have a different

perception of time. I ended up giving them a good talking-to on the phone.'

Building practice

In March, the students set off for the east of the Netherlands, where one of the main sponsors has a factory. 'They make timber-frame construction components there that we used to recreate the original house', says Jonathan. The Prêt-à-Loger house was erected for the very first time on a site in Almelo. It was built with the help of students, which was great practice for Versailles, where they would have to be able to build it themselves within ten days. 'Those ten days included the entire house. If you are renovating an existing house, you could do it within three,' he emphasises. 'In that case, all the cabling and sensors are already integrated within the prefabricated panels.' After an opening ceremony in May, everything had to be quickly dismantled and transported to France in a column of eight open trailers and three closed trucks. On the competition site in Versailles, Prêt-à-Loger certainly stood out: in between 19 architectural tours de force filled with designer furniture, there was just one terraced house full of things bought second-hand from an online auction site. It attracted an amazing number of positive comments. 'Many of the visitors live in similar houses and could identify with it,' says Kruizinga. 'We also took the whole garden with us, resulting in an abundance of flowers and butterflies, whereas the rest just had a bit of gravel.'

Out of the ordinary

The competition period itself was very hectic. There were not only visits by all kinds of judges for more than two weeks, but visitors also needed to be given guided tours every day. 'There was also an entire programme stipulating how many times the laundry needed to be done, how often you needed to shower, boil water and use the oven – it had to operate like a real house. That continued throughout the public tours', says Kruizinga. The requirements were not always very realistic, in their view. 'The temperature needed to be at a constant 26 degrees, even though it was cool and cloudy outside,' sighs Jonathan. 'So we had to turn on the heating. This immediately revealed the quality of the greenhouse construction.' Being so out-of-the-ordinary, their entry in the competition involves a certain level of risk. 'We wanted to remain true to our concept, which meant making concessions to elements of the competition, even though we knew it would mean losing points,' says Kruizinga. 'For example, we copied the aspect of the original house,' explains Jonathan. 'In Versailles, all of the new houses had a southerly aspect, for optimum performance of the solar panels. We pointed diagonally south-east, which is not really optimal. We tried to remain honest and fair.'

Second skin for your home

Terraced houses with a second skin
The Prêt-à-Loger is a replica of a typical Dutch home with a through-room in Honselersdijk. The renovation consists of a greenhouse structure placed on the walls and roof of the house as a second, protective skin. On the sunny side of the house, the glass façade forms a conservatory or winter garden, which can be completely opened in the summer, bringing the garden back to its full size. It enables you to create space where and when you want it: in the house in the winter and outside in the summer.
Special transparent solar panels are built into the glass. An integrated system takes heat from the solar panels and uses it to heat the tap water. Interestingly, this way of cooling the solar panels makes them more efficient.
What is known as phase-changing material is used in the crawl space and this can distribute cool or warm air through the house, depending on the temperature.
A green roof is optional.

‘It is a question of mindset. We need to think about the longer term, about the transition towards a sustainable society’

Despite these concessions, Prêt-à-Loger was almost the winner. ‘It came down to fewer than three points out of a total of 1,000. That means that we may have not run the dishwasher properly on one occasion, or something similar,’ sighs Kruizinga. In the end, they achieved a great third place. In addition, the house won prizes in various categories: first prize for Sustainability and for Communication & Social Awareness and second prize for Energy Efficiency and Construction Management, Health and Safety. ‘We never expected to do so well,’ says Jonathan. A few days after the awarding of the prizes, it was back to Delft, where the house was rebuilt again. ‘That third time was the least fun.’

Mindset

The house will be staying in its current location on campus for at least two years, where it can be used for guided tours and graduation projects, for example. But the ultimate aim goes further than that. Jonathan: ‘We have always worked on the assumption that it needed to be feasible in practice – the competition was a first step towards that. If we have our way, we will be using it in a pilot project within a year.’ The technology itself is not an issue, as they have demonstrated. But other things are also needed. ‘Our concept calls for adaptations across the entire chain: the construction sector of course, but also the municipality, because of issues such as planning permission and zoning plans’, explains Kruizinga. ‘You also need to negotiate with energy suppliers, because you will be supplying energy in the summer and asking for it back in the winter.’

Funding is another issue. The investment costs can be offset against the reduction in energy costs, but this kind of renovation increases the value of the home, and therefore also the property tax payable. For rental properties, the rent will also increase as a result of which the tenant may no longer qualify for rental subsidy. ‘These issues create obstacles, when you’re actually trying to encourage people to do it,’ argues Kruizinga. ‘It is a question of mindset. We need to think about the longer term, about the transition towards a sustainable society.’ There is certainly enthusiasm for it. She has seen this at the many workshops she has organised for residents, businesses and government authorities. ‘Everyone is enthusiastic and we now need to put that enthusiasm into action.’

This was also demonstrated by the fact that the team secured the Ministry of the Interior as one of the main sponsors. In fact, the ministry’s support makes perfect sense. Prêt-à-Loger offers a solution to one of the Netherlands’ greatest challenges: making the existing housing stock more sustainable. There are four million terraced homes in the Netherlands. The majority date back to the 1950s and 1960s, an era when insulation was not yet an issue. ‘When gas was discovered in Slochteren, we had no need to insulate anything,’ argues Jonathan. ‘But the result now is problems with damp, draughts, energy consumption and even health. Besides, it involves so many homes that demolition and new construction simply isn’t feasible. In any case, we believe that these typically Dutch homes should be preserved.’

Housing quality

For the Prêt-à-Loger students, it is not only about sustainability, but also about housing. ‘These terraced houses are not only poorly insulated, but also rather small, which is why we developed a concept that solves all of the problems simultaneously,’ says Jonathan. Kruizinga: ‘We are making sustainability attractive by combining it with housing quality. Currently, energy conservation is the only consideration, and that takes thirty years to pay for itself. If the quality of the housing is improved, you benefit from the renovation straight away.’ At the same time, the concept can also prove useful in helping the Netherlands achieved its energy targets. ‘But we started by examining how we could make something attractive that people want to have,’ stresses Jonathan. ‘That is all about living conditions, space and comfort and not only the energy bill.’

Jenny Dankelman

From keyhole to pinhole

Professor Jenny Dankelman is Professor of Minimally Invasive Surgery and Intervention Techniques in the faculty of Mechanical, Maritime and Materials Engineering (3mE). In May 2014, she was one of 11 Medical Delta professors appointed. These are dual appointments at TU Delft, Leiden University and/or Erasmus University Rotterdam that are intended to form a bridge between the medical world and the world of technology. 'This combination offers real added value,' says Professor Dankelman.

The Aula building played host to a unique ceremony on 12 June: eleven newly appointed Medical Delta professors held a marathon inaugural lecture before an audience of hundreds of academics, medics, entrepreneurs and other interested parties. Together, they presented a summary of the latest developments in medical technology, ranging from 3D prints of the human body for surgeons to practice on to proton therapy for more targeted radiation of tumours. Medical Delta is a Zuid-Holland-based consortium of universities, medical centres, businesses and government agencies that aims to bring innovation to healthcare. Professor Jenny Dankelman has been affiliated with TU Delft for thirty years and is now also professor at the Leiden University Medical Centre. It could just as easily have been the Erasmus Medical Centre, she emphasises: 'We work in alliance with the Erasmus a lot, as well as with the Reinier de Graaf Gasthuis and the AMC Amsterdam, but there is currently more contact between my group and Leiden.' What matters most is the mutual cooperation, because it is indispensable for the development of biomedical technology. 'You cannot simply develop new technology and then check if it is suitable. You have to take the needs of the clinicians as your basis.'

Operating theatre

The best place to find out about these needs is in the operating theatre itself, where Dankelman and her colleagues can often be found. 'We do a lot of observational studies as the basis for our research. This enables you to take a critical look at what is happening and what improvements you could make. These observations then provide an effective basis for discussions with doctors. This is because what we see as a problem may not always be experienced by them in the same way,' explains Dankelman. Dankelman's career in medical technology actually started in the operating theatre. After studying mathematics in Groningen, where she specialised in control technology, she was awarded a doctorate at TU Delft for research into the circulation of blood in the heart muscle. 'I had made control engineering models that enabled me to make excellent predictions,' she explains, 'but I was told that I had to also test them out in practice. I then did this with the help of animal test subjects at the AMC. For that, I learnt how to conduct operations myself, and that experience is now proving very useful in my collaboration with surgeons.'

Instruments

In fact, she has been collaborating with surgeons since the 1990s. Because although technology has long played a role in medicine – just think of the microscope, stethoscope or x-ray equipment – for much of the time, surgeons have used traditional instruments such as forceps, scalpel, needle and thread. The emergence of minimally invasive surgery, also known as keyhole surgery, marked a revolution in the operating theatre. Professor Jenny Dankelman and her colleagues experienced this at close hand. 'When the minimally invasive techniques first appeared, we were one of the first technological research groups to explore what contribution we could make,' says Dankelman. 'Working as engineers in the operating theatre was something quite extraordinary at that time.' What started out as a development that solely concerned instruments has now developed into an extensive field of research. 'In addition to the development of instruments, we also conduct research on the control of these instruments by humans: human-machine interaction. We also look to the patient. How can we use our instruments to characterise tissue, and is it perhaps possible to treat that tissue immediately in a way that is minimally invasive?'

One new technique for treating tissue being developed is the use of water jet cutting to make holes in bones. For the meniscus procedure, a new instrument has been developed that is both flexible and extremely rigid at the same time, enabling bone to be cut. Work is also underway on controllable needles and catheters that can also be used in the MRI. 'Thin, rigid, controllable and yet also MRI-compatible: these are not

‘You cannot simply develop new technology and then check if it is suitable. You have to take the needs of the clinicians as your basis’

DORA

Even the operating theatre itself has become the subject of research. ‘We noticed that, with all these new technologies, there were increasing numbers of checklists, which were threatening to distract from their purpose,’ explains Dankelman. This was the inspiration for DORA, the Digital Operating Room Assistant. ‘We intend to use it to make processes in the operating theatre run more smoothly, with a focus on the equipment. We are trying to replace the checklists with technology, so everything happens automatically. Is the equipment in place, has it been maintained, have there been issues that remain unsolved? You can integrate a step like this within a simple solution, obviating the need for manual checks. It provides peace of mind.’

properties one would logically combine within an instrument,’ says Dankelman. Dankelman has observed a noticeable trend for instruments to become increasingly thinner. This is because surgical intervention is increasingly done through catheters and needles. If catheters and needles replace endoscopic instruments, intervention can take place through much smaller incisions. Keyhole surgery would become pinhole surgery.

Practice makes perfect

Of course, clinicians need to learn to work with all these new instruments. This training cannot take place on patients, which is why the development of training systems is now high on the agenda. A good example of this is the simulation programme SIMENDO – short for SIMulator for ENDOscopy – a serious game that doctors can use to learn the basic skills of operating with an endoscope, such as hand-to-eye coordination and gauging depth on a two-dimensional camera projection. ForceSense was also recently launched onto the market. It is a system for practising that provides feedback on the force that the doctor exerts on tissue. This is something difficult to sense when using an endoscope, which results in a risk of tissue damage. ‘Surgery is extremely complex. In a system like this, you can only incorporate those skills for which training can take place outside the operating theatre, such as psychomotor skills,’ says Dankelman.

This means it is important to know when someone is ready for the next step: operating on animal test subjects or under supervision in the operating theatre. This is why training simulations include a scoring system, similar to that for computer games. Setting it up is not an easy process. ‘What exactly is the essential skill and how can it be assessed objectively? We decide on that in close collaboration with the surgeons and those in training. For example, you can check how smoothly someone is able to make a movement or how often he or she makes a mistake by dropping something or touching something that should not be touched.’

Senses

As the name suggests, minimally invasive techniques are less invasive for the patient, which means that patients who may be too ill for a regular operation can still be treated. There is also a reduced risk of infection. This technology is continuing to develop. ‘It is a relatively new specialism and there is potential to make a great deal of progress,’ says Dankelman. ‘In the future, we want to be able to reach everywhere in the body. For that, we will need our instruments to be able to determine what type of tissue we are dealing with: whether it is a tumour, or not, for example.’ This is why the research is now focusing on tissue typing. ‘You can do that using optical or acoustic sensors developed by research groups we are working with, but the tissue may also have certain elastic properties or surface properties that you

can sense. Our aim is somehow to get the surgeon's senses to reach the tip of the instrument.'
What benefits the patient also ends up being cheaper, because the number of days in hospital and other cost items relating to long-term hospital admissions fall significantly. However, these benefits require an investment. 'Developing these instruments is an expensive business, but you need to have faith that it will turn out cheaper in the long run,' says Dankelman. That faith is out there: in 2012, Technology Foundation STW gave the go-ahead for the research programme entitled 'Instruments for minimally invasive techniques' (iMIT), involving a total of 7.5 million euros. With Dankelman as programme leader, knowledge institutions and businesses will work together on multifunctional, interactive instruments. 'We aim to develop controllable needles and catheters that can be manipulated, as a result of which we will soon be able to treat patients with a single instrument. We hope to be able to use the very same instrument for both diagnosis and treatment. It is a great challenge.'

Mobile operating theatre

Dankelman also faces another great challenge in the future: making minimally invasive techniques accessible for countries and places where healthcare is much more difficult to reach. 'That could solve all kinds of problems, since the risks of infection, for example, are much lower.' In the future, operating theatres may no longer need even to be sterile. 'If you put some kind of balloon around the equipment, you only need to keep the area around the incision sterile.' That would make operations possible outside of hospitals or even in the open air, enabling deployment in disaster areas or in developing countries. 'Can we create something that is simple, robust and affordable at local level? I am thinking of some kind of mobile operating theatre. This is something that I intend to start completely from scratch.'

Delft Women in Science

Thirty years ago, Professor Jenny Dankelman was the only female member of academic staff in the 3mE faculty. 'I found it difficult to make my mark in this men's world,' she recalls. 'That soon passed when I took a closer look at the difference between male and female behaviour. If you understand men better, you also start judging them differently; you end up realising: they don't really mean it that way.' In 2006, Dankelman was closely involved in setting up Delft Women in Science (DEWIS), the network for women academics at TU Delft, which she chaired from 2008 until 2010. 'It is important for women to have a fair chance. If there are women who are just as good as men, but they lack confidence or have difficulties with the masculine culture, that is not good for TU Delft. However, it is possible to prepare women for the fact that it is a masculine culture. We provide DEWIS training courses for that.' By setting up the Delft Technology Fellowship especially for women, TU Delft has been trying to increase the number of senior female academics since 2013. Dankelman welcomes the initiative, although she believes things are not yet progressing fast enough. 'There also need to be more women in appointment committees. Men also need to learn that women express themselves differently. For example, a woman will be much more reluctant to say that she is the best, even though she may have the same ambitions as a man.'

Ernst ten Heuvelhof

Educating the world

Professor Ernst ten Heuvelhof is Professor of Public Administration in the faculty of Technology, Politics and Management (TPM), where he is also the Director of Education. In 2014, he was appointed as Director of Open and Online Education in the newly-established TU Delft Extension School. By bringing together open and online education, TU Delft aims to reach out to students across the world whilst also improving education on campus. 'We are very much at the early stages of developments', he says.

I graduated...
as a planning specialist and lawyer and have always been fascinated by technical issues. Before I joined TU Delft, I worked for an urban design consultancy, cooperating closely with engineers. My contribution was primarily legal and commercial, two aspects I found reflected in the profile of what was then about to become the faculty of Technical Policy Administration, now TPM. I have been at TPM since the very start – when I arrived in 1992, the entire faculty could fit in a few rooms in the building of the Civil Engineering faculty. Here, I work on projects in the energy, space and water sectors. They are typical Delft projects with a significant administrative component. Issues in urban design and spatial planning always involve administrators and decision-making, so I am very much in my element.

Education needs to be improved...
across the board, and not only at universities or in the Netherlands. The new Extension School can contribute to that, because it will help raise the average level of knowledge in the world. I also believe that we can improve the education we provide here on campus. I am talking here about blended learning: a mixture of contact hours and online teaching. It seems to me to be an attractive way of learning for students. The number of contact hours will decrease, but it is mainly the large lectures that are affected. From an educational perspective, they were already under pressure as it has been shown far too often that very little is learned at them.

Online education...
is something we have had here for many years in the form of Collegerama and Open Course Ware and more recently via the Massive Open Online Courses or MOOCs. Now, the portfolio is being massively extended, to include such things as in-company training courses and online Master's programmes. For businesses with branches across the world, having their employees take corporate training courses online can prove very useful. New in this list are online courses for professionals. Although not free of charge, participants can obtain Continuing Education Units. These special credits are compulsory for certain international groups of professionals and are similar to the Permanent Education Points for accountants here in the Netherlands.

In the past...
you didn't know any better. Collegerama also started out as a lecture in two 45-minutes sections. A lecturer stood stock-still in front of the class – movement was not possible because of the camera. Now, we make videos lasting a few minutes and students respond to that. While waiting at the bus stop, they take out their phone and watch a quick video. It suits their rhythm. After it, they become distracted again, because they have only a short attention span, but they would probably never even have started that 90-minute lecture. Making these kinds of videos is not so simple. The text is completely scripted, and students can read it at the same time. Giving lectures is different, because it is much more relaxed. Making these videos is very time-consuming, but if done properly, you can keep reusing them in subsequent years. Even that is not as easy as it sounds – the material can quickly become outdated.

In the TPM faculty...
blended learning has been incorporated within the Bachelor and the result is excellent, with an enormous variety of teaching and learning methods. These include traditional lectures and seminars/ tutorials, as well as a range of online tools. For example, we start the Bachelor by having students do online quizzes. They are given 30 multiple-choice questions and you can use the wrong answers to identify gaps in their previous education. For example, if you get questions about random sampling wrong, you are referred to a MOOC you can take to fill the gap. Development is still continuing and we are still in the very early stages.

The need...
for technological education is growing rapidly across the world, to such an extent

that you should open six new universities of technology every week for the next ten years, it is said. 'Teaching the world' is a key argument for open and online education. Personally, I find it very inspiring educating the world. With online education, we have such amazing reach too.
But not everything can be done online – students also need to do practical assignments or laboratory research. Virtual labs are possible for some of this, or students can come to Delft for a few weeks every year. We can also forge alliances with other universities, with them covering the practical components. But this costs money. We are currently trying to create a mixture of free and paid-for education. I imagine that in the future we will be saying: the content is openly accessible, but you will need to pay for official diplomas. That is a decision we still need to make. But the pioneering process is amazingly enjoyable: thinking about the technology, the teaching methods, the quality and the business models.

For the MOOC...
on Solar Energy we noticed that 0.1% of the people who registered for the MOOC also applied to study at TU Delft. That may not seem many, but it amounts to 40 students. Now we need to find out how many of that 40 would have come in any case, but it is still interesting. Online activities leave behind traces. How often you watch a lecture, when you click on something else, whether you upload a paper on time: we can see exactly how people are studying. This information can then be linked to education and examination results. You can then analyse all of this data using big-data methodologies. This enables you to improve your study programmes: now that really is evidence-based design! We have a research budget for this and are conducting the research together with Gert-Jan Houben from Delft Data Science. So education is now becoming the subject of research itself. What could be better than that?

I myself have...
also taught a MOOC, for which some 17,000 people registered. Slightly more than 200 students enrol for Systems Engineering, Policy Analysis & Management every year. That means that our MOOC reaches as many people as SECAM does in 80 years. That MOOC was an offshoot from Next

Extension School and edX

Professors Rob Fastenau and Ernst ten Heuvelhof are the Dean and Director of Open and Online Education at the TU Delft Extension School, established in 2014. In the years ahead, they will be developing an Extension School along the lines of the Harvard Extension School, in which all of TU Delft's open and online education can be offered to students across the world.
A key feature of the Extension School is cooperation within the edX platform. Since 2013, TU Delft has been offering Massive Open Online Courses (MOOCs) via this online education platform, also used by MIT and Harvard among others, to provide access to courses since 2012. These MOOCs provide free online access to the knowledge of TU Delft to everyone, anywhere in the world. One of the reasons why TU Delft has chosen edX is that the material can be published there under an open licence, making it available for others to use.
Starting in 2015, there will also be ProfEd courses for people wishing to update their professional skills or do additional training alongside their existing job. The first TU Delft ProfEd will be 'Economics of Cybersecurity'.

‘The first car was like a horse and cart without the horse. Then the car emerged, followed by mass production and suddenly humans adapted their lives to fit the car’

Generation Infrastructures. It was a major ten-year research programme examining network-based industries such as energy, transport and telecom. We originally planned to write a book featuring the highlights from ten years of doctoral dissertations, but then we realised that a MOOC would be a much more accessible way of using our research results. People from universities across the world contributed to the research programme and some of these have also given lectures in the MOOC. Margot Weijnen and I were the anchors for it all, doing the intros and outros and all the summaries. Previously, we had also been the directors of research for the research programme.

Peer review…
started out as a new feature on the edX platform. When you upload a paper, you eventually receive five reviews. In exchange, you also have to review five papers yourself. It is a great system. If you let the side down, the group will let you know about it, as they do if you are the only one to complain about something. It creates a completely different dynamic. In SECAM, we now have Bachelor students review each other’s papers, in addition to the reviews by lecturers.

What education will be like…
in ten years’ time? I haven’t the slightest idea. But, we can consider how technical innovations emerge. Take the first car, which was like a horse and cart without the horse. Then the car emerged, followed by mass production and suddenly humans adapted their lives to fit the car. They start moving further away from work and suburbs emerge. The entire pattern of life changes. The man who first built the car based on that horse and cart had no idea of what the consequences would be in terms of spatial planning.

You can see it…
in all of the industries affected by the internet: the music industry, publishing, travel agencies and so on. In the early stages, there is a reaction: the first e-books were just PDFs of printed books. Then new forms and business models develop, which accelerates things. Take a platform like Blendle, for example, where you can download separate articles from all newspapers and magazines. The development of it took a few years and culminated in a model that could not have been predicted in advance.

That is exactly…
what is now happening with online education. We started with Collegerama, the equivalent of the horse and cart without the horse or the PDF of the book. MOOCS are a next generation, but you should not imagine that this is the end phase. We are probably only at about stage two. Things will not start to consolidate until around step ten, in a couple of years. What matters is that we are participating and are willing to take the next steps. We certainly are. We demonstrate this by being pioneers in a prestigious platform like edX, in which we are one of the leading universities.

It does not need to end…
with education. We can also put our research online. We did that with our MOOC Next Generation Infrastructures. We were the first to do that. Most research is still hidden away in inaccessible journals. What could this mean for the world? The MOOC on Solar Energy elicited such moving responses. One student was living in a village that only had power for two hours every day. Thanks to the solar panels that he was able to make, his mother can now earn money all day long with her sewing machine and his brothers can do their homework in the evenings using a light. The neighbours also benefit. This could also happen with water purification, or combating epidemics, or nutrition. When you share research and education, you can reach millions of people. I think that is fantastic.

Ronald Hanson

‘Quantum mechanics is completely counter-intuitive’

Professor Ronald Hanson is Antoni van Leeuwenhoek Professor at TU Delft’s Kavli Institute for Nanosciences. In May 2014, Hanson and his colleagues succeeded in becoming the first in the world to move data reliably from one quantum bit to another ten feet away, without the information travelling through the intervening space. This method of teleportation represents a major step forward in the development of quantum computers and the quantum internet.

Why did you start doing quantum research?
I always found quantum mechanics interesting, but especially when you can measure something for yourself. A lot of theoretical work is being done, and there is the research at CERN, for example, where thousands of people are working on the same thing. Here in Delft we’re just a small group, but we can measure fascinating quantum phenomena in our experiments just as well as they can with the Large Hadron Collider. You have a lot of say in what you do, so you get the chance to do pioneering work. That’s what makes it special. In a certain sense, there is a common thread between my graduation research, my PhD work and what I’m doing now, even though the whole research field has changed. Professor Hans Mooij, a pioneer in nanotechnology, was the father of quantum research at Delft. Leo Kouwenhoven, who is now professor of Quantum Transport and Cees Dekker, professor of Bionanoscience, both grew up under him. These two entire departments both come from just one man.

Is TU Delft a leader in quantum research?
That’s undeniable. For me that was one of the reasons for coming to Delft, because Delft has been leading the world in this field for over twenty years. If I’d gone into business, I would probably have aimed for the top too. For me, it’s important to do things in science that have never been done before. And that’s what we are trying to achieve in our research here. But if we ever stopped being among the best, I simply wouldn’t enjoy it as much. As far as I’m concerned we have to make sure that never happens. The best people go to the best places to do their research, and they make each other stronger. But that can also be a vulnerable situation. Universities like Harvard can afford to buy the best people; a Dutch university can never hope to do that.

In May, you made headlines across the world with a teleportation experiment. How did that feel?
It was really fun. We had already published an article announcing this experiment, but this time we got a lot of international attention. I had spoken to a couple of journalists under embargo, including John Markoff of The New York Times. He wrote a very positive piece which came online just after the article was published in Science. Apparently a lot of journalists read The New York Times, because after that it just snowballed. Suddenly there were all these camera crews at the office while I was actually having a day at home with the children. But then after a few days all the fuss subsided. There were still the more specialised journals, but that’s less hectic.

Are you ever going to repeat that experiment over a greater distance?
That’s what we are working on now, yes. We have a lab set up on the other side of the campus, which is connected to our lab here with a fibre-optic cable. No experiment has yet proved conclusively that the phenomenon of quantum entanglement is real. Because in previous experiments it was still possible that there was a signal of some sort from one electron to the other. So for the next experiment we will locate the two test set-ups over a kilometre apart, because we are able to measure quickly enough to know if the particles have communicated with each other, even if that signal was moving at the speed of light. This kind of experiment is called a loophole-free Bell test.

You once said that you do not understand it all completely. What did you mean by that?
We have all kinds of theoretical formulas that predict what will happen in practice – and they work. We understand those formulas. But then you ask yourself, would you understand what is happening on an instinctive level? And that’s where you have to say no, because the whole of quantum

‘Currently, if we want to understand something extremely small, we always come up against the laws of quantum mechanics which govern the behaviour of very small objects’

mechanics is completely counter-intuitive. This also means that any metaphor you try to use to describe it is bound to fail. It seems impossible that if something changes here, in the same instant something else happens three metres away as a consequence. The danger lies in concluding that one particle is sending some kind of signal to the other particle – but that is not what is happening. Or at least, this is what we want to prove conclusively with the Bell test.

What are the practical applications of your research?

The QuTech centre was opened a year ago with the aim of developing techniques that make use of quantum phenomena. We are working on several projects. To start with there is computing using quantum mechanics. We think that will help us to solve a number of problems that we can’t solve with standard computers, because a quantum computer computes in a really different way. An ordinary computer computes step by step. A quantum computer, on the other hand, could carry out huge numbers of computations simultaneously and so it could calculate things that we are not yet capable of calculating.

The second is a quantum internet, which will involve using teleportation to send information over long distances. That could run in parallel to the normal internet. If you download a video from YouTube, for example, then the regular web works fine. But if you want to be absolutely sure that no one else knows what’s in the message you’re sending, you could use the quantum internet. That guarantees your security by applying the laws of nature. The thing is, you cannot intercept the teleportation process. That really is something that we couldn’t do without quantum mechanics. At present, we encrypt everything, and we hope that the code is very difficult to crack. But if you have enough computing power, any code can be cracked.

What will I use the quantum internet for at home?

As a citizen, you don’t want the government to listen to your communication and you want your bank transactions to be safe.

I think we will start to use the quantum channel alongside the regular internet channel. You’d only use the quantum channel when you wanted to send sensitive information. And then it wouldn’t matter so much if it was slower or more expensive, because you wouldn’t use it to send a lot of data. But how expensive it might ultimately be is difficult to predict. It’s even difficult

Loop-hole free Bell test

Professor Ronald Hanson and his colleagues have succeeded in deterministically transferring the information contained in a quantum bit – the quantum analogue of a classical bit - to a different quantum bit three metres away, without the information having travelled through the intervening space: teleportation. The results were published in Science.

To achieve teleportation the scientists made use of an unusual quantum phenomenon: entanglement. When two particles become entangled, their identities merge: their collective state is precisely determined but the individual identity of each of the particles has disappeared. The entangled particles behave as one, even when separated by a large distance. The distance was three metres in this case, but in theory the particles could be on either side of the universe. Einstein didn’t believe in entanglement and called it ‘spooky action at a distance’.

Hanson is planning to repeat the experiment over a distance of 1300 metres, with chips located in various buildings on TU Delft’s campus. This experiment could be the first that meets the criteria of the ‘loophole-free Bell test’, and could provide the ultimate evidence to disprove Einstein’s rejection of entanglement. Such a test is considered ‘Holy Grail’ within quantum mechanics.

to say when it might be ready. In five years time we aim to have a working connection between Leiden, The Hague and Delft. We are already looking at whether there are fibre optic cables that we could use, so it should be possible very soon.

Would error correction be a problem for the quantum computer?

That is indeed a major step that we will have to take before we can produce a functioning quantum computer. If we made one now, it would stop working very quickly. The simplest way to achieve error correction is to copy and compare information. At least, that is what we do with regular data. If you can do that it doesn't matter so much if a 'zero' somewhere is changed into a 'one' by mistake, because there will be three different copies of that information. That's not possible in quantum mechanics; it is a basic rule that cloning is not possible at the lowest level. If I give you an electron and I don't tell you what state it is in, you cannot copy it. And if you start measuring it to see what state it is in, then you will disturb that state. But what you could do is to see whether two quantum bits have the same value or a different value. If they are they not the same, then there is an error. So with entangled particles, you can get information about a shared property without knowing the state of the individual particles. That is hard to imagine, because in the 'normal' world that's not possible.

A quantum computer uses qubits - how do you make those?

Basically, you can create qubits from anything that behaves according to the rules of quantum mechanics. If it's small enough and you can screen it off, then you can use it. When you're developing a quantum computer, you will have to make a choice at some point. Then other factors will come into it. Perhaps there is a company that will want to invest in making them from a particular material. There are now four or five variants in contention. In my research, I work with individual electrons in diamonds. Another example is using small rings of superconductive materials, another of Hans Mooij's ideas. These are the two ideas with which the most progress has been made for 'solid-state' qubits, and so it will be possible to make chips from these in the future. Many people think that you'll eventually have to make chips anyway, because otherwise it will be difficult to work with large numbers of qubits. But there are also research groups that are working with individual atoms. They hold the atoms in place using a laser beam in a large vacuum chamber. Such systems still perform the best when it comes to quantum computing, but in the future we are going to need a billion of these particles. How will that work if each one needs its own laser beam? Those groups have always been ahead of us, but now we're catching up. Teleportation as we did it had never succeeded before, for example.

We could also use quantum computers to develop materials and medications. How would that work?

Quantum computers are particularly good at certain things. One of those things is finding prime factors of large numbers, which is purely mathematical, but that is what current methods of secure communication are based on. The other thing is computing with molecules. Currently, if we want to understand something extremely small, we always come up against the laws of quantum mechanics which govern the behaviour of very small objects. For example, inside a molecule there are all kinds of entanglements between the particles. In order to develop new materials or medicines, you need to calculate what is happening at the quantum level. We can do that for a molecule such as methane, which is made up of a carbon atom and four hydrogen atoms. But for a glucose molecule – which is not even much bigger with its six carbon atoms – we'll probably never manage that without a quantum computer. And there will certainly be a lot more examples than just drugs or materials. We are now pretty much blind at the quantum level. A quantum computer will suddenly bring this level into focus because you could say it understands how nature works at that lowest of all levels. There are so many interesting things that happen at the nanoscale. That's why quantum computers will be so useful to us.

Nick van de Giesen

Water for crops and for the city

Professor Nick van de Giesen holds the Van Kuffeler Chair in Water Management at the Faculty of Civil Engineering and Geosciences since 2004. He specialises in modelling complex water management systems. In 2014, he won the TU Delft Best Professor Award, which is presented annually to a professor who excels in education and research, and serves as an exceptional inspiration to students and PhD candidates.

Water for crops and water for urban areas. Those are the two global challenges that Professor Nick van de Giesen sees for water management. 'More and more people are moving to cities, and those cities need water, that much is clear. But what few people realise is that for every kilo of food, you need a thousand litres of water.' So if you want food, you need water, and with the population of the world growing at its current rate, the demand for water is growing very rapidly too. 'Estimates vary, but by around 2050, we will need to grow between 50% and 100% more food than now. That is rather a lot.' But Van de Giesen is optimistic that it will be possible. 'I don't see that as an insurmountable problem, but we will need to work hard on it, and it does represent the main challenge in my field.' Nevertheless, agricultural production is feeling the pressure in many places, partly due to urbanization and growing incomes. 'Even though food prices are very high compared to recent decades, in the Netherlands it's still difficult to make a decent living as a farmer. At the same time, we can still afford to choose nature rather than agriculture.' The other options include increasing productivity and expanding agricultural areas. 'In a country like the USA, you cannot grow twice as much on the same area of land - efficiency is already high.' Van de Giesen sees two regions where there are still plenty of opportunities. 'Africa and Latin America will become the food producers of the future.' But this does not mean that we should destroy major natural areas in the Congo Basin and the Amazon to grow food, he warns. Those areas are important for biodiversity. The surrounding areas of savannah are suitable for farming, however. 'There is a reasonable climate, reasonable soil and relatively few people live there,' says Van de Giesen.

Climate

When you think of water for food, you immediately think of irrigation, but that is deceptive according to Van de Giesen. 'Most crops get enough water from rainfall. With better weather forecasts, you can work out the best time to sow seed or harvest your crops. But if you do need to irrigate your crops, you will need to know where to find water reserves and whether you can safely use surface water, for example.' That knowledge is often lacking. 'Billions of money will soon be going to Africa to prepare the communities there for climate change. That is strange, because we know almost nothing about how the climate works, so we don't know what is going to change.' The problem lies in the lack of data. 'You can make beautiful hydrological models, but a model makes sense only if you feed data into it and that sometimes gets forgotten.'

The TAHMO project will change all that. TAHMO stands for Trans-African Hydro-Meteorological Observatory - a joint initiative by TU Delft and the Oregon State University. The aim is to build a network of 20,000 small hydro-meteorological stations in Sub-Saharan Africa. The measurements from these ground stations will be combined with satellite images of the earth in order to build up a comprehensive picture of the hydrology in Africa.

The ground stations need to be robust and affordable, however. That's why one of the components used in the weather stations is the Disdro, an acoustic rain gauge that costs only a fraction of the price of a commercial rain gauge. The secret lies in the use of an inexpensive piezoelectric sensor, the kind that you find in musical greetings cards. That idea came from a student five years ago, but the path from idea to finished product is a long one. 'A proof of concept is only ten percent of the work, that's what they told us. But even that was probably optimistic,' sighs Van de Giesen. 'It depends on electronic circuits; China is the cheapest place to have those produced, but then you have no guarantee of quality. You can also have it done in the Netherlands, but then it is

too expensive. And once you have a supplier, you need to test what they have done each time, and often there are months in between. How can you do that for all the components? At TU Delft, we do a lot of research into digital manufacturing, and hopefully that will speed up these processes. We hope that production can soon take place on campus.'

Economic value

Affordable or not, the weather stations will ultimately need to be financed. Van de Giesen has strong opinions about that. 'You can make an initial investment as part of your research project, but eventually the weather stations need to be able to sustain themselves.' One of the goals of the pilot projects recently launched in Ghana and Kenya is to find out how that might be done. But there is money to be made in weather data, Van de Giesen is sure of that. 'Weather data has tremendous economic value; in the US that value is estimated at over $30 billion annually. So in Africa we must also be talking about billions.' But this value is a little diffuse, Van de Giesen admits: 'For us it means, for example - should I cycle to work today or not? Everyone can get something out of that information worth a few euros, but you can't go around collecting the money from everyone. So here, weather forecasts are typically part of the work of the government. In Africa that's different.'
So how could you extract that monetary value there? In Kenya, there is 'Index-Based Weather Insurance', which allows farmers to insure themselves against drought or floods. 'The insurance company has a network of weather stations and if no rain is recorded for ten days at a critical point during corn cultivation, the farmers will be compensated for the money they spent on seed,' says Van de Giesen. 'As weather stations are not their core business, they could do the same thing using our stations, so that they would not need to worry about maintaining them anymore. That could be done for the same price initially, and if we find more customers who want the same data, that price will go down.'

Cotton

In Ghana, there is a plan to sell weather forecasts to farmers via their mobile phones. 'It is often companies that finance that,' says Van de Giesen. 'Imagine that you are a large jeans manufacturer and you want to have Egyptian cotton. That is grown in a wide area from Egypt to Senegal. Usually, the harvest is paid for partly in advance. The company would want the farmers to have access to things like credit facilities and reliable weather information.' The weather stations in Ghana and Kenya will be located next to schools. That will have a number of advantages. 'They can be used for teaching, which lends some extra legitimacy to the project. And also they will be protected better than if you just placed them somewhere in the middle of nowhere.'

Water and the city

The situation in the Netherlands is very different, you might think, but that is not always the case. 'Our cities are actually just like the Africa of the Netherlands, that's

Delft's best professor

The prize for Best Professor came as a big surprise for Nick van de Giesen - but a very pleasant one of course. 'It's a great honour to join that illustrious list of winners. Even Leo Kouwenhoven, a professor who has won so many accolades, calls it his greatest prize.' But the modest Van de Giesen does not quite understand what he has done to deserve it. 'Maybe they saw that I was working very hard on educational renewal. For example, I started to alternate large lectures with workshops. This was a lot of fun to do. We gave all 300 students a parsley plant, and they had to see how quickly the water would evaporate. They had to weight it, water it and measure or estimate all kinds of environmental parameters. But everything that they learned in the workshops was also tested in the exam - and that was something new. They weren't able to go away and read it all out of a book again afterwards.' Although he continues to innovatie, traditional lectures are still on the menu. 'Different people learn in different ways, so I offer all those ways of learning. The customer always comes first.'

‘Forecasting a tsunami event is very complex, for example, but there is much you can say about monsoon-driven events. And the areas where the monsoon occurs are very populous’

how little weather data we have,’ says Van de Giesen. But there is an explanation for that. In accordance with the directions of the World Meteorological Organisation, all KNMI weather stations are sited in rural areas. This is supposed to ensure that comparable measurements are taken all over the world. Cities, however, have their own micro climates. ‘The weather at the front of a building can be different to the weather at the back. That means you have to take an awful lot of extra measurements,’ says Van de Giesen. ‘That doesn’t necessarily have to be done with rain gauges; you can also use radar.’

This happens as part of the European research programme RainGain, for example. Recent advances in radar technology mean that rain radar can measure precipitation on the right time and space scale for urban areas. This should lead to better protection against flooding, including early warning systems and higher storage capacity. ‘Actually, we have quite a strange attitude to water in the city,’ says Van de Giesen. ‘For our drinking water, we collect water in reservoirs in the Biesbosch, then we filter it in the dunes. But the water that falls directly onto the city, we try to get rid of that as quickly as possible using drains and pumps. If you have good rainwater falling, why would you not want to use it?’ But he focuses on the risk of flooding. ‘You want to avoid any damage from flooding because so much economic and human value is concentrated in the city.’

eWaterCycle

Just how destructive floods can be was shown clearly in Bangkok in 2011, when billions of dollars’ worth of damage was caused by flooding. The idea of the eWaterCycle - a detailed model of all the water on earth - was in part a response to those floods. TU Delft is currently developing the eWaterCycle with Utrecht University and The Netherlands eScience Center. The strength of the project is that it is the first global model that can make water predictions at least ten days in advance and to an accuracy of one square kilometre of land area. ‘We already have global weather forecasts, but no hydrological forecasts yet. You might also want to make predictions about water drainage.’ Governments could use that information to make decisions to limit damage, for example by evacuating people or even by breaking a dike in order to protect an urban area. ‘Some things are more difficult to predict than others, though,’ he adds. ‘Forecasting a tsunami event is very complex, for example, but there is much you can say about monsoon-driven events. And the areas where the monsoon occurs are very populous.’

One country that would definitely benefit from this is Myanmar. And that is a country where Nick van de Giesen can regularly be found these days. After years of isolation, the country has been catching up in many areas, including water management. Myanmar has significant water resources, but it suffers from annual floods as well as having areas where there is not enough rainfall. In the 1970s and 1980s, many local water engineers were educated in Delft. TU Delft has been working with Myanmar again since 2013. Van de Giesen: ‘It’s a very beautiful land full of water and the people are very eager to learn. The literacy rate is 93%.’ The long period of isolation has also had some advantages, he thinks. ‘There are a lot of things that they haven’t done wrongly yet.’ For example, much of the water is still untouched. If it chooses the right path forward, Myanmar could soon become one of the forerunners in the field of integrated water management.

Battle of the brains

Myanmar, Africa... Van de Giesen takes just as much pleasure in them both. He stresses that he really does not see his work as some kind of development aid. ‘Some people do research in the Arctic, for me it is in Africa. Of course, I get along well with the people there and I have my network of contacts, but I’m not going there to show them what to do. Africa is capable of developing itself.’ On the contrary, there is mutual benefit in the work being done there, and that does not apply to food production alone. ‘There’s a lot there for us as a university too. Just remember the ‘battle of the brains’. Recently everyone has been going to countries like China and Brazil. And TU Delft is out there too, setting up joint research centres, and that is positive. But there are almost as many people living on the African continent as there are in China. We might have to wait another 30 years until Africa reaches the same stage of development as China, but we could just as well start working with Africa today.’


PLAY

Alexandru Iosup

Entering the next level of education

Dr Alexandru Iosup is an assistant professor with the Parallel and Distributed Systems group at the Faculty of Electrical Engineering, Mathematics, and Computer Science (EEMCS). In 2014 he was voted overall Best Lecturer at TU Delft. He stood out because of his unique approach to teaching: the gamification of courses. 'Gamification is all about students choosing their own path through a course,' says Iosup.

Over the past few years registration numbers have been steadily rising at TU Delft, but traditionally it has been hard to attract students to science and technology (STEM) programmes. Alexandru Iosup believes he knows why. 'Students consider STEM subjects to be very difficult. That is due in some measure to how we present ourselves as an institution. If we act elitist and tough with our students, they will not spread a positive message about us ,' he says. 'Of the students that do come, many do not finish, and only about 30 per cent graduate on time. That is saying something. And 'on time' is even including an extra year for personal development, or perhaps to become the president of the volleyball club. This is not just at Delft; it is a problem worldwide, but especially in Europe,' he continues.
He speaks from experience. 'I think there are serious problems with higher technical education, as I found out for myself.' While studying computer science in Romania, Iosup managed to work full-time while completing his degree. 'That was partly because I needed the money, but also because I was bored,' he confesses. 'I felt the style of education with its fixed schedules and lectures was not suitable for the better student.' The problem with strictly defined courses is that they are usually aimed at the average student, neither challenging the top students, nor encouraging all students to explore beyond the course requirements. This will also cause problems once students have finally graduated. 'It does not match anything you will experience in your professional life, which is much more exploratory and challenging'. Instead, Iosup says, 'You want students to be ready for work and enthusiastic about their skills. They should be able to grow in their careers, to keep learning and improving their whole lives, but if they are disappointed with the educational process, they may no longer be interested in personal development.'

Entrance-level skills

According to Iosup, there are two ways to tackle this. One is what he likes to call the Russian school of education, where the rules are very strict and it is socially unacceptable to fail. The other is to take as a starting point that all students are different, and adapt to them. 'Currently, we do not really adapt to our students, but we are not too strict with them either--although we act as if we are. We are sort of navigating in shallow waters.'
To improve the educational experience, Iosup acknowledges two often-dismissed aspects in particular: that students all have different entrance-level skills, and that they also all have different personalities and interests. 'What would be the perfect environment to involve people of different skill levels and with different personalities? Many games do just that,' says Iosup. Enter the gamification of education.
Gamification is the use of gaming techniques in non-gaming environments, such as educational courses, training programmes or market research. 'You could even operate a whole company using gaming mechanics,' explains Iosup. It is not just about points and levels either. 'Everybody understands rewards, like money or points. The problem is that points are an extrinsic reward, so as soon as you stop them, people are likely to lose motivation and end their good behaviour.' Again he is speaking from experience. As far back as 2003, while still an undergraduate student in Bucharest, he worked on gamifying his first course. 'I was only 23 and I was co-principal investigator. We had been awarded a Microsoft research grant to create a gamified course. It must have been one of the first in the world,' he remembers. 'We did create it, but we did not get the necessary support from the university. They thought the risks were too high, and the course was never used.' Fast forward ten years and Iosup gets another shot at success, an opportunity he seized with both hands. Iosup is grateful for that chance. 'Not every group, or even university, is willing to take a risk on gamification, even today,' he says.
So what gaming mechanics does Iosup use? 'There are many techniques. For

‘What would be the perfect environment to involve people of different skill levels and with different personalities? Many games do just that’

example, if you want people to get involved in something and stay involved, you should give them an incentive at the start that will make it more costly to quit than to stay in. This is called on-boarding,’ he explains. ‘The best simile is a mobile phone contract with a ‘free’ phone included.’ So how do you on-board students in a course? ‘After the first lecture, we give them a voluntary quiz, for which they can get half a point towards the final mark. Since it is only the first lecture, and most students succeed, they will feel they can do well in the entire course. And they build on that. Once they have done well in a number of lectures, it gets psychologically more difficult to quit.’

On-boarding

Another important element from gaming is addressing different personalities. ‘You have the achievers, the explorers, the socialisers and the winners,’ says Iosup. ‘Achievers typically like to solve everything that is on offer, especially bonus assignments. Explorers would prefer to try their hand specifically at what is outside the regular programme. They particularly like open assignments. Socialisers are there because their peers are. They like classroom discussions and they are always willing to show others how to do things, which is why they prefer team assignments. Winners prefer the course elements where they can be the first to answer a question, or come top of a ranking,’ he explains. All these personalities have their uses within the group. Winners, for example, are useful for motivating the rest of the group. ‘It is only natural that the professor is better than you are, but if someone who started out at the same level is now much better, you may feel you have to up your game.’

Using different elements of gaming in the course, Iosup caters to the various personalities. Students can then follow their own path of advancement; they can opt for more explorative or competitive elements as best suits them. ‘For example, there were students who wanted to create their own game and they had the opportunity through an open assignment.’ Throughout the course, students can get points for all sorts of achievements, except for mere presence during lectures. ‘I do not give points for presence; that is no reason for a reward. Doing something useful for yourself, now that I can reward,’ stresses Iosup. If that means that in theory you can score zero out of ten for this course, the opposite is also possible. ‘Students can get more points than are needed to pass the course, but that requires much extra effort. We rarely get students who score over the maximum. Maybe three or four out of 150 to 200 students will achieve a perfect ten for each course. When we designed the course, we carefully calculated the flow of points, and which types of students would get which kinds of points. Reward should be fair, not lead to inflation.’

In addition to points that count towards the final mark, there are other kinds of rewards. For example, access tokens, which grant students access to additional content or to a bonus exercise, comparable to reaching the next level in a game. Moreover, at the end of the course the top 20 percent of all students, regardless of the type of path they choose, are invited to join extra lectures. ‘They can attend an afternoon with a lecture and a hands-on exercise, purely for the pleasure of learning, so not for course credits,’ says Iosup. ‘The topics are chosen from the hottest topics in the field, and we get young top researchers to coordinate the afternoons.’

Students love the new approach. ‘We get very positive feedback and heart-warming testimonials. We had one student who had failed the exam several times, but she realized that with this setup she could concentrate on the course elements that were best suited for her. She still had to do the exam, but is was less stressful as she was coming at it from a different starting point.’

Pass rates

Iosup has gamified several courses already, but the most successful one so far has been Computer Organisation. ‘It is one of the most difficult courses in the curriculum,´ admits Iosup. ‘It teaches students about the main components of computers and how these work together to deliver different trade-offs of performance, energy efficiency, reliability, and so on. It is a systems course, and systems are challenging because of all the different components. Some of these, like processors, are physical parts, while others, like algorithms, are abstract concepts. To take this all in is difficult for the beginning student, but very useful for future computer scientists and engineers. It gives a lot of information and it also builds a particular mind-set. You have to know something about everything, but you have to accept that you cannot know everything about everything.’

Pass rates for this difficult course went up from 60 to 80 per cent. Impressive results, but it has taken a lot of time and effort, admits Iosup. ‘I basically trained for it since I was eighteen, when I was already a self-taught games designer. That must have helped. When I started the process a few years ago, I did not know whether it would work, and it took a lot of effort to convince people I had to do this. Now we are in the

production phase. We are fine-tuning parts and we have to update the content every year, but that takes only one or two weeks.' However, the three months the course takes are also currently very labour-intensive. 'The course involves many small, frequent tests, which have to be evaluated and the results reported back to the students,' he says. 'We are now building an ICT system to solve this.' Although Iosup was voted best lecturer, he likes to point out that it was all teamwork. And out of the ten or twelve people who have worked with him on this over the past few years, he would like to single out one in particular: 'Otto Visser knows such a lot about games, and that has been a great help. He also coordinates the practice part of the course, which is mainly programming. We use Assembly as a programming language, and he is an expert at it.' As it happens, Assembly is one of the most difficult types of programming languages around. So why do students have to learn it? 'High-level computer languages are closer to the way we communicate, hence easier to learn. But Assembly is actually the only language the computer speaks, so other languages are converted into it by automated tools. That is great for most tasks, but both performance and energy-saving are lower when you programme directly in Assembly,' says Iosup. Assembly is used e.g. in the core of weather predictions, where it is important to have very efficient forms of processing. After all, you need to know where the hurricane will make landfall before it hits the coastline. 'Otto Visser helped a lot in developing the practice part of the course. He is a geek like the rest of us, but he is also very good with students in the lab. He deserves to be cowinner of the award.'

Vicarious pride

As it is, Iosup won the award. He was very happy with this recognition for his novel teaching methods and the effect it has on students. But most of all he simply loves to teach. 'I love teaching, but then I'm lucky to love pretty much everything I do. It is very rewarding to see students grow. I really enjoy it when I meet former students and they come and talk to me. A few years ago, I was in Singapore for a conference. I had the pleasure of meeting some students whom I had taught way back in Romania. They had since obtained PhD degrees; I think I may have had something to do with them pursuing academic careers,' he smiles. 'I have this vicarious pride in my students' achievements. I also feel I have received a lot in life myself. Teaching is a way of giving something back.'

Let me entertain you

Gaming is not just part of Dr Alexandru Iosup's teaching, it also plays a role elsewhere in his life. Not only does he develop computer games in his spare time, but in 2011 he was awarded a Veni subsidy for his research into online games with large numbers of players. 'Entertainment is a big part of our lives; it used to be television but we are focusing increasingly on games,' he says. 'Massive multi-player online games require a large and expensive infrastructure. Hence, the games market is dominated by large companies. Although the Dutch are very good at creative start-ups, they could not join this market,' explains Iosup. Cloud computing has come to the rescue, however. 'With cloud computing you only have to use the infrastructure you need, then pay for what you use. The idea is that small companies can now concentrate on their main business, such as game design, and leave the infrastructure and ICT to professionals.' The research does not stop there, however. 'Initially, games were virtual worlds that had to be maintained. In the meantime, the social experience has become so important in gaming, that you need to include it to enhance game play experience, and to be able to compete in the market. And now that there are hundreds of millions of players taking part in the most popular games, there is also the issue of content generation. The same content for every player will no longer do; people would get bored, as somebody else has already played it before them and spoilers abound on the Internet. Players need customized content and you need enormous computational power to do this; it is a whole new type of platform, which we find very appealing to work on.' As with his teaching, Iosup is taking gaming to a whole new level.

Chris Verhoeven, Guido de Croon and Bart Remes

The power of the swarm

Ir. Dr Chris Verhoeven, Dr Guido de Croon and *ir.* Bart Remes all work at the TU Delft Robotics Institute, the institute that brings together Delft robotics research under one roof. They specialise in small robots, which they see huge potential for. 'A swarm of nano robots acting together can do more than they could do acting individually, and often more than one large robot,' says Chris Verhoeven. These opportunities are being examined and tested in the TU Delft Cyber Zoo, the laboratory for flying and walking swarm robots, which opened in 2014.

Imagine... a swarm of nano satellites in space detects an earthquake down below. They alert a swarm of drones closer to the affected area, which fly in to survey the extent of the disaster. Shortly afterwards a team of airborne robots drops off a colony of flying and walking robots that begin an on-the-spot search-and-rescue mission. They scan collapsed buildings to seek out survivors and verify whether the area is safe for the human rescue teams that are now arriving. Does it sound like science fiction? According to researchers at the TU Delft Robotics Institute, robot swarms will be science fact within a few years.

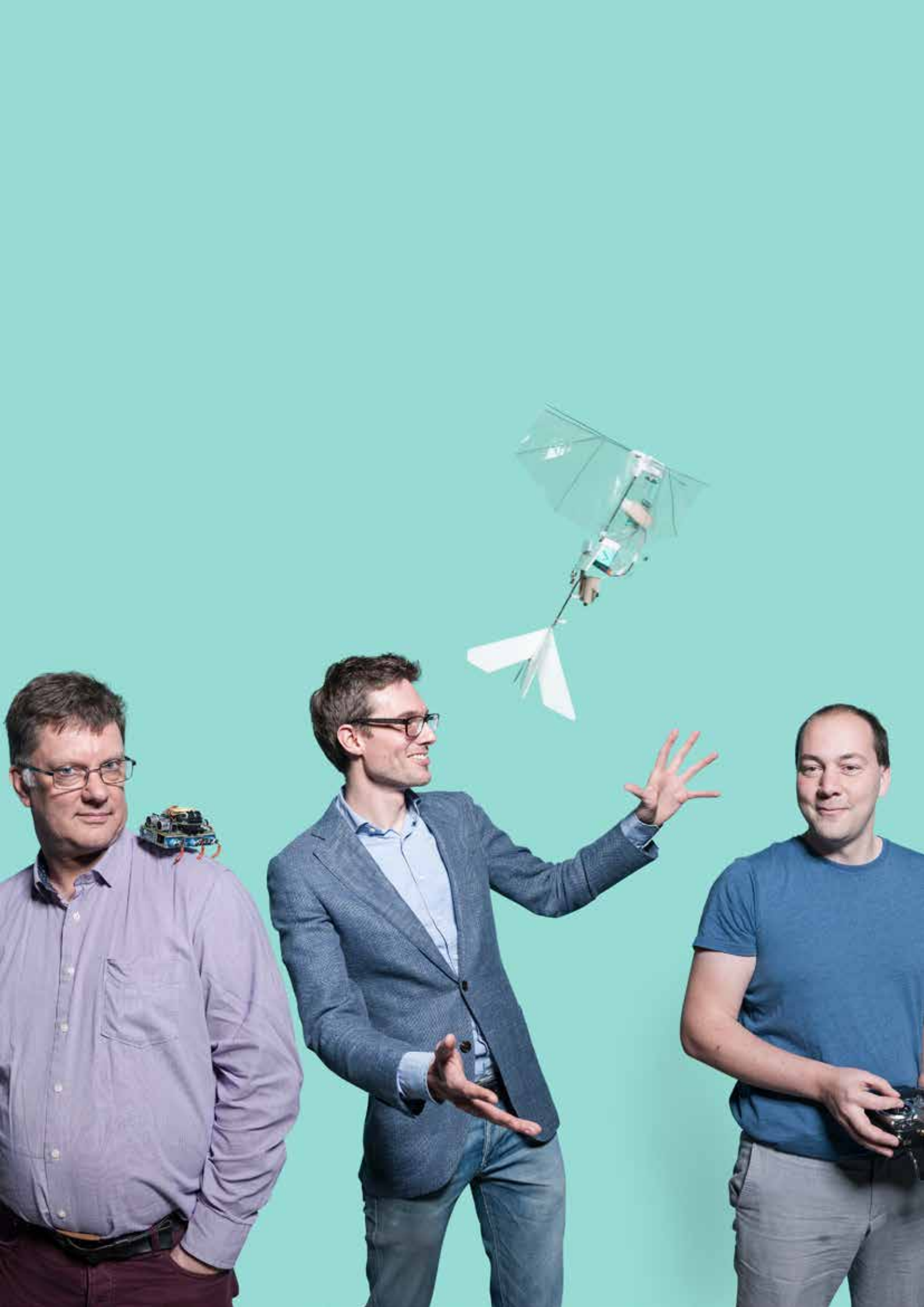
The idea for swarm robots came about around ten years ago during the search for potential applications for the nano satellites in the Delfi programme. As the term 'swarm' suggests, the inspiration came from nature. 'In the animal world, the smaller a species is, the more mutual cooperation there is but the less individual intelligence. And the more stupid you are, the better you can work with others,' says Chris Verhoeven. With progressive miniaturization and recent developments involving smartphones and electric vehicles, robot swarms are now within reach. However, as befits a university, this is something of a foray into unknown territory.

'We are working on tiny robots that weigh only a few grams and have very little computing power,' explains Guido de Croon. 'Nevertheless, we want to use this kind of system to carry out very serious tasks, such as rescue operations. 'If they work together, they can explore a building much faster than a larger robot could, for example.' That's not only because there are so many of them and their size, but also because of their diversity. 'As well as having multiple versions of the same robot, you could also have different types working together,' says Bart Remes. 'You can combine flying robots and walking robots, and fit each of them with their own sensors. That way, one of them can search for obstacles in a building while the other detects whether any gas is present. Just like in an ant colony, there are scouts and workers with their own tasks.'

Verhoeven has another practical example: the fight against drugs. He has a vision of hundreds of robots flying and crawling around our airports in the not-so-distant future. 'In Wageningen they've recently developed an electronic nose', says Verhoeven. 'If we mount that onto our robots, we could have them flying around at Schiphol. Whenever they smell drugs, they will just hover there, circling around. That will alert the crawling robots, which will crawl their way over the pieces of luggage and flag up the suitcase that contains the drugs.'

It is this kind of collaboration – known as ecosystems – that is now being investigated at the Cyber Zoo. 'If you want such a swarm to operate independently, the robots will need to have their own energy supply, for example. That means that they will go off to do their work, but occasionally they'll need to come back to recharge; but they can't all do that at the same time,' explains De Croon. A unique aspect of the Delft research is the autonomy of the systems. 'We want them all to have processors and sensors on board, and we want them all to be able to think for themselves, rather than having a big computer somewhere that does that for them. They need to be able to work with others, but also to find their own way home. We are working hard to develop new algorithms to enable swarm intelligence.'

But for other things they are happy just to use existing expertise. 'We can't do everything ourselves,' says Remes. There are two areas in particular that they leave to other people. Firstly, the sensors. 'For that we are hitching a ride on smartphone technology. Smartphones are getting ever smaller, ever more compact and ever more efficient, with more sensors in them. That's great for us,' says Remes. The second is the battery technology. 'Many car makers have invested money in new battery technology that will also give us a boost. Our flying pocket drone can now fly for around eight minutes. Using another battery, that could



soon be twenty minutes for the same system.'

'We take maximum advantage of the mass market,' says Verhoeven. 'If it's not already being done in industry, we don't do it either. If smartphones don't have a sensor to detect radiation, then that's just bad luck, no matter how much we would like a Geiger counter in our systems.' It's not due to unwillingness or lack of know-how, but a deliberate choice. 'Otherwise that would quickly become a research direction in its own right' explains De Croon. 'The sensors not only need to be compact and energy-efficient, but preferably also mass-produced, so that the price is low.' And that is not the only advantage. 'The quality also improves,' says Verhoeven. 'The penalty for poor performance in consumer goods is very high. If a manufacturer has to recall a car because a sensor fails, it costs an awful lot of money. We don't use cheap stuff, only we don't pay the bill ourselves.'

DelFly

'Above all, you need to cooperate and keep looking to the outside world. It's better to concentrate on what you are good at than try to do everything yourself,' concludes Remes. And concentrating on what they are good at is leading to some remarkable results, it seems. There is the DelFly, the dragonfly-like robot that flies with flapping wings. In 2008, it was the smallest air vehicle in the world to be equipped with a camera and has been listed as such in the Guinness Book of Records since 2010. 'Things have continued to evolve. We fitted the most recent version of the DelFly II with two cameras so it can see depth, just like the human eye. That means that it can also avoid obstacles now. So we've added intelligence to something that already existed.' It's the perfect example

Who are they?

Chris Verhoeven, Guido de Croon and Bart Remes share a passion for small robots. Where does that passion come from?

Chris Verhoeven, of the Faculty of Electrical Engineering, Mathematics and Computer Science is associate professor and theme leader for the swarm theme within the Robotics Institute. 'I do value my engineer's degree; so much so that I put it front of my doctor's degree. I have a background in analogue electronics. I am good at design and electronics design methodology. My natural tendency is to want to know exactly how something works. So if I come across a component in an electric circuit that has been assigned a particular value and I don't know why, I will find out, even if that takes me ten years. Students who learn design theory from me often comment that they are understanding how electronics works for the first time.

Guido de Croon, Faculty of Aerospace Engineering, is assistant professor in the lab. 'I act as a scientific supervisor for PhD students. I have a background in artificial intelligence. In other words, how do you make these small systems so smart that they do what you want them to. For me it all started with computer games. In real-time strategy games, I always thought: this opponent is really stupid, there must be a better way than this. Then I started studying artificial intelligence. Eventually, I figured out my passion lay with the intelligence of robots, specifically robots that interact with the real world.

Bart Remes, Faculty of Aerospace Engineering, is project manager. 'It's my job to make sure that these projects achieve results. What I personally like the most is building the small pieces of hardware. My motivation is making things smaller and smaller. I've been doing it ever since I was a child. Going on holiday with my parents, I wanted to take a toy aeroplane but then there'd be no more room in the car. Ever since then I've been trying to make things smaller. Now when I take the train, I have three drones in my backpack.'

‘We are making the smallest hardware in the world, the smallest automatic pilot in the world, plus the software that makes the system intelligent enough to do anything’

of what TU Delft is good at. ‘Elsewhere in the world they send the camera images back to a ground station where a computer does all the calculations. We do all that on a computer on board the DelFly with limited computing power. All you need are some smart algorithms. But it means that soon they’ll be flying around autonomously in the real world.’

And we’re already well on our way to our next objective: the DelFly will soon be flying through windows and doors too. ‘If we want it to go and explore buildings in the future, avoiding obstacles isn’t going to be enough – it’s going to have to go through the door, or some other hole that’s big enough.’ For that too, smart algorithms are used. ‘We first made the rules ourselves. We had a program of 23 rules,’ explains De Croon. ‘When we say ‘rule’, we mean something like ‘if you are within three meters of an obstacle, you turn’. That works reasonably well, but not quite well enough, so we went back to nature for inspiration. ‘We had the idea of recreating an artificial form of evolution within a computer simulation.’ The results were quite stunning. ‘The simulator came up with a short program of eight rules.’

How does an evolution simulator work exactly? ‘You start with a hundred robot programmes with rules in random order - things like: ‘turn left immediately’. But that is no use if you are right next to a wall, so that rule may not reproduce itself. Once you’ve had the first generation of random individuals, then you take the rules from those that performed the best – the ones that came closest to the window. Then you recombine those and use them when you let the next generation fly around. It’s the survival of the fittest,’ explains De Croon. ‘It was really satisfying to see that over time, the robots really did get better and smarter. In the beginning they’d fly straight into the wall, but later they could dodge an obstacle and finally they flew right through the window.’

Patient

The simplest rules in the simulation led to the best results. Verhoeven knows all about this. ‘We have a small walking robot that actually performs worse as it is given more rules. The larger the repertoire of actions, the greater the chance of things going wrong.’ He looks for the explanation in nature again. ‘An insect’s repertoire of actions is very limited. A beetle can spend hours on his back waving its legs in the air before a leaf brushes up against it or something, which gives it the grip it needs to turn around. Insects are very patient. We have to remove our human impatience from the equation.’ De Croon saw that in the simulation too. ‘Our digital insects preferred to fly round again to get into a better position. That took a little longer than what we humans might have chosen to do, but it resulted in fewer collisions.’

Whether the flying and walking robots really will be used in disaster situations or the fight against drugs or for some other purpose, is still a completely open question. ‘We’re working on fundamental techniques that could be applied in all kinds of situations. You might use a swarm to inspect installations in a factory. In that situation too, they will have to work together, avoid obstacles, and come back to charge their battery. We are currently working on the ecosystems that make all those applications possible,’ says De Croon.

The next phase has already been planned, says Verhoeven. ‘We want to set up a second Cyber Zoo at the Science Centre, but this time one where we allow the weather to come in. If that works, we’ll be able to open the doors and allow them out into the world,’ he grins. He has one concern. ‘Drones should not be banned. We in the Netherlands are the leaders in this field.’ Remes agrees. ‘We are making the smallest hardware in the world, the smallest automatic pilot in the world, plus the software that makes the system intelligent enough to do anything. That will give us a five-year head start on the rest of the world.’ But there’s also more to it than that. Remes: ‘We do our experiments outside; we want our systems to function in the outside world. Normally you have a clean lab environment where everything works perfectly and once you get outside, nothing works any more. We do it the other way around entirely. First we first go outside to see which problems we need to solve in the lab, so that it can really work out there. That’s what makes it special.’

Ewoud de Kok and Siem Kok

Plucking the fruits of online education

If you Google 'sleeping students', your screen will be awash with images of students catching forty winks in lecture halls all over the world. Not because they have all had a late night, but because lectures are not challenging enough, as students Ewoud de Kok and Siem Kok know from experience. Things needed to improve. That is why they founded the FeedbackFruits company in 2012, which makes software for making higher education more interactive. In 2014, ten Dutch universities were using FeedbackFruits. 'Our ambition is to improve the education experience of 100 million students worldwide.'

Many good ideas are conceived in the shower or on a bicycle, and only rarely behind a desk. FeedbackFruits was born at a coffee machine. 'We were all standing around the coffee machine discussing the lecture we had just been to, when the lecturer passed by and everyone fell silent,' explains Ewoud de Kok. 'I thought, what a pity that so much good feedback never finds its way to the lecturer. I then had the idea of a feedback app for students that they could use to send it directly to their lecturers. That's where the name comes from. FeedbackFruits is about the fruits that you pluck from feedback.'

De Kok studied econometrics at the University of Amsterdam. 'I did a project for making the largest computer room CO_2-neutral, and that's what aroused my interest in renewable energy. I then went on to study renewable energy technology in Delft.'

Siem Kok came to Delft via Enschede. 'I did computer science at the Saxion University of Applied Sciences and took a pre-Master's track at University of Twente, but I really wanted to leave Enschede. TU Delft always responded more promptly than anyone else to my questions on how to make the switch.'

Accelerator

Their criticism of teaching is not aimed specifically at TU Delft - on the contrary. 'I think very highly of Delft. What I noticed in Amsterdam is that everyone was prepared to talk about everything, but as soon as it came to doing anything, people simply applied the brakes. In Delft, if you show quality and the will to innovate, then they press the accelerator,' says De Kok. 'People attach less credibility to what you say to them than to what you actually bring to the table.'

They have been supported in particular by Cock Huizer, the manager of the Education Technology department. 'From the very beginning, Cock Huizer has believed in our idea.'

The original idea came from Ewoud De Kok. Siem Kok already had experience with a homework supervision start-up company. The two met and started philosophising on how teaching could be improved. The result was the first feedback app, which was tested at Applied Physics. 'The feedback went directly to the teacher, who then discussed it with his students in the lecture hall. As a result, the lectures were improved, but we would rather have had the discussion on the whys and wherefores on our platform,' says Kok. 'So that was just the first step. We then took a closer look at exactly what aspects of teaching we wanted to improve.'

The answer, more than anything else, was the interactivity. De Kok brings out a sheet. 'Look, students go to their lectures individually, and then study their books, and repeat that until their exams. There is very little interaction between the students themselves in that process. Meanwhile, the lecturer focuses on transferring knowledge during lectures, so it's all one-way traffic.'

Kok had the same experience: 'If you had read up on the material, you were effectively penalised if you then went to the lecture, because you would simply hear the same thing all over again. That is certainly not an enrichment of what you had read, and yet that is what it is supposed to be. You do this three or four times, and then you start to wonder whether you should just attend the lectures, which would save time.'

Challenge

Things could also be much better for the lecturers themselves. 'Just because a particular teacher is the one delivering the

‘It is no fun for students to have to listen to a dull lecture, but it may become more interesting when someone starts talking about the breakthroughs in his field of research’

lecture does not necessarily mean he is the best presenter,’ explains Kok. ‘Sometimes, the tempo is too slow or those listening have already heard what is being said on a previous occasion. After all, lecturers themselves are busy too and may not always have time to confer with one another.’ Part of the solution already exists - the internet. ‘There is so much material available on the internet, and we want to make it available for on-campus teaching. That makes it more enjoyable for the teachers as well. It means they can enter into discussions with their students during lectures, rather than trotting out the same script as they did last year, with five minutes set aside for questions at the end.’ It will also make the teaching more challenging for students, believes Kok. ‘At the moment, you can start learning the week before your exam; if students notice that they don’t gain anything from going to the lectures if they haven’t prepared for them, the element of challenge will return.’
They are referring here to the ‘flipped-classroom model’, a new teaching model where knowledge is transferred via online material. This makes it possible to go into the material in greater depth during contact hours and to include the students in the discussions. ‘We think that some teachers will stand out much more if they are truly involved with the learning process,’ explains De Kok. ‘That is why we believe in the ‘flipped classroom’, where knowledge transfer predominates; this is done before the lecture, so there is then time during the lecture for more interactive teaching methods.’

Share, Live, Dialog

FeedbackFruits is plug-in software that supports the ‘flipped classroom’ model. It can be used in combination with Blackboard or other digital teaching systems. FeedbackFruits contains three important tools: Share, Live, and Dialog. ‘You use ‘Share’ before the lecture,’ explains De Kok. ‘The essence is that you can discuss the material online.’ After all, you cannot ask questions during the lesson, because it is about knowledge about which it is assumed you know. ‘Part of Share is a search engine for online teaching material in which teachers can launch searches. As a result they no longer have to transfer all the knowledge with film clips they have made themselves, but they can use the best of what there is.’
‘Live’ comes into action during the lectures. ‘Lectures still involve a teacher standing in front of a large group of people. ‘Live’ contains interactive lecture tools that the teacher can use to ask the students questions, and vice versa. You can also have students solve problems themselves ‘in the crowd’. This way, the teacher becomes more of a director of these processes, who only intervenes when necessary. After all, you should allow students to discover as much as possible for themselves. Give help only when they really need it,’ says Kok. After the lecture, there is ‘Dialog’, a web page for each course where students can post their questions and comments about the lecture. There is also a Learn tool for students with which they can easily make interactive summaries of all the material. ‘You can also convert these summaries into questions that you can use to test yourself,’ he continues.

Extra work

All well and good, but does it not mean a lot of extra work for teachers? ‘That is something we are bearing in mind during the development stage, because if it takes up too much of the time of the teachers, it is not likely to be adopted very quickly. On the other hand, the point is to improve teaching, not to save teachers time. And although teachers find it difficult at first, they start to appreciate it after a while,’ says De Kok. ‘Sometimes there are still ten people online at midnight, half of whom are teachers.’ Now though, the results speak for themselves. ‘A few months ago, a teacher showed me exam results for a subject he had been teaching the same way for five years, but now for the first time through us,’ recalls Kok. ‘You could see that the number of eights and over had risen strongly, but then so had the number of fours and under. In other words, there were people who did not perform because they did not prepare. That is certainly better for the group as a whole, the fact that students know that it remains challenging if they do prepare.’
Many teachers can derive pleasure from FeedbackFruits, believes De Kok. ‘It offers teachers the opportunity to outsource the things they are not so good at and to concentrate on those areas that motivate them. You have to look at where someone’s strength lies. The way in which a leading researcher teaches is perhaps different to the method used by someone who has teaching in their blood.’ It will be the students more than anyone else who will benefit from this. ‘It is no fun for students to have to listen to a dull lecture, but it may become more interesting when someone who is not so good at presenting starts talking about the breakthroughs in his field of research. I have seen it happen: people who fall asleep until someone asked a question about the professor’s research. I think that is where we should be heading towards in education.’

Urge to innovate

Looking at the rest of society, De Kok finds it remarkable how little ICT is used in teaching. However, TU Delft is at the forefront in that respect. 'The urge to innovate at TU Delft is enormous, including when it comes to teaching. The fact that teaching methods have become outdated can be seen all over the world. TU Delft is one of the forerunners in Europe to be doing something about it.'
This will also open doors for FeedbackFruits. The annual edX conference was held in June 2014 in Delft. edX is a non-profit platform for online education, where MIT and Harvard and others offer courses, known as the Massive Open Online Courses (MOOCs). FeedbackFruits won the Hackathon that was organised on the fringes of the conference with a plug-in that allows courses and content on the platform to have a Creative Commons licence allocated to them more easily. 'This application will be incorporated in edX. Last week, we were in Boston to present our entire system, which they may want to integrate in their MOOCs.'
Kok was not present at the conference in June; he was visiting Stanford University at the time. 'At Stanford they wanted to talk about how we could use our software for feedback on their teaching of MOOCs. They are very interested in the options in relation to things like online comments, discussions, and peer-to-peer feedback,' explains Kok. Conversely, you can use FeedbackFruits to make MOOCs suitable for flipped classroom campus education. 'Why should someone who has invested blood, sweat and tears in making an online course have to give presentations during lectures?' asks De Kok. 'Take people like Arno Smets and Miro Zeman. They are the absolute world leaders when it comes to solar panels. If we give these MOOCs a Creative Commons licence, teachers all over the world will be able to work with this knowledge. They would use edX for that, with FeedbackFruits integrated. That is our vision.' And with the help of TU Delft, he sees a rosy future. 'TU Delft has taken us this far and will take us to where we want to go. Even when we were in Boston, everyone said, 'Oh, you're from Delft.'

Silicon Valley-mentality

Ewoud de Kok and Siem Kok are co-founders of FeedbackFruits. 'We have now been in existence for two-and-a-half years; at 28, I'm the oldest - in other words, we are a young dynamic team. It consists mostly of trainees, graduates, and students who work part-time alongside their studies. There are many students from Delft, but also educationalists from Utrecht and designers from Amsterdam,' says Ewoud de Kok. 'We try to remain radically innovative - what you could call the Silicon Valley mentality. We want to keep innovating and so keep the team highly energetic and dynamic.'
Siem Kok is in charge of the development team. 'We have a large team of developers, and we continue to expand. So one of the things I am involved with is the recruitment of new developers. But we only want the best, so it takes a lot of time,' he admits. 'Every time a new university concludes a contract, we have to integrate the system. We are now trying to automate that process as much as possible. At the same time, we want to roll out as many new options as possible. The users we have now are the early adopters, and you want to include them as quickly as possible in the innovation process. But there are also universities for whom that does not work so well - they prefer an older version. We are therefore now working towards a very stable environment of an older version, which will then be the product version.'
There are now ten universities in the Netherlands that use FeedbackFruits. 'At every university we are recruiting campus ambassadors who are helping to introduce the software. It's going really well. So far, everyone who has embarked on a pilot project has progressed to a full campus licence. 'In other words, we have a success rate of 100 per cent,' says De Kok.

Ernst-Jan Bakker

TU Delft in Brasil: working together on a biobased economy

Ir. Ernst-Jan Bakker is Director of the Brazilian Joint Research Centre of TU Delft and BE-Basic, which was opened in 2012. It was established two years ago in order to intensify cooperation between scientists and academics at TU Delft and in Brazil. The year 2014, for example, saw the launch of three major new research projects and the first doctoral candidates also began their dual-degree programme. 'We have realised a significant rise in the number of joint activities,' says Bakker.

What is the focus of the cooperation in Brazil?

Our main focus is currently the bio-based economy, with bio-energy and biochemistry as key components. It is difficult to get things off the ground if you take up the entire TU Delft portfolio – it is so wide-ranging. This way, it is easier to approach partners in a targeted way and attract projects. The long-term cooperation with Brazil developed over time. Patricia Osseweijer, who is professor of Biotechnology & Society, and Luuk van der Wielen, TU Delft's Distinguished Professor Biobased Economy, have been involved in bilateral projects in Brazil for years. The emphasis on the bio-based economy also relates to the link with BE-Basic. The Joint Research Centre is a 50-50 collaboration between TU Delft and BE-Basic, and BE-Basic is led by professor Van der Wielen. In any case, this focus on bio-based is not a restriction: in principle, we are here for the whole of TU Delft.

So everyone is welcome then?

Definitely, in September the faculty of Aerospace Engineering signed a memorandum of understanding with the Instituto Tecnológico de Aeronáutica. They intend to collaborate on research and education. A major delegation came for talks with their counterparts here, so this is the start of something really great. TU Delft and BE-Basic have also joined a platform working on the development of bio-kerosene for aviation, together with KLM and SkyNRG. As part of that, we are developing various other industry-related projects around kerosene. That also touches on what we were already doing here, especially on biofuels.

You are based at the University of Campinas (UNICAMP). Why there?

Campinas is a great central location for us to do our work, because of the concentration of parties working on the bio-based economy. Of course, that includes the University of Campinas itself, but also other research institutes with which we are cooperating. There is also a lot of bio-based industry in this region. In addition, Campinas is close to São Paulo, which regularly proves useful as an economic centre. For example, we have a good relationship with FAPESP, a funding body run by the state of São Paolo, similar to the NWO in the Netherlands. FAPESP funds R&D projects. So far, FAPESP and BE-Basic have jointly funded ten of these kinds of projects, involving cooperation between Dutch and Brazilian academics and scientists. This year alone, we have secured three new projects, in two of which TU Delft is the coordinating university.

Is it necessary for TU Delft itself to have a presence in Brazil?

Our cooperation with Brazil has been running for a long time, since at least 2000. This involves bilateral relationships between professors in Delft and here in Brazil. However, the problem is the difficulty with upscaling. There is a cultural difference and the academic years in both countries are different. There is also the issue of distance and the fact that everyone has very full agendas. There are limits to what you can achieve when you are 10,000 km away from each other. Contacts are good, but it is difficult to expand on the activities. We are eager to do that, because Brazil is important in our field. Besides, personal relationships matter a lot here in Brazil. This is why we came to the conclusion that we need a local presence in order to achieve expansion. If you look at the portfolio, you can see that it turned out to be true. There has been a significant increase in the number of joint activities.

Why is Brazil important for us?

While the Netherlands are just venturing out into the biobased economy, Brazil has taken it to great heights. They have had bio-ethanol here for forty years: that is an amazing wealth of experience.
Then, there is the scale of the sugarcane

plantations – sugarcane is the raw material used to make bio-ethanol – and the number of factories that process it. The Netherlands has a lot of knowledge in fields such as modern bioprocess technology, synthetic biology, and genomics. Knowledge that is located not just at TU Delft, but also at industrial partners such as DSM and Corbion. Dutch and Brazilian expertise are well-matched, as Brazil has outstanding scientific knowledge in all kinds of areas related to biofuels, such as conversion technology, the emission of greenhouse gases, agricultural productivity and soil conditions. Brazil is also investing heavily in education and research in the fields of bioeconomy and bioenergy, areas in which TU Delft's portfolio is well-filled. That is another excellent match and it creates a lot of opportunities.

What has been achieved in the last two years?

We are now reaching the stage when we are completing the first projects. It's early days yet, but we are achieving results. For example, in the space of two years we have achieved an impressive volume of R&D projects totalling 6.5 million thanks to the cooperation with FAPESP. These are projects between Dutch and Brazilian partners, and not exclusively TU Delft, but we are very well represented. We are involved in three of the last four projects allocated.
It primarily involves the Biotechnology department and Geoscience & Remote Sensing, Professor Ramon Hanssen's department. With remote sensing, you monitor the world from a great height using satellites. You can use it to see how much land is in use and what condition the sugarcane is in, for example. UNICAMP has a good research group in the field of remote sensing as well. They primarily use satellites, whereas other techniques are also used in Delft, such as radar. A doctoral candidate is spending a year here researching how you can gain a better picture by combining satellite and radar. It is great to see how the research groups complement each other so well.

What is the relation between food and fuel production in Brazil?

Here in Brazil, there is a strong synergy between food and fuel production. In any case, only 0.5% of the land surface is being used to grow sugarcane. Brazil also keeps a close eye on it. Brazilian researchers concluded this year that developments in biofuel cultivation actually have a positive impact on food production. Research into soil conditions or knowledge about the water system and about fertilizers, for example. The mechanisation of agriculture is also important. Not long ago, most of the harvesting here was done manually, but mechanisation has now become quite advanced. Unfortunately, the country's population is not equally well fed in all regions. There are some serious problems with poverty, but it is more a problem of

The right man in the right place

Ernst-Jan Bakker spent years working at the Energy Research Centre of the Netherlands (ECN) and TNO. He did an internship in Brazil as a student and he spoke quite good Portuguese with his wife, who is Brazilian. 'We were very happy in the Netherlands, but when this vacancy came up, I started to have itchy feet. It is great that it turned out well: I was appointed in August 2012 and we were here two months later.' His knowledge of Portuguese has proved very important in his position. 'With our academic contacts, you can cope reasonably well with English, but not for day-to-day things. In any case, contacts with the people with whom we work a lot run much more smoothly in their own language. It makes things much easier: the language is important.'

As director, his main focus is on enabling bilateral projects. 'My role involves taking care of funding and bringing together academics. I regularly organise workshops at which Brazilian and Dutch academics meet each other and learn about each other's work. They can then make joint decisions about new research proposals.' To fund these, I have a lot of contact with funding organisations such as BE-Basic and FAPESP. 'For example, it is my job to make sure they put out a call each year on a specific theme. We have been doing that since 2011. These projects also involve postdocs and doctoral candidates going in both directions. It is a wonderful exchange of knowledge and people.'

‘It may be possible to use that pulp and the straw to make fuel, or extremely useful raw materials for the chemicals industry. This enables you to create more value’

distribution than food shortages. So in Brazil, the biofuel production has a clear positive influence on food production.

What can Brazil actually learn from us?

Brazil has years of experience in what we refer to as first-generation biofuels, which involves using sugarcane to make biofuel. The second generation involves using also the waste from sugarcane, not only for biofuel, but possibly also as a raw material for the biochemical industry. Our scientific interaction is primarily in that area. If waste accumulates, it becomes an expense, whereas if you use it as a raw material, you can actually make money out of it. When harvesting sugarcane, you leave the straw and buds behind, and after squeezing out the sugarcane, you are also left with a dry, fibrous pulp. It’s called bagasse, and you can see in the photo. That pulp is now combusted in order to make electricity, which means the biofuel factory also sells power. It may be possible to use that pulp and the straw to make fuel, or extremely useful raw materials for the chemicals industry. This enables you to create more value. Besides, fuel is a bulk market, financially interesting because of the volume, but the margins are very small. If there are developments in the field of natural gas or shale gas, it will be questionable as to whether you can still earn money from biofuels. It is a vulnerable area. However, if you can also devise additional processes that obtain something from the residual flows as well, that improves your business case, which is in everyone’s interest. TU Delft and BE-Basic are very good at that.

What cooperation is there in the field of education?

All sorts of things are happening. With the University of Campina, we are organising dual-degree projects for doctoral candidates. There are now various Brazilian doctoral candidates who can secure their doctoral degree both in Delft and in Brazil. We are now also in the process of bringing a dual-degree student over here from Delft. So far, this is uncharted territory: the requirements everyone sets need to be harmonised, for example in terms of administration, and you need to put in place agreements to support all of that. We are aiming for 25 dual degree doctorates by 2025.

There is also an educational programme, involving a series of separate courses, so far often focusing on the bio-based economy. Although these courses are intended for undergraduates, postgraduates are also welcome. Most of these are intensive courses lasting a week, because we have to fly in professors from Delft. Next February, we are organising a course that will be attended by fifty people, half of them students and the other half professionals eager to continue to develop in their specialist field. There is a lot of interest in this kind of education with an international character and a mixture of academic and industrial lecturers. We can easily deploy industrial lecturers by making use of our partners.

We also contributed to the Massive Open Online Course (MOOC) that TU Delft developed about biotechnology. Because Brazil makes such an excellent case study, we developed three modules for the MOOC in cooperation with UNICAMP. One module is about the history of bio-ethanol in Brazil and there is one about how bio-ethanol is produced. The third module is about how sustainable Brazilian biofuel is at the moment, and includes a brief reference to the food versus fuel debate, but we also look at such subjects as greenhouse gas emissions and socio-economic sustainability, including such issues as working conditions.

In recent years, Brazil has become a fashionable place to do business...

When Europe entered the economic crisis, a lot of countries started looking for new markets. Brazil has a massive internal market, with a population of almost 200 million. When things started going wrong in the rest of the world, the economy was doing quite well here. The middle classes in Brazil started to thrive and increasingly began to consume. That proved to be an excellent engine for industry. Brazil was completely inundated by people who want to engage with the country. But if I look around me, I think that we are one of the few who approach things in this way. With a permanent base here, a strong focus and independently developed activities. I think that is unique. There are very few universities doing things like this. That is really necessary. If you just come here wandering in for a coffee and return home again, things will soon be back to business as usual.

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