Tedx Talk IUBH

Breakthrough is a bold word for a sudden change after a long struggle, usually in scientific work – and I am still attending school.
Since my hobbies involve tinkering with electronics, coding, and building electronic devices among more common things like swimming, climbing and drumming or hanging out with my friends, I have had the opportunity in recent years to present projects I have been working on at different competitions in the field of Science, Technology, Engineering and Math, or STEM – the equivalent to the German abbreviation for MINT.

In the projects I have done so far I experienced several breakthroughs – on different layers and with different outcome: Concerning the conference's topic I would like to focus first upon changes in everyday life that could qualify as a breakthrough in retrospective. Second I will then focus on systemising the *different kind* of experiences with breakthroughs I had in projects I did.

Looking back some years, my family was living in Berlin and I was attending primary school in third class, when my parents started to look for a secondary school with a focus on natural sciences, because I already showed a growing interest in this topic.
We visited several schools' during their open days – and in one secondary school some girls from the 7th class showed Robots they have build and programmed to do a little stage performance together with their human masters.
I was absolutely fascinated by this and instantly wanted to attend this specific school to start building and programming robots immediately! The huge disappointment was, that robotic courses are starting with class 7 earliest – meaning I would have to wait another three years! My emotions went up and down, I was totally disappointed, angry, and impatient as well – I simply could not accept having to wait so long for something that is absolutely fascinating me. (I still seem to have this attitude).
A few months later on Christmas, my family had a big surprise for me: I was given a robotic construction kit, just like the ones they had at school.
So I started building the models from the construction manual, trained myself the graphical programming interface – and soon thereafter something had to change as well.
After a few months I build my own models – first a little machine than can draw geometric shapes:
Here's a little video of the plotter in action…
In 4th class I used the same basis for the next model, but this time it scans objects – it is a very simple version of a 3d scanner. It moves a probe downwards until it hits an obstacle and counts the steps necessary – and does this over a certain area. The principle is rather simple, but it was nearly impossible to build with the included sensors, so that the error in measurement grew with every single one – no calibration during the process was possible, because the number of sensors that could be connected was limited.

This pattern continued over the next years and I realized I needed to extend the possibilities of the robotics kit I was working with – so I was searching for ways to build own sensors and attach more electronics to the little computer inside the programmable brick.
I am fascinated by the visual effects you could do with LEDs, especially the cubes made from them. So one day I started building one my self – it is this 5 by 5 by 5 LED cube. I chose to use 5 LEDs, because a matrix of 5 by 5 pixel is the minimum you need to display

letters. And one funny aspect I really like it that the design is cheating in a funny way: Instead of addressing every single LED in the cube (you would need 125 lines that can be switched on and off independently) you simply do this by layers: If switched fast enough, the human eye is too slow to notice that only one of the five layers is switched on at a time. So you only need 5 layers with 25 individually switchable LEDs and 5 by 5 by 5 equals 30, not 125...

Concerning the sensors I found an electronic kit on the internet that flashes a little LED in sync with your pulse. My parents ordered it for me and I hooked it up to the programmable brick to experiment with some kind of biofeedback. Because I really like to travel, experience nature and we had moved to Duisburg, so I can only rarely see my old friends, I had the idea to combine that sensor with Google Streetview – so at least we could use this technology to walk or jog along the same routes, real and virtual. Streetview allows you to explore distant places visually – all you need to do is to press a button to move on and walk a lonely road or a busy street. I used a motor from the robotic kit to hit the cursor-up key after a few heartbeats and build a little case for the circuitry. When you move in from of your computer, the exercise makes your heart go faster, which, in return makes the motor press the button faster – and you move inside streetview correspondingly to the exercise and your body feedback.
I was awarded from Google for this project, because the broader idea is that people could visit foreign places, become fascinated with the nature and hopefully develop interest other cultures, too, leading to a greater understanding between humans.

But the more I worked with the robotic kit, the more I got aware of its limitations – it was time for a change again, just adding sensors did not help anymore.
So when I was 13 I started building an eye tracker, because vision and robotics always fascinated me. I wanted to build a wheelchair that can be controlled by eye moments alone.
I was inspired when I came along the story of a graffiti artist, TEMPTone, who sufferes from ALS. He was locked inside his body for 7 years, before his friends build him an eye tracker that allows him to do art again – painting virtually, only using his eyes.
I did this project with a fellow student, Paul, and this time I used a completely different and far more sophisticated hardware – a proper microcontroller and a single board linux computer. Oh, and a webcam, where I modified the electronics on the camera board.

Looking back at these 4 years, some patters – you can call them breakthroughs, too– are noticeable :

Not having to wait for three years before school curricula finally and graciously allow you to do what you are burning for – that was definitely a big breakthrough and life changing event, even though I was very little at the time!

The smaller changes – or at first barely noticeable breakthroughs – dealt with the possibilities and inherent limits of the technic and robotic systems I worked with: From rebuilding models by the book, inventing own ones, expanding the sensors with ones I developed myself, biofeedback to building an LED cube with it – these were all small transitions or barely noticeable breakthroughs in the course of everyday life.

By continued progress I became more and more aware of the limitations – and as soon as a certain frustration threshold was reached, I tried to get around the limiting factors.

One other huge impact was taking part in the STEM competitions. Especially Jugend forscht is absolutely thrilling – the atmosphere is very encouraging, both from other participants and the jury: we don't really compete against each other there, it is more a meeting of like minded people and it is always fascinating to see the cool ideas, theories and inventions the other students come up with. It is highly addictive – you want more and more of it…

So far, this is a first systematization of (everyday) breakthroughs I experienced in self-development – but there is a different scope to breakthroughs as well – like a cross section with the ones discussed so far being longitudinal.

I will discuss **4 different kinds** of breakthroughs on the basis of my last project, the eye-controlled wheelchair I did with a fellow student, Paul:

There is of course **the big breakthrough** – from one instant to the next there is a sudden insight, like a flash of light, and you know that something has changed:

After the electronics were developed – we modified an off-the-shelf webcam – I was trying to write the code to extract the pupil's position within the video frames. I had different filters running on the picture – in code, that is basically just a huge table of numbers and you apply different kinds of math to it. But first of all I just could not narrow the visual information down to the pupil only. Late in the night, without my parents knowing about it, I secretly continued to work on the project – and with a few tweaks I was able to print out the coordinates of the pupil. It was this specific moment that I knew, I made it – it is possible to build an eye tracker by yourself and use it to navigate a wheelchair or any other platform.
As soon as I got the coordinates, the rest of the path seemed clear: I just needed to check if these coordinates are within certain regions to distinguish between commands like drive forward, turn left etc. All I needed to do was just switch on the motors accordingly, probably add some obstacle detection circuitry – and I would have had the whole project ready.
This flash of insight into problem solving is something very fundamental, it is discovering knowledge – but it cannot be forced. Sometimes a shift of perspective helps or a time-out. In our western culture we have the famous story of Archimedes, who was given the task to find out if a present given to the kind was made of pure gold – or just beaten gold – without destroying it. Archimedes found the solution while taking a bath and ran to the kind immediately – exclaiming "Heureka". A big breakthrough at the time, he solved a mathematical mystery and will be remembered for this forever (the Archimedes Principle). But there is an alternative version of the story – let me show you a short excerpt from the movie PI. My parents have shown this scene to me a few years ago, because it is fascinating to watch and think about it. It is the discussion between a young mathematician striving for a solution he cannot grasp and his old and wise math teacher.

This is the essence of the scene – the point of the story is, you cannot force upon a breakthrough – and in the longer run, it might be just the starting point of further developments.

The breakthrough I experienced was the insight that I developed a working principle, a proof of concept. It was amazing and flashy; it really was a <u>break</u>through.
Of course, there is a but – and it was bigger than I first imagined. It was a very long way from here to the wheelchair we presented at the Jugend forscht science fair – and a really *lived experience* that understanding or realising a working principle is just not enough – you have to build upon it and continue working on the subject. Unfortunately school education as I have experienced it so far stops here: we do not go beyond this.

It is a **different kind of breakthrough** to transform an insight into something that actually works, mastering all the little throwbacks and problems – because there is always the devil in the details…
This kind of breakthrough takes much more time and it is a very slow and sometimes really annoying process. The change is not as abrupt since you can see your project's progress. But if you look back and reflect upon the project, you realise again how much energy and passion went into it. One very good way to do this (even if I do not like it that much, I must admit) is to write about it.

This is the **third kind of breakthrough** – to document your work to make it comprehensible for others so that they again can draw their own conclusions from it, benefit, add ideas and distribute knowledge further.
It is even more annoying than developing a working prototype from an insight – but it helps to review the own work, sort different approached used and get it into a reference that can be viewed upon in total, like a narration.

Apart from changes that deal with the work and progress of your own work there can be additional breakthroughs on a biographical level – like the ones I started with:

I know for fact that getting the robotic kit and winning first prize on the national level of Jugend forscht are life changing events and breakthroughs. Especially with Jugend forscht it is like an invisible door has been opened last summer – I was able to take part in scientific events that I otherwise cold not have attended at all. It is a little bit like a forecast into a future that could be – and a special training and assistance from Jugend forscht and the cooperating parters to support me and others in it.
It is a little bit like magic – similar to discovering or inventing things – entering an unkown territory, our future.