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Teaching in pace with the times

Digitalisation is fundamentally changing the working world, and also presents vocational colleges with new challenges. Educators in the didactics of technology at the TU Darmstadt are supporting them on their path into the future.

Von Jutta Witte

Enter the light, modern room, and you walk into an Industry 4.0 scenario. Eight modules are available here for the new way of teaching that is „in pace with the times“, including a digitally controlled high-bay warehouse, robot assembly station, automated CNC milling machine and a station for the camera-operated quality control – all the usual components that are linked together in a factory. An intelligent sample piece goes through production, bringing the information required for its manufacture with it. Pupils and teachers are just discussing how processes could be further improved.

„Participants should make the change in technology and the working world their own change.“

Prof. Ralf Tenberg with an iPad that belongs to a Tec2screen.

Photo: Katrin Binner

It is a „Smart factory“ on a scale of 1:1 that went into operation at the Philipp Matthäus Hahn School (PMHS) in Balingen in Germany at the start of the 2017/2018 academic year. It is part of the Learning factory 4.0, which also includes a mechatronics laboratory where students learn the principles of programmed controls and are able to simulate automatic processes on a tablet. The vocational college centre on the Schwäbische Alb has bade farewell to „as you were“ learning. Experts in the didactics of technology education from the TU Darmstadt are supporting the school in this as part of the project „Digitalisation and vocational training“.

„We wanted to set a starting point for a new way of learning and the co-operation with the training facilities,“ explain Heiko Käppel and Markus Häusel. The two engineers and vocational college lecturers are furthering learning factory and project at the PMHS. They want to familiarise the next generation with the digital working world, with its fast innovations and increasingly short half-life periods for knowledge – without ditching the strong principles acquired in analogue learning. Professor Ralf Tenberg, head of the working area of the Didactics of Technology Education, describes what awaits young people in technical professions today thus: „The role of the specialist is moving away from the centre of the systems behind them.“ They were facing highly complex technology, and were increasingly becoming knowledge workers. Access to machinery would become less and less directly operative, and instead increasingly sensory, analytical and diagnostic. „We are practically training into a vision,“ says the expert.

In the thriving region of the PMHS, companies are increasingly opting for full automation. They need people with sound technical knowledge, but also with methodical, personnel and social expertise. No company can afford familiarisation times of up to six months any more, as the qualified mechatronics engineer Mikel Weisser, who is currently training as a certified automation technician, knows only too well. As part of his dual training, the 22-year-old has hardly had any contact with the subject of „Industry 4.0“. But he and his fellow students appreciate the high-calibre facilities of the PMHS that much more. The practical experience that they are able to gain here through „learning by doing“ in an industry setting provides them with a tremendous advantage later on in their professional careers.

But the equipment alone is not enough. Without new educational concepts and changes in the organisation of the school, nothing will happen. „We need to teach differently,“ say the two project supporters. Which is why they are trying not only to mesh theory and practice more successfully in a holistic approach, but also to teach the basic knowledge, simulations and implementation of the course content, in an integrated basis on machines and systems. The aim is also

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Photot: Christoph Jäckle

Learning factory at vocational college – new learning processes are replacing old teaching formats.

to improve the interplay between students, teachers and trainers by means of a collaborative digital platform. So a „genuine“ transfer of knowledge would be encouraged between the school and companies on the one hand, but also amongst the companies on the other.

It is an ambitious project, and one that, with regard to uncertainties and provisos in particular, also requires presentations and coaching amongst the staff. As part of the scientific backing, Professor Ralf Tenberg and Dr. Detlef Messerschmidt are supporting the school on every relevant level. The Darmstadt experts are supporting the further development of the didactic-methodical concepts for lessons, encouraging team-building amongst the staff, developing new forms of co-operation between the learning venues, and also guiding the necessary further development of the school organisation. „What we're doing here is classic change management,“ explains Tenberg. „And our aim is that the participants should make the change in technology and the working world their own change.“

The well-founded analysis and evaluation by the scientists secure a sustainable design that will continue long after the end of the project. The PMHS is currently well on track, which is evident just from a look at the learning field of „Process optimisation“. Until now, 16 students were „taught“ simultaneously on an old five-axle robot, learning basic programming steps at the most, but now the whole world of robotics is opened up to the budding industrial mechanics. On two modules at the learning factory, or on the digital twin of the machines, they can act out or simulate specific problems, develop solutions for process optimisation and back-couple them perspectively to their training organisations via the collaborative platform „Moodle“.

„With this scientific support, this could lead to a lighthouse project for school development,“ believe Käppel and Häusel. Ralf Tenberg has his sights set beyond the vocational college landscape. Although technology education overall has become a recognised field of science since its launch at the TU Darmstadt nine years ago in line with digital transformation and the debate surrounding Industry 4.0, the expert believes there is still a tremendous need for action at general schools. His vision: technology as a compulsory subject from nursery school to every area of training.

The author is a science journalist with a doctorate in history.

The Didactics of technology education at the TU Darmstadt
The working area of Didactics in Technology Education Human Sciences carries out publicly funded research and development projects. It is currently supporting the projects „Digitalisation in vocational training“ by the land Baden-Württemberg and „Digitalisation in vocational training“ by the land Hesse; the pilot project „Sustainability audits in vocational training“, by the Federal Institute of Vocational Training, and the land Hesse's school trial „Vocational college at the transition in training“. The working area has a new learning and teaching lab that meshes theory and practice, and provides trainee vocational teaching staff with an innovative learning environment.

Philipp Matthäus Hahn School
The Philipp Matthäus Hahn School (PMHS) has around 2500 pupils, and is the commercial school centre of the Zollernalbkreis. The 2016/2017 school year saw the launch of one of 16 „Learning factories 4.0“ in the land. They are supported by the land Baden-Württemberg along with the current project „Digitalisation in vocational training“. It involves two pilot classes of the PMHS – trainee mechanics in their second training year, and future industrial mechanics in the third year of their training.

Foams, gels, thin films

Regine von Klitzing's research objects are neither clearly liquid nor clearly solid, but a mixture of the two. The physics professor and her team want to develop functional coatings and „switchable" foams from this „soft material".

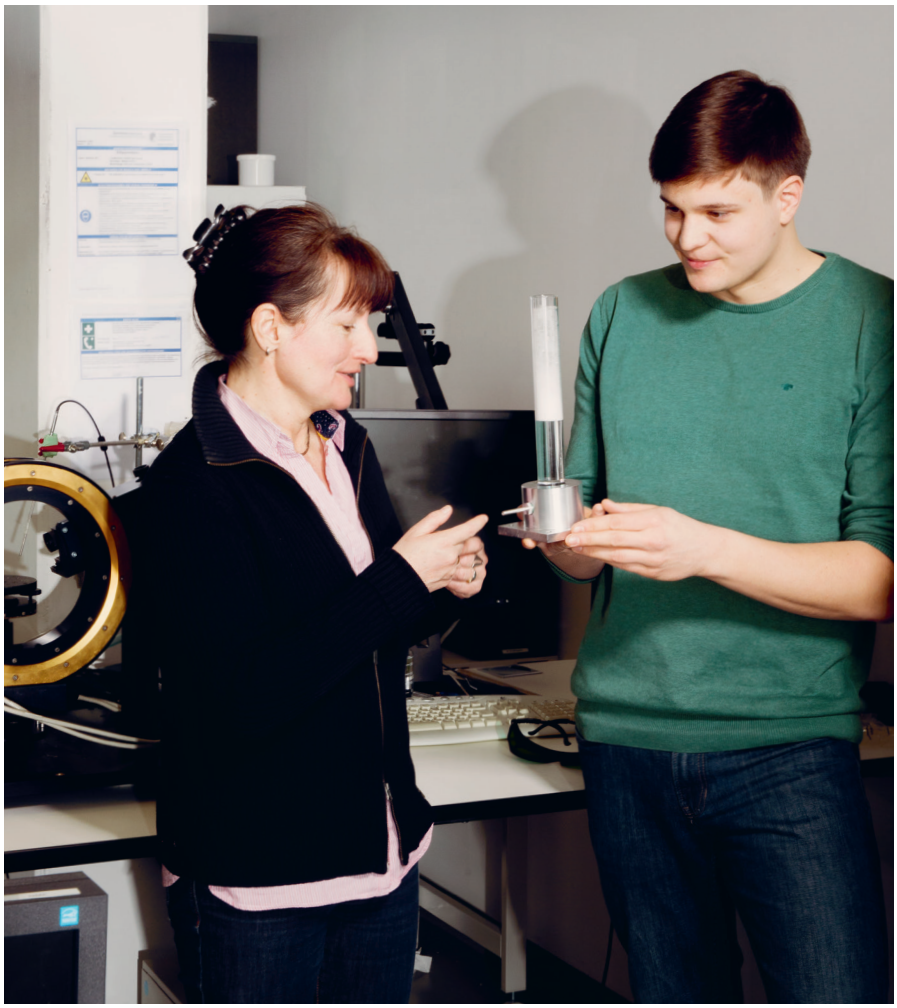

Photo: Katrin Binner

Regine v. Klitzing and colleague Matthias Kühnhammer, want to investigate the structures in makroscopic foams by means of neutron scattering. Therefore they develop a complex specimen environment.

By Christian Meier

A cappuccino tastes best if it's made with soft, creamy milk froth. It's difficult to achieve similar success with oat or almond milk. Size is one reason for this: tiny protein particles stabilise the foam and provide fine air bubbles. Cappuccino froth illustrates how something that is only a few nanometres in size (millionths of a millimetre) can change the macrocosm that is perceived by an individual. For Professor Regine von Klitzing, researching these bridges between large and small is a tremendous challenge. And although her team at the Institute for Condensed Matter Physics at the TU Darmstadt is not dealing with milk froth, the material class to which the tasty topping belongs is called „soft material". By this, physicists mean a kind of mixed aggregate state between „solid" and „liquid". This includes gels such as blancmange, elastic plastics such as rubber and, as already mentioned, foams.

It isn't only the beguiling taste of some representatives that makes soft material so interesting. Technology should also benefit, for instance with intelligent surface coatings that act as sensors or that change their shape and become active themselves. Von Klitzing's team wants to thoroughly research the complex world of soft material, including creating brand new materials with specific functions and properties. Von Klitzing has decades of experience in this field. Her team combines expertise with comprehensive experimental facilities. „We cover the entire range from the synthesis of new materials to their characterisation," the physicist sums up one strength.

The researchers see a potential for intelligent surfaces in certain nanogels. They consist of a spherical net of chain-like molecules called polymers that dissolve in water. When warm, the polymers do not dissolve so well in water. The tiny spheres push the wetness out. The consequence: they shrink. And because this occurs at a specific temperature depending on the particular material, the nanogel can be „switched" between large and small. Gels also exist that respond to other signals. „Some can be switched with the pH values, others by moisture or magnetic fields," explains von Klitzing. The team tests gels made from various polymers and adds nanoparticles to them. For instance, gel particles to which gold nanoparticles have been added can be „switched over" with a focused light beam.

One other focus of von Klitzing's research are very thin liquid films that are enclosed between solid surfaces or air. „We are researching the interactions in these films with certain additives such as molecules or particles, which is one example of how our re-

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search has an interdisciplinary base on the borderline between physics and chemistry," she says. One aim is to understand what stabilises thin films. This knowledge is important for the cosmetics, pharmaceutical and food industries, all of which often use foams, emulsions and suspensions. Emulsions are a mixture of two non-miscible liquids and consisting of fine droplets of one of the two components in the other, for instance fat droplets in water. With suspensions, solid particles float in a liquid. Foams are created by has bubbles in a liquid. In all three cases, thin liquid films separate the particles, bubbles or droplets.

The particles, droplets or bubbles tend to combine in order to minimise the energy of the system. In certain emulsions or foams, this is prevented by what is known as the Pickering effect: if particles settle on the surface of the bubbles or droplets, they cannot combine to form a bubble or droplet. „We use environment-sensitive particular such as nanogels to switch the stability of the foams," says von Klitzing.

The team uses neutron scattering to study the microscopic properties of these „switchable" foams. A new neutron source in Lund in Sweden, the European Spallation Source (ESS), provides more detailed insights than any other existing ones. Von Klitzing's co-worker Matthias Kühnhammer is involved in the development of a new kind of flexible sample environment for the ESS. It will make it possible to investigate the samples far more quickly with the very highly intensive neutron ray there. „Our holder should therefore allow the quickest possible sample change," says Kühnhammer. To this end, the device contains a number of cylinders that can be pushed around like a magazine in order to measure the next sample. The Darmstadt researchers are collaborating on the project that is funded by the Federal Research Ministry for Education and Research (BMBF) with the University of Bielefeld and TU Munich.

The researchers do not only use particles to stabilise foams. For instance, they apply surfactants to the boundary surfaces between liquids, longish molecules with their ends in one or other of the liquids. Added polymers bring the surfactants closer together, which increases their effects and therefore stabilises the liquid film. Another stabiliser is based on the physical law of maximum entropy. This requires systems to strive for a secondary state; in a sense, to seek freedom of movement. Thread-shaped polymers that are attached to the surfaces of particles would be inhibited if they came too close to each other, so they keep their distance in order to maximise entropy. The film between them remains stable.

„We try to switch the stability of foams using environment-sensitive nanogels."

In order to understand these and other mechanisms, the researchers use various measuring methods, such as atomic force microscopy or neutron scattering, to investigate their foams and gels. They have their mechanical properties, electrical charge or response to pressure in their sight.

And who knows: maybe in ten years' time the barista will be asking how stable and foam you want your cappuccino froth to be on a scale of one to ten – and set the coffee machine accordingly.

The author is a science journalist and Doctor of Physics.

Information

The „Flexiprob" project in which Regine von Klitzing's team investigates foams and nanogels is part of the BMBF funding programme „Researching condensed materials with large facilities 2016-2019". The scientists at Darmstadt are developing a flexible samples environment in co-operation with the University of Bielefeld (Prof. Thomas Hellweg) and the TU Munich (Prof. Peter Müller-Buschbaum).

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Hope in the battle against common diseases

A team led by biochemistry professor Felix Hausch is working on substances that offer a new approach to treat three widespread diseases: depression, chronic pain and obesity. Initial studies are highly promising, but there's still some way to go until the drug is ready for the market.

By Uta Neubauer

In Germany, around four million people suffer from depression. And according to a study by the Deutsche Schmerzgesellschaft, the German Pain Society, as many as eight to 16 million people are affected by chronic pain. Nor is the situation any better when it comes to our weight: around one in six of us is obese. The situation is even worse in other countries. So if one single drug were available that would help with all three problems, it would be an unparalleled source of revenue.

That a wonder drug such as this does not have to remain an audacious vision quickly becomes clear in a conversation with the biochemist Felix Hausch, Professor for Structure-Based Drug Discovery at the TU Darmstadt since October 2016. Our physiology contains a protein molecule called FKBP51, he explains, and this protein plays a significant role in all three of the common illnesses named above: „We know from human-genetic studies that people who produce too much of this protein as the result of a gene variant are more prone to depression." Animal studies have also shown that FKBP51 plays a role in chronic pain. Energy metabolism is also influenced by the protein: muscles produce more FKBP51 if an individual lives on a high-fat diet. This reduces the absorption of glucose, and so can promote obesity and diabetes.

Thirteen years ago, when he was still at the Max Planck Institute for Psychiatry in Munich, Hausch already recognised in FKBP51 a potential target for the development of medicines. If the protein is blocked, then the tendency to depression, obesity and chronic pain should decline. But there was one problem: the target protein has a number of close relatives that look similar but have different functions. So a substance that inhibits FKBP51 will also bind other proteins in our body, which can have dramatic side effects.

"We still need to improve a few molecular properties."

The breakthrough came five years ago. By serendipity, Hausch and his colleagues discovered that their target protein can changes its molecular structure. „So suddenly a pocket opens, and the protein looks different." The close relatives do not do this. This paved the way for the development of inhibitors that bind selectively to FKBP51.

As the starting point, the researchers selected Tacrolimus, an approved pharmaceutical substance that is obtained from bacteria and that is known to bind to FKBP51 and other members of this protein family. Tacrolimus is used after organ transplants, for instance, in order to suppress the body's defence reaction. Hausch and his team changed the substance chemically so that it no longer influenced the immune system. Other modifications led to Tacrolimus derivatives that are even better at binding to FKBP51, and above all in a selective manner.

Now the scientists are focusing on two representatives of the new substance class, called SAFit1 and SAFit2. SAFit2 is a candidate in the battle against depression and chronic pain. The molecule passes the blood/brain barrier so that it can reach the control centre for these two diseases. SAFit1, the precursor of SAFit2, does not reach the brain, and was initially considered less promising. However, Hausch explains, this substance is currently undergoing a renaissance. He believes it may possibly be used to fight obesity. What was a disadvantage has now turned out to be a benefit, because the drug is desired to work in fatand muscle tissue rather than the brain.

Initial studies in mice were promising and had no side effects. The concept is supported by studies in mice where FKBP51 production has been entirely switched off genetically: they survived for a similar period of time, moved around the same and ate just as much as their non-manipulated littermates. So the question now is: why do we need this protein? „It must have played a role in evolution," believes Hausch. In times when food supplies fluctuated, fatty deposits were life-saving energy reserves. Likewise, as sensitivity to pain was essential for survival in primitive times, nature presumably accepted the chronification of pain. Incidentally, the inhibition of FKBP51 only counteracted chronic pain in animal trials, but did not affect the acute perception of pain. „This is crucial," emphasises Hausch, „as otherwise we would, for instance, burn our hands on a hot plate."

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Small molecule, large effect: Prof. Hausch inspecting a model for new substances against pain, obesity and depression.

Photo: Katrin Binner

Current results are promising, but the further development of the substance is by no means trivial. SAFit2 can pass the blood/brain barrier, but only to a small degree. Reducing the size of the molecule could increase brain penetration. Nor is the selectivity as good and broad as it should be. „We still need to improve a few molecular properties," says Hausch. It will probably take some time until the substance is ready for the market, especially as development costs are growing exponentially. For instance, the clinical tests on thousands of volunteers – a prerequisite for the approval of any new drug – are extremely expensive. As a university is not the right setting for these studies, the biochemistry professor is already considering starting a company. He thinks this could be up and running in about eighteen months' time.

The spin-off will probably start with a substance for obesity. If it is possible to optimise brain penetration, then the development of an analgesic would be feasible. Antidepressants are at the bottom of the list. Why: Obesity and pain responses are easy to identify in animal testing. „You can measure the BMI in mice, but how are you going to tell if they're depressed?" asks Hausch. He could imagine the new drug being tested directly on depressed individuals once it has been approved for use as a drug in chronic pain. However, that could take years, and Hausch is well aware that success is by no means guaranteed: „The three diseases that we are occupied with are extremely heterogeneous when it comes to the causes. So developing the substance is not unlike a bet." But then, at least it is a bet that the researchers in Darmstadt have a good chance of winning.

The author is a science journalist with a doctorate in chemistry.

New substances from bacteria

In the EU project Tacrodrugs, scientists in Germany, Spain, Portugal and Norway are researching new substances for use against chronic pain and depression that are derived from the natural substance Tacrolimus. One of the aims is to develop biotechnical methods for manufacturing the substances. Bacteria of the class streptomyces are being used as the production strain. Biochemistry professor Felix Hausch of the TU Darmstadt is receiving funding of € 250,000 for this work. His team is tasked with the prediction of suitable molecular structures and with checking the bacterially produced substances. The Tacrodrugs project started in January 2017 and is scheduled to run for three years.

Current publication

Georgia Balsevich et al., Nat Commun., 2017, 8(1):1725, DOI: 10.1038/s41467-017-01783-y

Deep knowledge of water quality

Desalinated seawater can easily be stored underground. However, toxic by-products occur during infiltration. And these are something Professor Christoph Schüth and his team are taking a closer look at. Their aim: to have the best-quality drinking water for arid areas.

By Silke Paradowski

Israel has declared war against drought. Five desalination plants generate around 600 million cubic metres of fresh water every year, which is about 70 percent of the consumption required by private households. Because the vast plants cannot be regulated flexibly, in times of lower demand and when the supply lines are being worked on, the country has too much of the precious wet stuff. „They need intermediate storage capacity," says Christoph Schüth, Professor of Hydrogeology at the TU Darmstadt. The water is fed into porous layers in the subsurface known as aquifers, and stays there until it is needed. This has one disadvantage: the desalinated water is chlorinated. If it seeps through the soil, the chlorine reacts with organic substances in the soil and toxic compounds such as chloroform are formed.

Photo: Katrin Binner

Prof. Schüth, Dr. Sakaguchi-Söder and doctoral candidate Abrha (l. to r.) examining toxic substances in water.

In the German-Israeli joint project „MAR-DSW", Schüth, Dr. Kaori Sakaguchi-Söder and doctoral candidate Behane Abrha want to find out what happens to these trihalomethanes in the water. They do this using stable isotope analysis, a method which Sakaguchi-Söder has developed further in her doctoral thesis and customised for the analyses in Israel. „This method is a speciality of the TU, and it enables us to establish the isotopic composition of all elements that form the trihalomethanes," she explains. Water samples are taken from various points of the aquifer and analyzed in a gas chromatograph that „blows up" the molecules in it. The researchers can then examine the isotopic composition of the fragments. One of the reasons this is significant is that in the breakdown of the harmful substances, the microbes preferentially degrade lighter isotopes. If the sample contains predominantly heavy isotopes, then this means that the breakdown of the harmful by-products is quite advanced. „The analysis of the isotopes can be used to conclude on how fast and to what extend the substance has broken down," explains Schüth.

In order to correctly interpret the obtained data, the team also simulates the underground microbiological breakdown in the laboratory. Halfway through the research project, „the method is ready to be used," announces Sakaguchi-Söder. Samples will soon be taken in Israel that will then be analysed in Darmstadt. „The data will be incorporated in a hydrogeological site model," says Schüth.

The examination method, which was developed at the TU, could be used anywhere in the world where water is stored in aquifers, he adds. The formation of trihalomethanes may differ depending on the soil type, but thanks to MAR-DSW, science and the water industry understand the basic processes that occur during the infiltration of the water. „In order to respond to the increasing shortage in water with desalination, it is critical that artificial groundwater recharge can be established as a safe and sustainable method," he continues. „And we are doing our bit to help with this."

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Project and partners

The joint project „Artificial groundwater enrichment as a sustainable solution for the storage of desalinated seawater" (MAR-DSW) is sponsored as part of the German-Israeli co-operation in water technology research by the Federal Ministry of Education and Research (BMBF) and by the Israeli Ministry of Science and Technology (MOST) (funding code 02WIL1386, term 2016 until 2019). The amount is 250,000 euros. The Israeli research partners are Ben-Gurion University, the Volcani Center of the Agricultural Research Organization and the water supplier Mekorot.

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