port 2

analog port 1

USB

w-esp

GPIO

Geert Roumen

B2.2

introduction

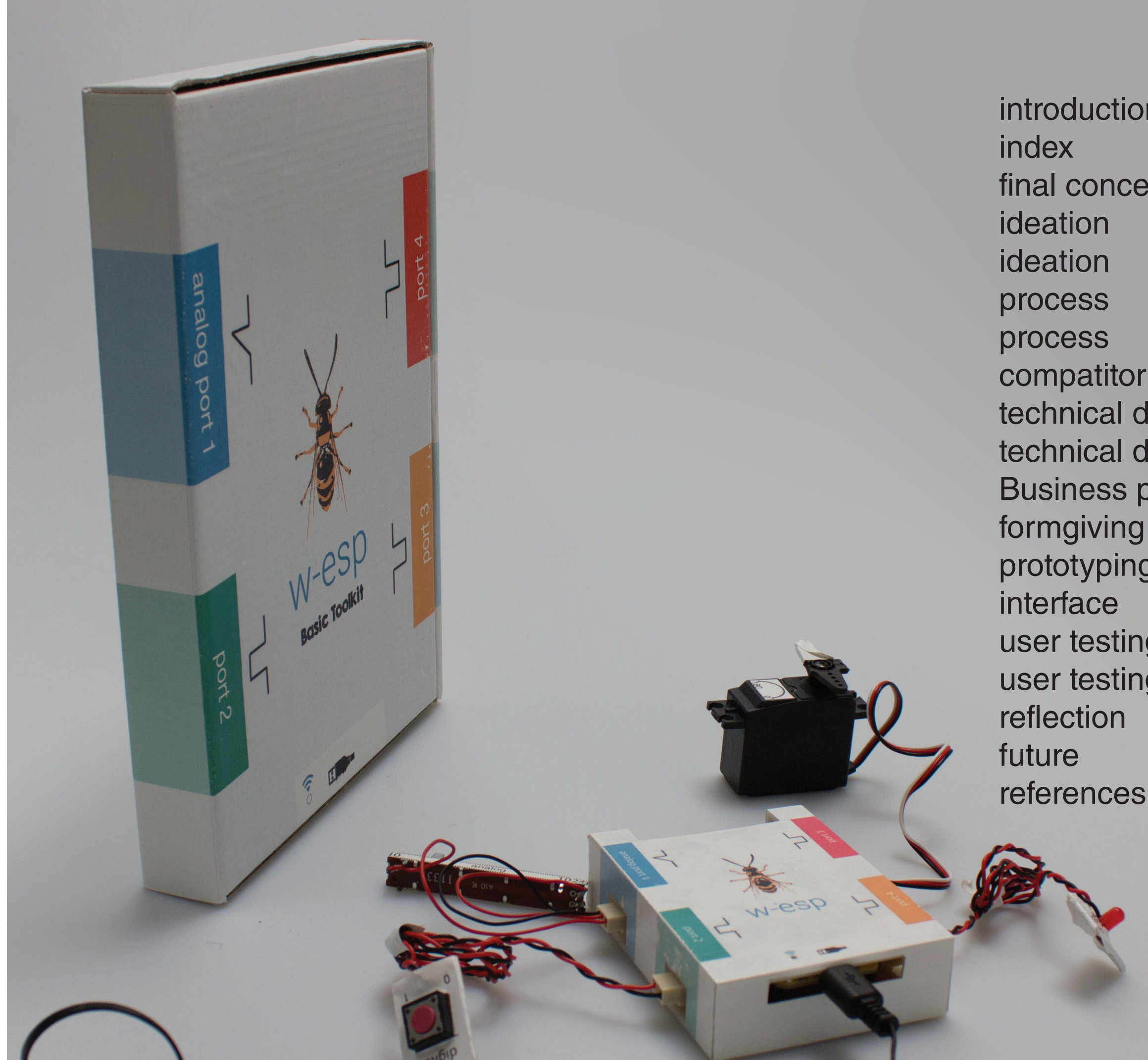
In this report I will describe the process, design decisions, final design and specifications of the w-esp, a playful learning toolkit for learning students (12-14 years old) 21st century skills (Thijs, Fisser & van der Hoeven, 2015).

> *“The main challenge is to develop an integrated Design Based Learning Approach (DBLA) that combines a learning process with the use of a set of simple and playful building blocks that allow children to easily create diverse simple designs in a trial and error process. “ - Project description playful learning toolkits (id.tue.nl, 2015)*

There are different reasons why this is important for education one is that the attitude towards STEM (Science, Technology, Engineering and Math) related subjects is decreasing when students go from primary education to secondary education[p25-26 Zin in wetenschappen], this is a problem because to prepare these students for the 21st century they have to be able to be critical citizens and it is a priority of the EU countries to educate our children (the value of) technology.

> *I hear and I forget. I see and I remember. I do and I understand. - Confucius*

I focused on making a hands-on toolkit that enabled the students to build interactive systems with the internet of things, because by letting them play and hack around with it they become more capable of changing the future and recognizing the opportunities that the future has to offer.



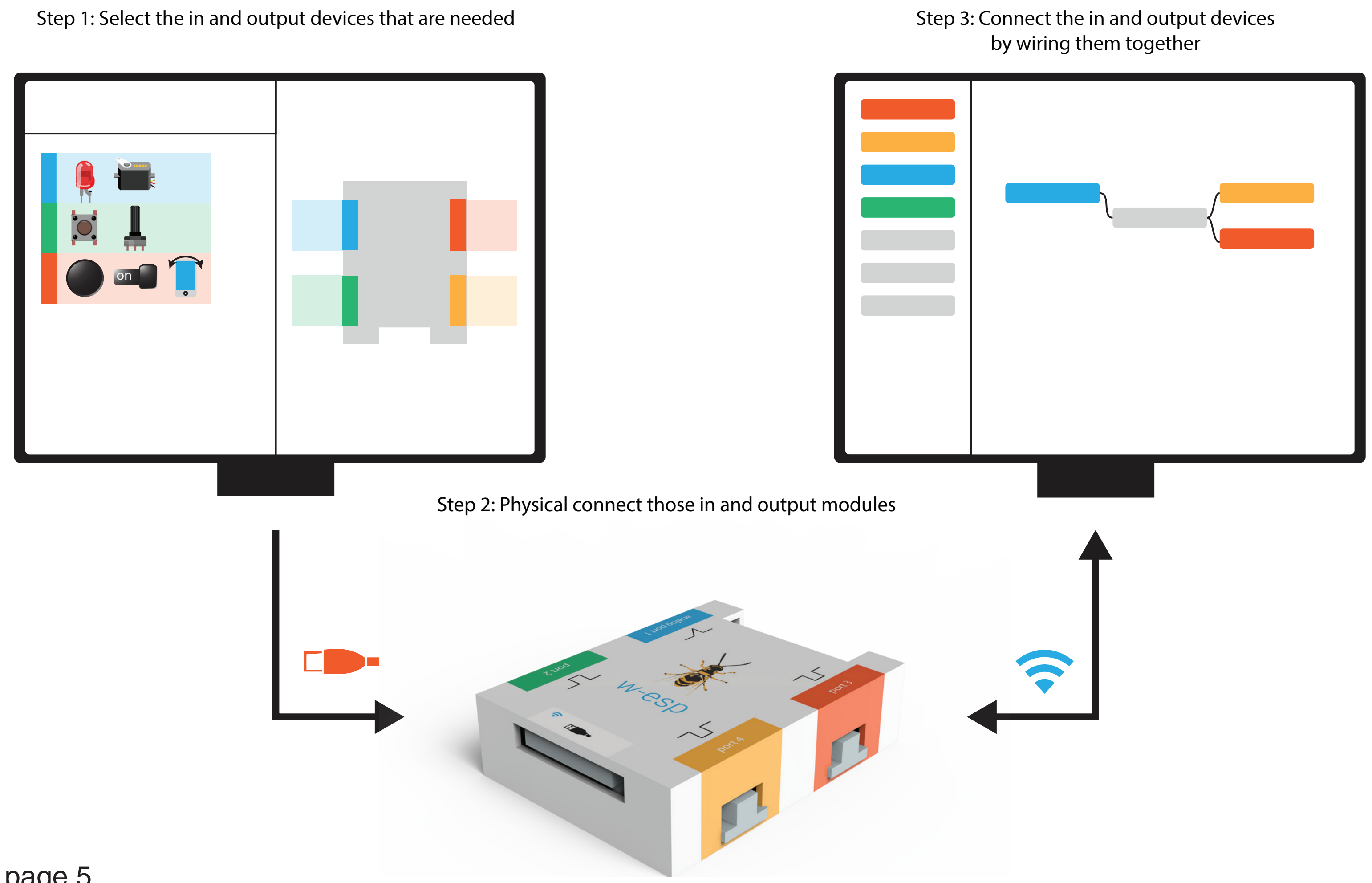
index

final concept

The final concept of this project (the w-esp) is a toolkit that enables the first and second year students of secondary education to connect sensors and actuators to the internet and create interactive systems that use the internet of things. This could be for example a locker that is controlled by your mobile phone, a system that prevent your grandmother from sleepwalking, automatically feeds the chickens… the sky is the limit.
The process of building such a system consists of three steps. First the w-esp needs to know which sensors and actuators are connected to the board, by using a drag and drop system [see step 1] the user can drop the in- and output icons on the different ports. After doing that the hardware needs to be physically connected to the w-esp [step 2]. Now the students can open a flow chart programming system based on Node-red(IBM) [step 3] in which they can flows consisting of input blocks, output blocks and processing blocks.

I learned very early the difference between knowing the name of something and knowing something. – R.P. Feynman

In this way the children can learn about programming concepts, without the need to learn difficult syntaxes and languages, they also can use the internet (social media, mobile phone) as in or output and in this way create awesome projects.



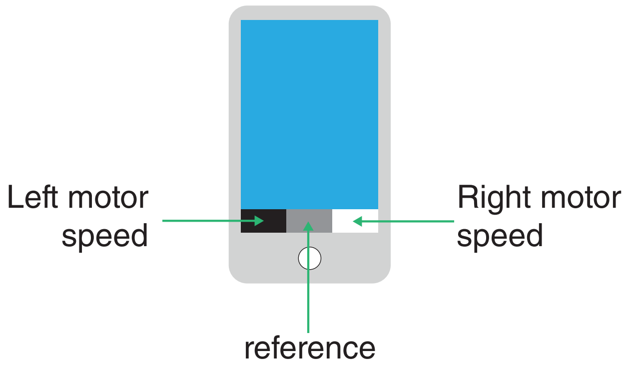
ideation

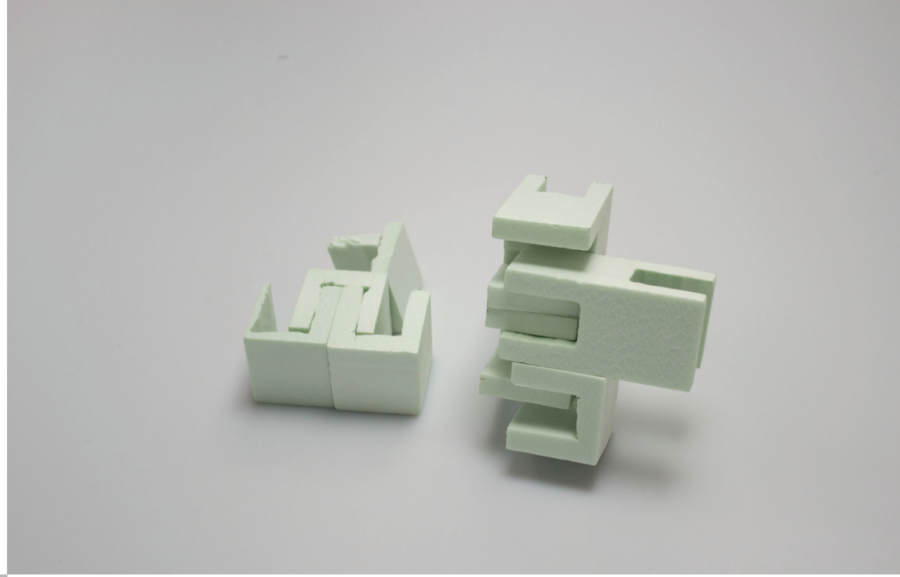
We started this semester as a group, we brainstormed and discussed the values that we found the most important. Enabling students to explore based on curiosity. Create real value for a context. Openness for own input/creativity. And last but not least room to excel and grow.

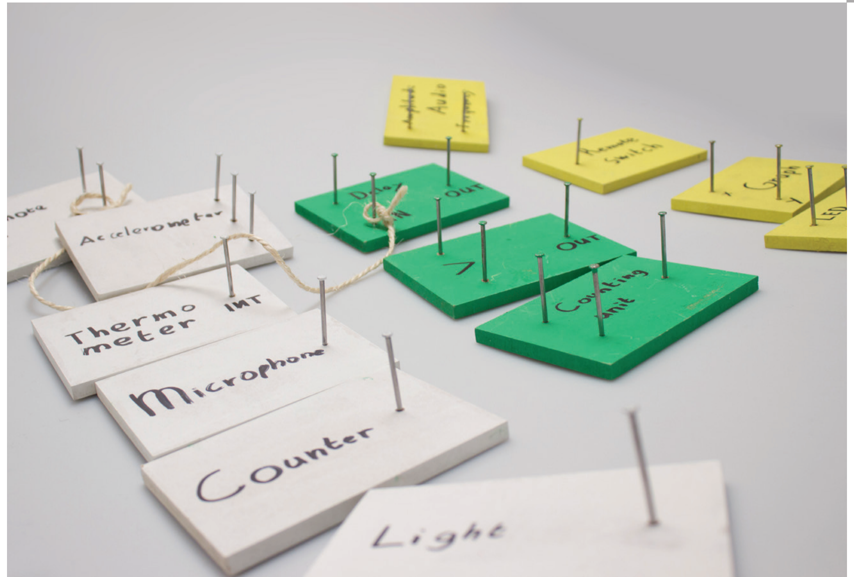
After defining the core values for our project we brainstormed on different concepts. One is an energy toolkit, where we give the children building blocks that they can use to transfer from one energy to another (for physics class) in this way. For example they can convert movement to sound and sound to light, they learn the concepts and learn how they could be used for communication and research. Another idea was to build a robot that is driven by your mobile phone, by having three light sensors and the phone can control the robot by changing the light intensity at those three places. In this way students can be able to build cheap highly advanced robots. We also focused on how to prepare the students for the 21st century. What is a better way to do that than to let them design the ideal world on an empty planet. This creates awareness about politics, technology, scarcity and the environment. We looked at what was already in the schools (subjects, materials), what are the current trends in our changing world (that they need to be aware of).

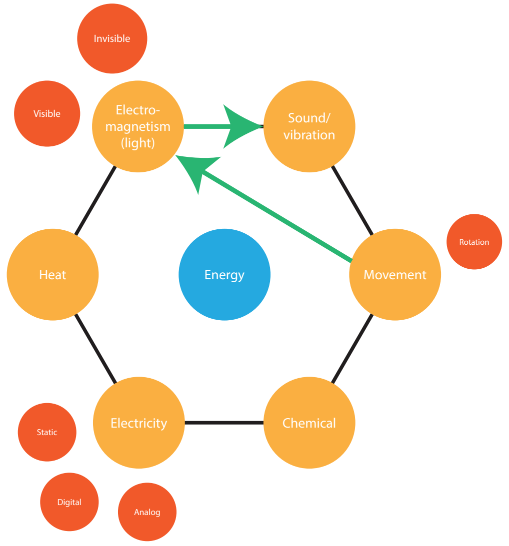
I visited a school that used a context/design based learning method they combined the different science subjects in the first three years of secondary education in a design based way. They did for example did research on Galileo Galilei, designed a pendulum and did research with this pendulum about the period of swing. In this way they learned about the different disciplines (history, physics, construction and building) in a design based way.

We talked to Eelco Dijkstra (an expert in the field of ICT education and together with the ministry of education shaping the ICT education of the future for Dutch secondary education).









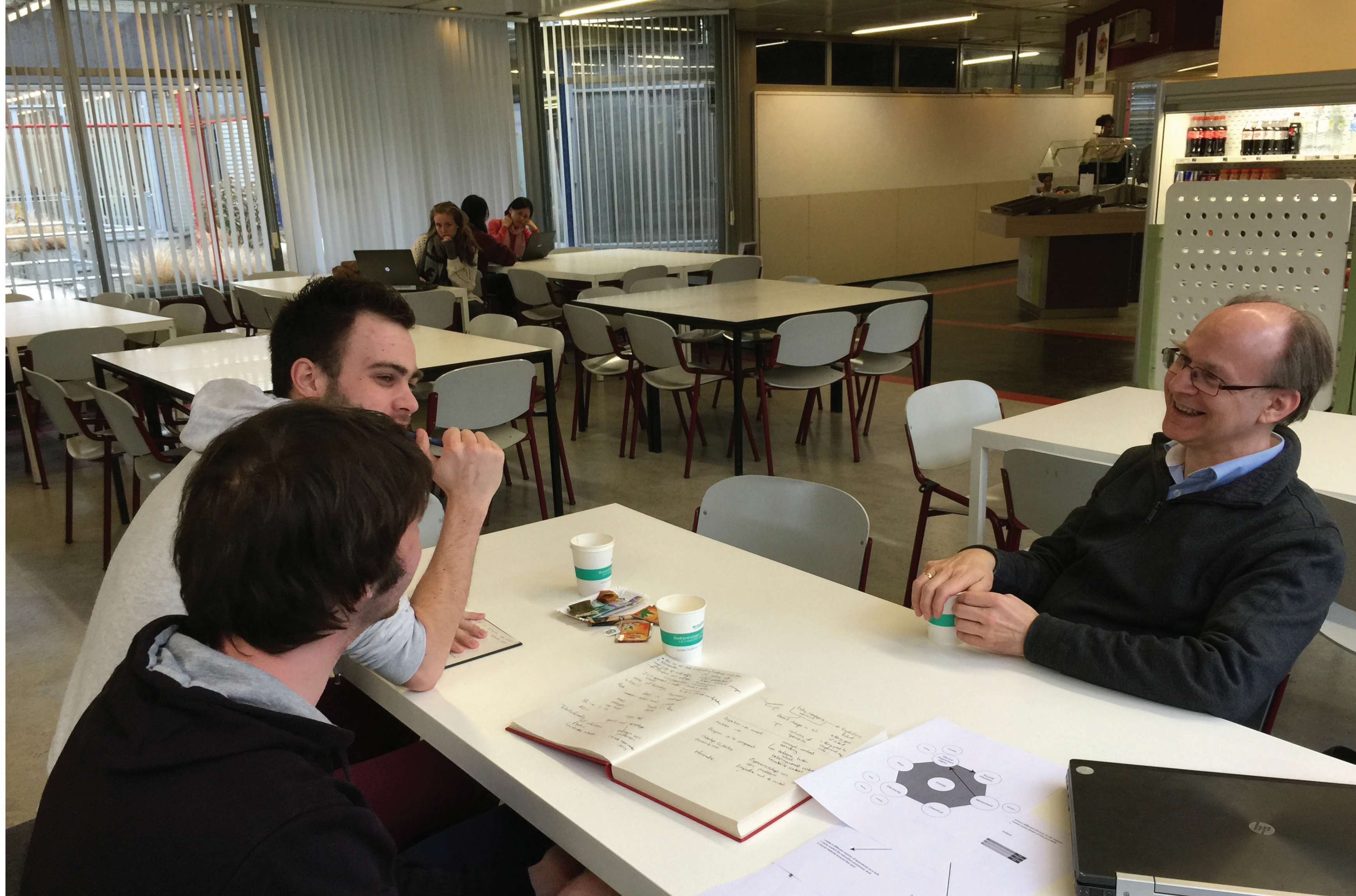
ideation

Some insights that Eelco gave us:

- Children need to have a context that is close to their imagination to design for. He once did a project with students for KLM (the Dutch airplane company), but the students only got interested after visiting this context.
- Nowadays the education is based on the just in case model, students learn concepts because they could be relevant in the future. The just in time will be much more important because in the future children will have to adapt to the fast changing world.
- Education should be focused on letting children find their element as early as possible so they have the time to become expert in that area, because according to (Ericsson, Krampe & Tesch-Römer, 2009) they need 10000 hours of deliberate practice to become an expert.
- The most important programming concepts that children need to learn are the elementary building blocks, the ways to connect those blocks, the concept of creating new blocks and re-using them.

During this project I focused on the most innovative schools as a starting point, because they could help me to make a future proposal, instead of starting from the less innovative schools and changing the past.

Based on this idea I decided to focus on a product that enables the children to learn to build systems for the future, by wiring the in- and output together.

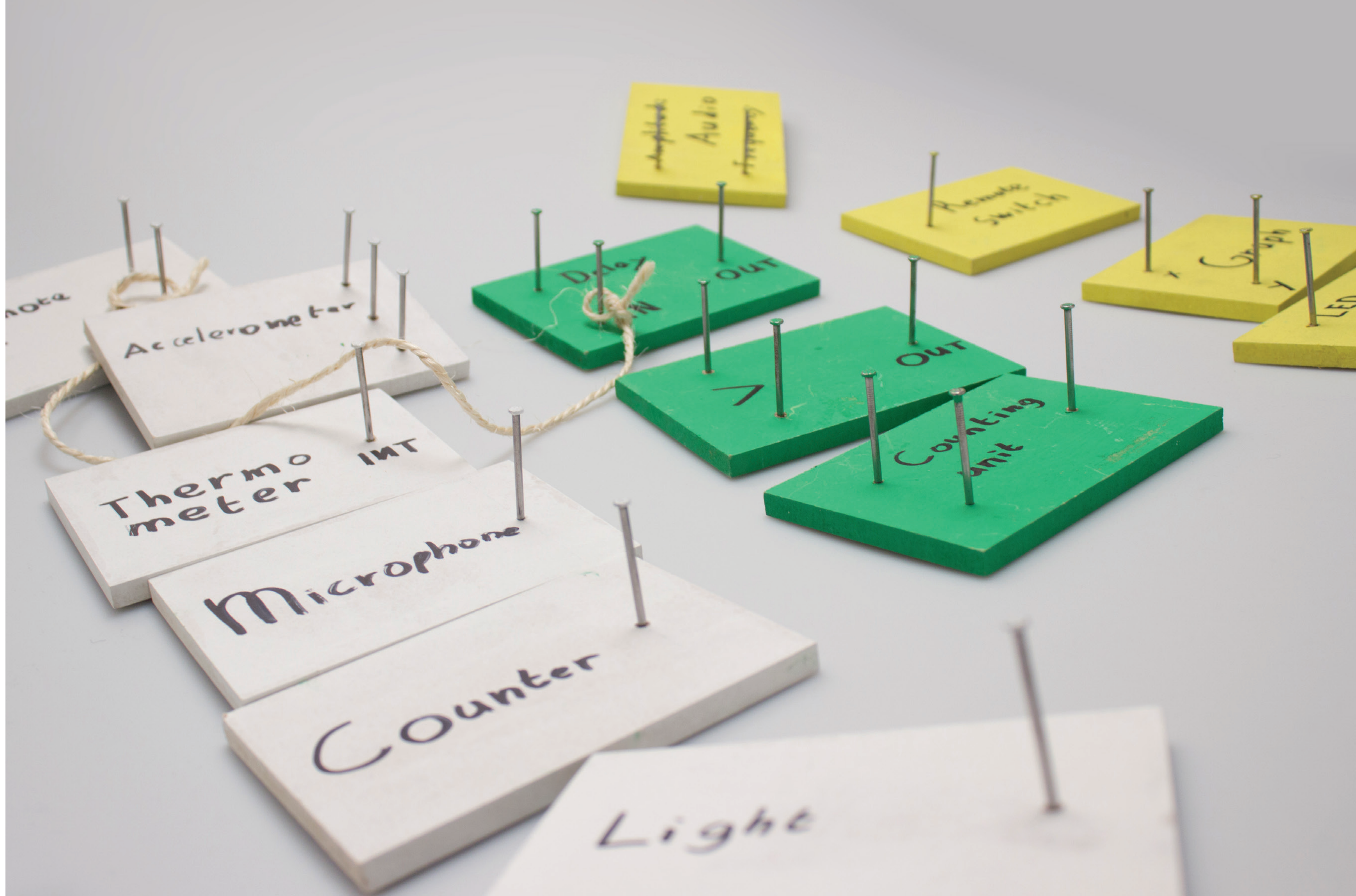


process

We made a prototype to make this concept tactile and to try out different scenario's to see if we had enough blocks to solve certain design cases. Altough making it physical stimulates the tinkering behavior, in the end this will be software based because making systems by wiring hardware blocks to each other is too expensive and less open (limited amount of blocks).
During the first cross coaching session we received the feedback that we have to choose certain scenarios because our project was still too open/ unclear. What are the goals we want to realize (learning goals).
After this cross coaching session we realized that it was better to all go our own way; because the different team members had different goals and expectations of this project.
I made different design cases to show that my toolkit could be used to solve them.

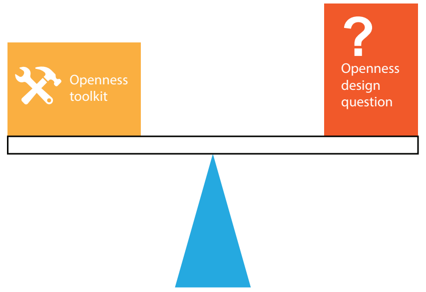
- Doing creative research to find out if one-way policy could be interesting for your school, by measuring the amount of people that walk in certain directions.
- Designing a system for your grandmother that at night sometimes start to walk around asleep to warn her or someone else that it could be dangerous.
- Design a game for the future first year students to prepare them (learn the classrooms/ teachers)

During the stakeholder meeting I discussed my idea with different teachers/education experts. One teacher gave me the feedback that the concept of sensors/actuators is perhaps not clear for this age group. This could be solved by letting them come up with feelers (sensors) in their environment of in the classroom. By doing that they start to think about systems and how the world around them works, so they also get a better understanding of designing those systems. There was also feedback on the size

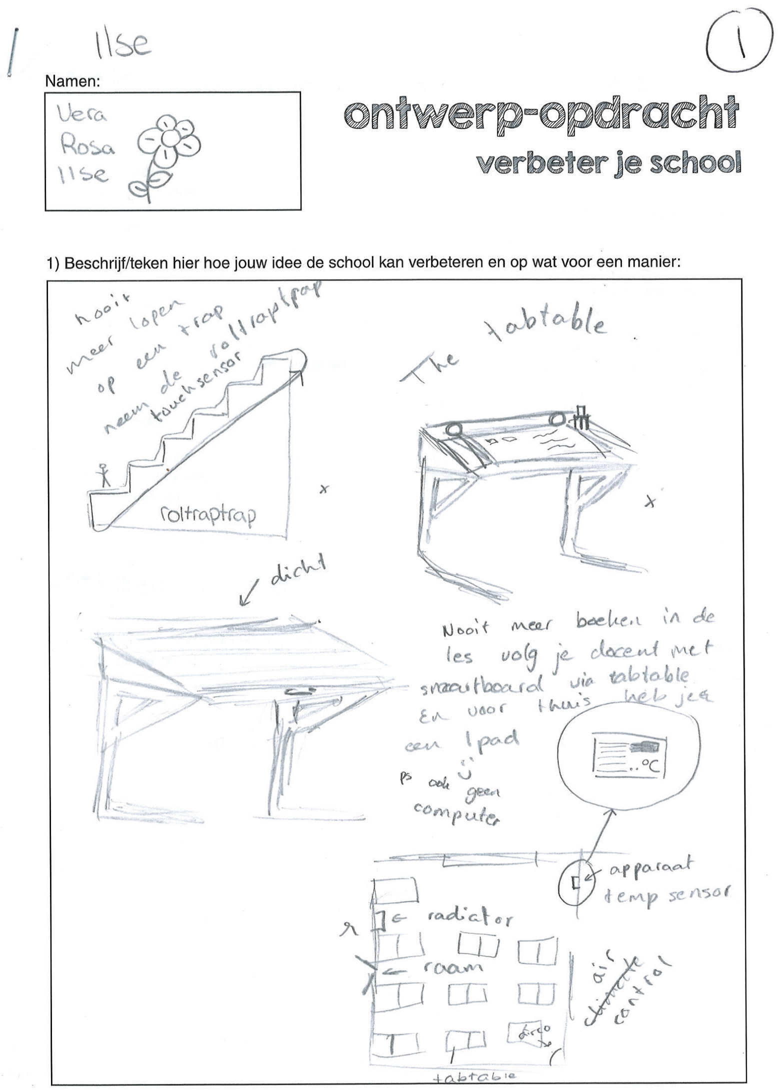


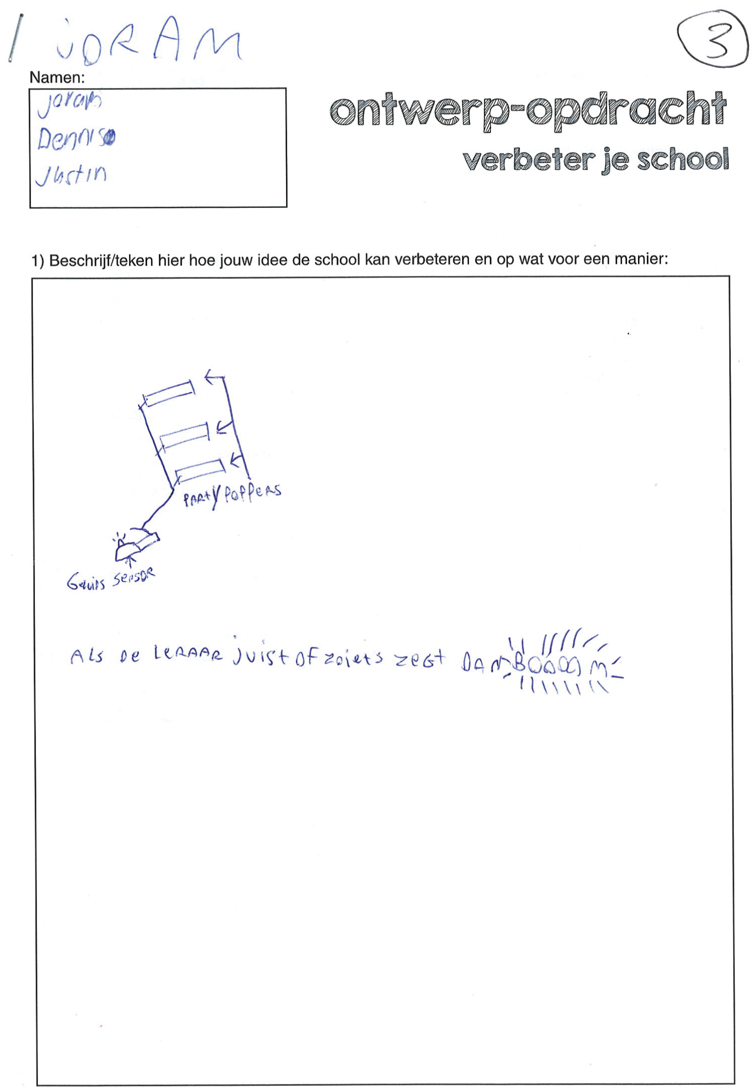
process

of the product (it should be bigger than a mobile phone (so they don't accidentally take it home) and a box that fits all the elements was also appreciated, because of practical reasons.
At mid-term demo day I received the feedback that I wanted to do too much for one semester and that I have to be more specific. Especially because I didn't have a working prototype I could get why this feedback is given.
After mid-term I started to work on course material for the Ostrea Lyceum, I could use eleven students who follow VWO science (an extra module). This quartile was focused on lifestyle informatics. Because I was still developing my prototype I decided that I want to test the creative process with those students (at the first lesion) and focus the second lesion on creating systems with node-red (and use their phones as input/output). In this way they got an idea on how the final product would work.
During a workshop with Eamer Beamer I realized that I could try to ask a more open design question because my toolkit is not really open (they can only choose to use certain modules) see the design based toolkit equilibrium. So I changed the design question to 'Make a system that improved your school with this toolkit…', in this way it is clear that they have to use the toolkit and they have freedom to come up with interesting design proposals.
For the last cross coaching session I made the interface work (for dragging the sensors and actuators into the w-esp). I asked several people for feedback and improved/simplified the interaction to make it as intuitive as possible.



Design based learning toolkit equilibrium





compatitor analysis

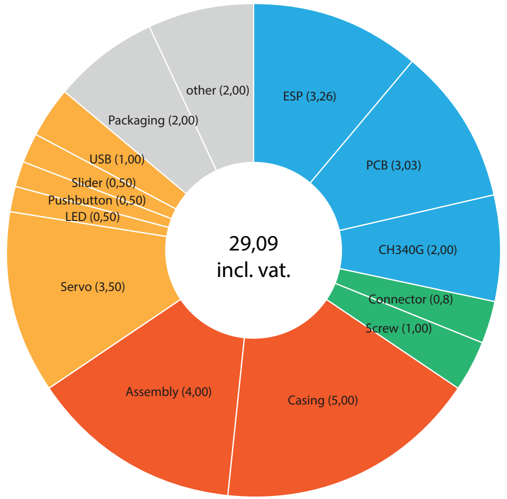
There are already products on the market that enable secondary education and primary education students to build interactive systems, and some of those are already implemented in education. Of course there is certain overlap of those products and the w-esp, also those products can be used in combination or next to the w-esp (the Arduino IDE is for example ported to work with the ESP chip (Maglie)). A small overview of the alternatives and why the w-esp is different from this alternatives.

The w-esp is plug and play;
There are products out there (for example Raspberry Pi that are focused on education but that need too much pre-knowledge to start.

The w-esp can be programmed by flow-based programming
There are already amazing visual programming language but most of them that are used in education are based on imperative programming (blocky and scratch). Flowhub is a new alternative started from kickstarter that focusses on programming in a flow based manner, but not (yet) implemented on the internet of things or hardware. It could be interesting to focus on this software in the future

The w-esp runs entirely in the cloud and is therefore perfect for learning about the internet of things.
Most microcontrollers such as Arduino run the program on the microcontroller themselves, w-esp is a gateway from the internet to the physical world. The w-esp could be cheap compared to other products because it is based on the ESP8266 chip

Part cost diagram in € incl vat for the basic toolkit



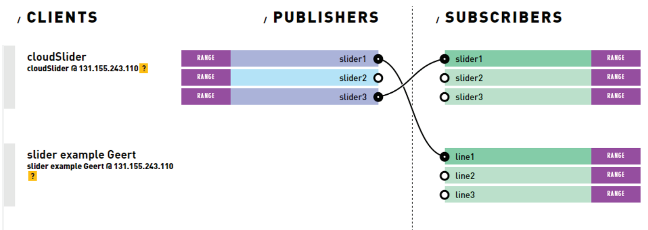
ESP chip	3.26
PCB cost (for >100 pieces)	3.03
Connectors	0,80
Screw terminals	1,00
Casing	5,00
Assembly	4,00
servo	3.50
led	0,50
pushbutton	0,50
slider	0,50
Packaging	2,00
USB cable	1,00
Other/unexpected	2,00

technical desisions

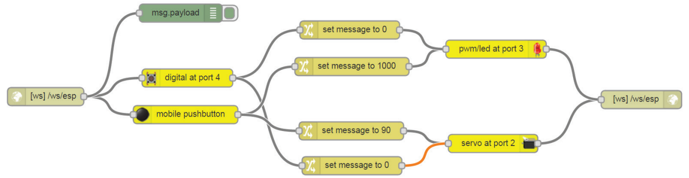
In the beginning I focused on using spacebrew (made by Rockwell group to make interactive spaces) as tool for wiring the in- and output together. On the hardware side I focused on using a Raspberry Pi, because it can function as server and there are GPIO pins available. It could also connect to WIFI by using a wifi-usb dongle. The Raspberry pi could than start a wifi hotspot that you can use to connect your phone and connect using Bluetooth with a wiimote. To enable the raspberry to use the internet it should be connected to an Ethernet connection with open TCP ports (it is hard to set this up in the school network)

After doing research to alternatives I found the ESP8266, this chip is much cheaper approximately 3$ has built in support for WIFI, and is better in controlling real time hardware (servo's and other components). The downside is that the ESP chip can't run node-red, so this package should be running in the cloud. This solves the TCP port problem, so I finally decided to develop the system further on the ESP chip.

The school would need to have a WPA2-personal network in the area's where the w-esp's are, the w-esp's than connect to a cloud based service such as node-red (IBM bluemix or a special w-esp service that I could offer).

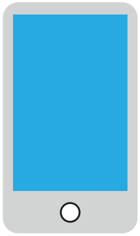


Spacebrew, connecting in and output directly



Node-red also gives the possiblity to add processing steps

smartphone

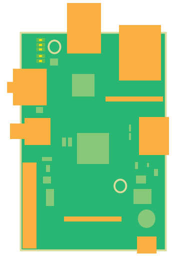


ost: free (already available in context)
Acceleration sensor
High-speed HD camera (50fps)
Sound sensor
Touch input
Bluetooth
Wifi

wiimote
by Euss psdevwiki.com

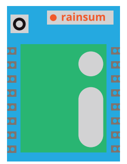
Cost: € 16,84 excl vat
Acceleration sensor
High-speed HD camera (50fps)
Sound sensor
Button input
Touch input
Bluetooth

raspberry pi
by Guitool wikimedia.com



Cost: € 30,54 excl vat.
GPIO input (no realtime)
ethernet
wifi (optional)
bluetooth (optional)
Can function as node-red server

esp8266



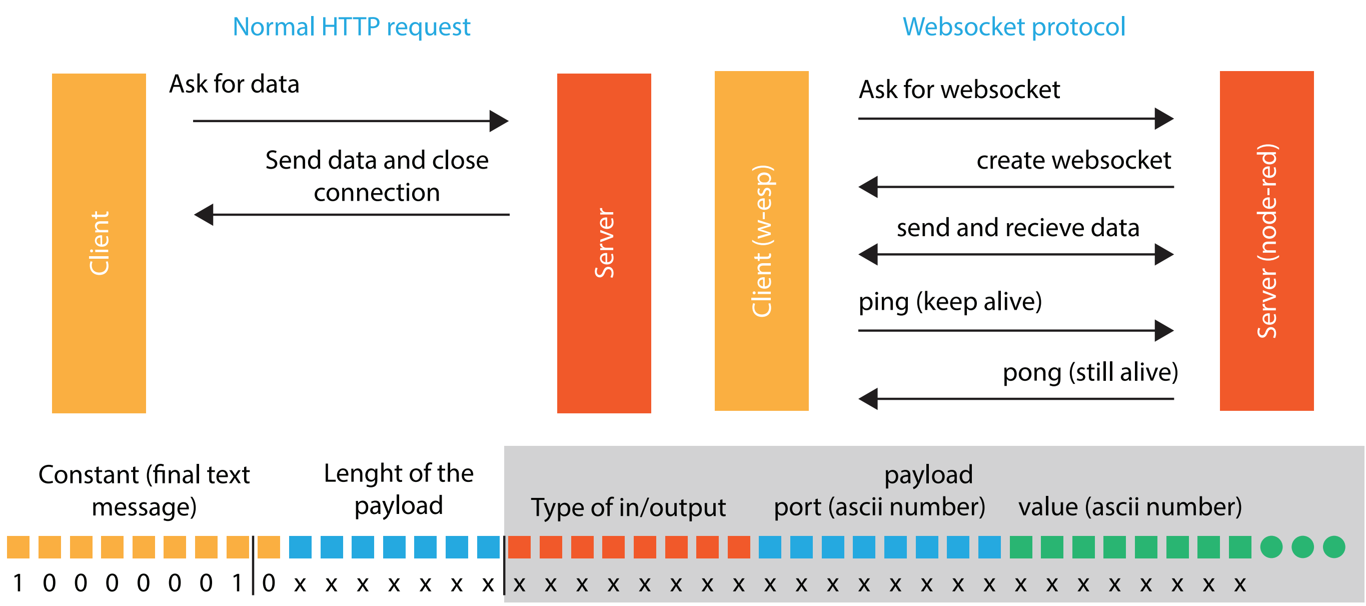
Cost: € <10 excl vat.
GPIO input (realtime with hardware trigger and PWM)
wifi
bluetooth (optional)
small
Can only function as client

technical desisions

Together with some basic components, a mobile phone and the internet the toolkit is open enough for students to create systems based on their own input.

To realize the gateway between node-red and the w-esp I needed to use the websocket protocol, so I ported this protocol to the LUA language on top of the TCP protocol that was already in there. The power of a websocket protocol (Fette & Melnikov, 2011) compared to normal HTTP communication is that the connection keeps open, and both the server and client can send and receive messages in real time. In the past this kind of systems were built upon MQTT or using (long) polling. This requires much more communication, and is not as fast as websockets. Because I use the web-socket protocol in a very simple way I was able to write the implementation in a very memory efficient way. (see the diagram)

After trying to program the ESP chip with c++ I found out that the makers of a development board for the ESP chip (nodeMCU) published a scripting programming language (LUA) that could be useful for developing this tool, because it is easier to communicate with the w-esp desktop software when using this language. I wrote the code for the ESP chip (see appendix), but the memory on the chip was full when every element was running, after optimizing the code where possible I realized that many modules of the LUA language were still unused (but using memory) I deleted those and the program ran stable after doing that.



business process

When bringing this product to the market there are three elements that could make profit. One is selling the product with a certain margin, second is selling the cloud service for a monthly fee, third is giving presentations and workshops on using the w-esp. The first is probably where the most margin could be made, because other competitors could also easily deliver that service (and schools also have the opportunity to run it locally).

The market consists of teachers (or coordinators of certain subjects at school), they usually buy larger volumes because when implemented in their curriculum the whole class needs a w-esp, parents of children that like to play around with electronics, hackers that want to co-develop this tool (high-tech hackers, but they will probably buy a ESP8266 development board), and the (low-tech) hackers that are not so much into programming but want to build stuff easily. It depends on how I place this product into the market how those market segments are divided.
I could use the network of existing channels for promotion (within education), use the network within the education conferences for promotion. Also advertisements in education magazines (NVON, Technasium) can be a way to get the target market.

For developing the software further I need to find a jQuery (front-end) and node-js (back-end) developer, also for creating a solid firmware a C++ hardware developer could be needed. My MVP right now is good to test the concept at a limited set of schools, but when I want to sell the product it needs to work solid and reliable.

Because I'm now building on top of node-red I have to publish the code as open-source code, this could be an opportunity to find or get input from developers. On the other side it also makes the possibility that competitors will sell the same product without developing costs (so they can be cheaper). By having good service and creating a solid brand and a product that teachers can easily implement into their curriculum I could keep a large market segment when competitors are offering cheaper alternatives.

Business model canvas

Key partners	Key activities	Value propositions	Customer relationships	Customer Segments
• Teachers • Students • Hackers (both co-developpers and end users) • Production PCB producer case producent hardware wholesale • Sales and distribution	• Developing software/ firmware • Managing manufactoring • Quality control • Maintaining and running online platform • Promotion (presenting, courses for ICT teachers, marketing)	• Creating a tool that enables students to do design based learning • Improving education • Creating enthousiasm for technology • Preparing students for the 21 century • Enabling hackers to do fast prototyping	• Presenting at education conferences (ICTdag f.e.) • Online advertisement • Advertisement in education magazines • Getting feedback through github	• Education (Primary education, secondary education) • Hobbyists/Hackers (Both children and adults)
	Key resources		**Channels**	
	• Certification • physical hardware case esp8266 PCB connectors external components		• Distribution and sales of the product are outsourced (funmetelectronica.nl, sossolutions.nl show interest.), both webshops • Distribution of the service contract will go through w-esp.com	

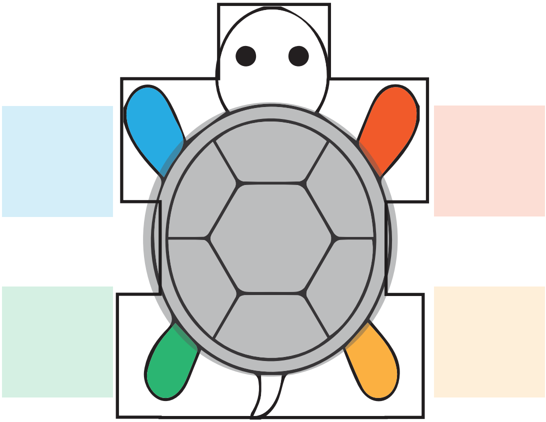
Cost Structure	Revenue Streams
• Production • Distribution • Certification • Advertising • Salary (for designers, teachers and developers) • Virtual private server (Amazon AWS)	• Fixed pricing for the w-esp • Serivce contrcact (montly fees) for the education software and debug platform • Giving courses/presentations about w-esp

formgiving

The goal during my final exhibition was to present the prototype in such a way that it could be put into the market immediately. Because of this reason I 3D printed the packaging and wrapped the casing with plastic foil (with signs printed on top of it). In this way the prototype looked as a close to the final product as possible. I chose to go for a clean and simple layout. I also explored the option to design the toolkit in the form of a turtle because than the students could see the analogy with nature (the legs can control thing (actuators) and feel things (sensors), the right front leg is more sensible so that is the analog port). But it could be too childish, and it would be more expensive/ difficult to produce. In the end I did go for the clean design of the w-esp instead of the turtlesp, but it could still be interesting to do more research about this.

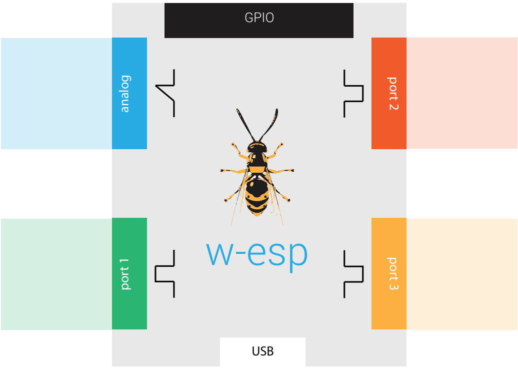
A turtle made out of foam, made to explore form

Turtlesp



Childish/ playful style
analogies to nature
Perhaps (10-14 jr), mostly primary education
More education related
Could have more narrative
solves the pin-mapping problem and conceptual (what is a sensor problem)
More expensive/difficult to produce

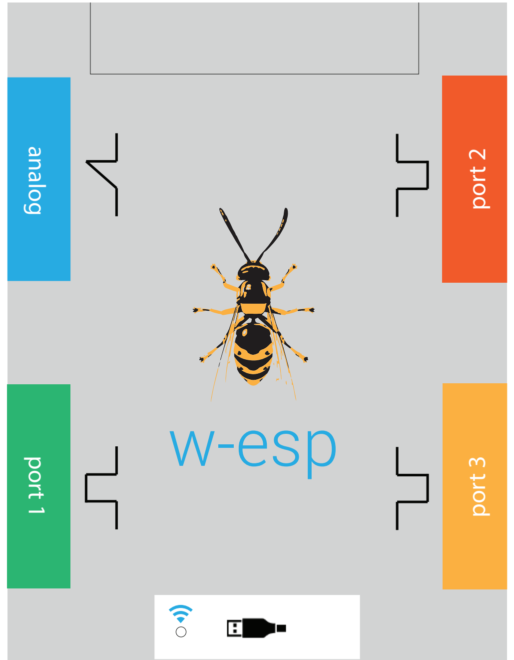
W-esp



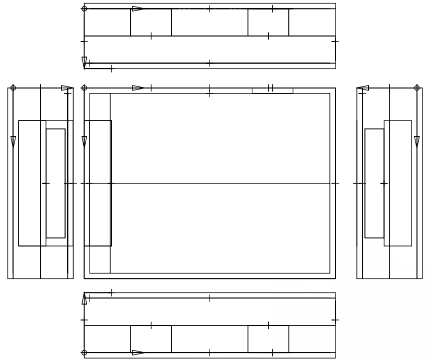
Clean and simple style
it is wat is is, a tool...
(14-18 jr), mostly secondairy education
More technology related
solves the pin-mapping problem
Simpler production

prototyping

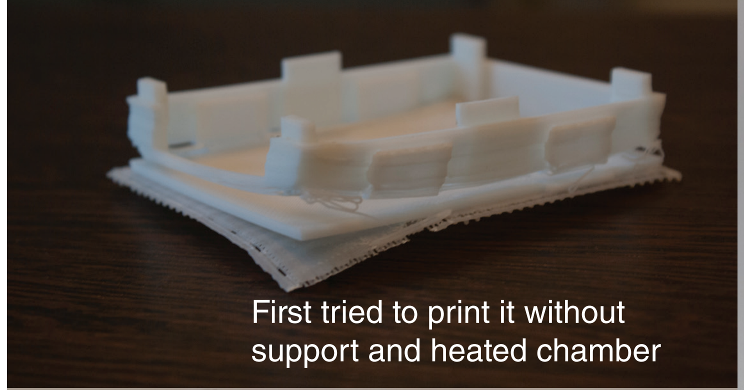
Creating a 3D CAD file of with real dimensions (check if it fits the electronics)



Creating a 2D vector visual of the w-esp

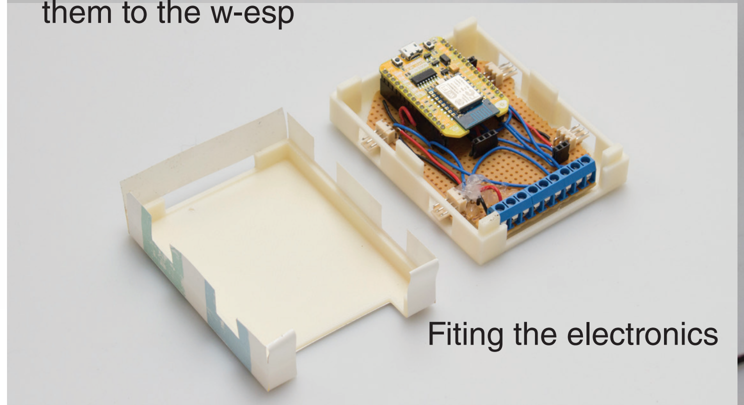


Creating a render of this file



First tried to print it without support and heated chamber

Printing the vinyl stickers, cutting them and sticking them to the w-esp



Fiting the electronics

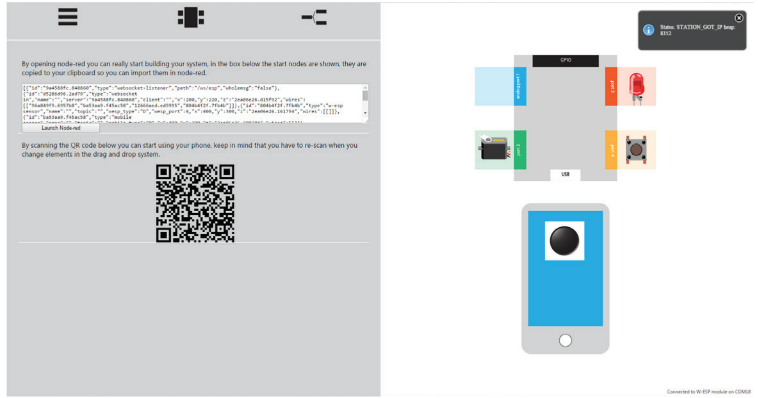
Final product, the box and the w-esp are the same layout and style

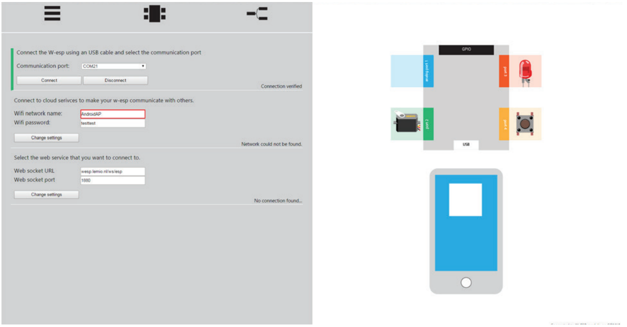
interface

At the user interface side I wanted to create a mapping that is as intuitive as possible, so I created a drag and drop system where users can drag and drop the different sensors and actuators to the ports of the w-esp, the interface automatically gives hints on where the different elements can go. (an analog sensor can only fit in an analog port).

The settings are also simplified, because when the w-esp is connected all the settings get downloaded from the w-esp, including the information on where the elements are connected. So when it would be used inside school the settings only need to be set once.

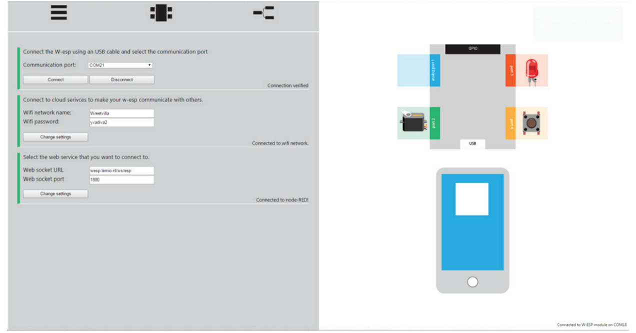
Also because a smartphone could also be part of the toolkit it is also shown in the interface and there are special mobile elements that will be shown or will run on your mobile phone (interface elements and data elements). After dragging the elements, the user can push a button and will go to the node-red interface; scan the QR code with his/her mobile that will lead to a web-app with the dragged elements included. In node-red the essential nodes are copied to the clipboard of the user so he/she can paste them and start building systems.

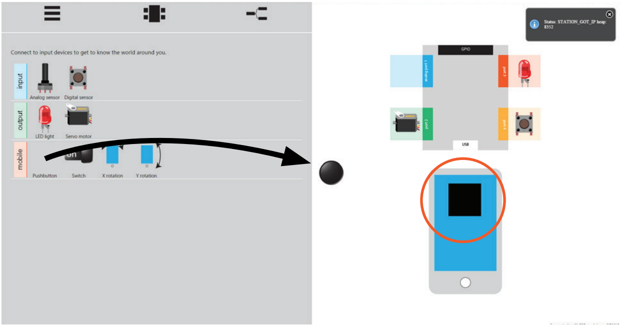




First the settings and setup is downloaded from the w-esp. It tried to connect to the wifi network but couldn't find the SSID name.

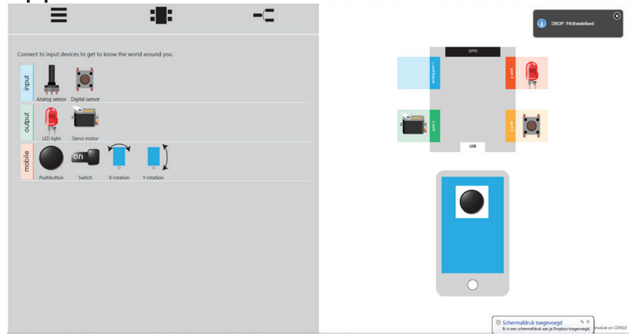
Everything is working and it is connected to the wesp.lemio.nl server





When clicking and dragging an element, you can see where it could fit because those ports get a black background

When dropping the element into the mobile screen it will generate a different web-application



user testing

At the start of this project I contacted several people that could be interested in co-creating this toolkit. I have quite some network in education because I gave workshops/presentations at several conferences (since 2011) about using Arduino or 3D printing in education.

During the last quartile of this semester I was able to use a 2nd year group from the Ostrea Lyceum on Friday mornings to test my concept on. During the first introduction course they learned what sensors are, I showed a demo of a system in node-red and they brainstormed (individually) on concepts to improve their school, after that they formed groups and chose the best concept (or combined ideas) from those groups (the think-pair-share method (Van Houte et al., p120)).

In the appendix are the results of the brainstorming sessions, it was interesting to see how creative those children are. It was a good choice to keep the design brief more open, because they were all able to come up with concepts that could be realized with the w-esp. It is better to begin really open, there is always the possibility to go from an extreme idea to a feasible one but the other way around is more difficult.

The second course I was not able to be there, but they improved and refined their concepts and gave feedback on each the concept of each other. They also played with node-red to do non-design exercises see appendix[n] (to learn what it is and how they can use it).

I did a final user-test at the RSG 't Rijks, Bergen op Zoom on two groups (1VWO, during ontwerp en onderzoek class) and (VMBO 2, during technology class). The school is open to innovation, the teacher is also owner of a web shop selling electronics (Arduino and related goods) to schools, he is also giving Arduino in to second year students.

user testing

During the user-test I realized different things; the interface of node-red looks still too difficult. It is not clear for them that certain components can only be an input or output (f.e. they wanted to use the slider to lock a locker, but it can only be used as input). They get the concept of describing everything is small steps, but they need some coaching to don't forget obvious actions. They understand the concepts of the flow chart programming, although I have to test it more (without me coaching and the time pressure of one hour for brainstorming and 'programming' the system).

I realized that the main difference between 2VMBO and 1VWO was that the 2VMBO class needed more guidance (in the form of do this, than that) while the VWO class was more into trying and logic reasoning, and they were also able to troubleshoot a problem before I solved it. Another insights was that during the second user-test they created a concept that didn't need the w-esp.

After this sessions I was able to discuss about the w-esp with the teacher Frank Hagenaars. He was really interested in it and could use his network within education (in Netherlands and Belgium) and his web shop to distribute it when needed. He gave the remark that it is better to create course material that is totally not design based (for example five closed solid courses), and that after doing this the children can use the tool for projects when needed. At their school they learn children Arduino in such a way, and after that they can use it in design projects when they want to use it (3 out of the 12 groups use Arduino), it also solves the 'problem' that the groups can also create projects that are not design based.

reflection

During this semester I was able to focus on one of the fields in design that I really like; education. This project has a clear user and because of this I was able to come in contact with the context easily. I have some network in the ICT education sector, because I present about Arduino and 3D printing at ICT education conferences, also my old ICT teacher had a lot of network in this sector and introduced me during my secondary education to lots of interesting people in this field.

I experienced that I need all the competencies I developed over te last years to develop the concept as far as possible, I didn't apply them because I was forced to do so, but only because I wanted to develop my concept further to make it ready for the market. I realized that going from a prototype to the market involves more skills than I thought in the first place.

I experienced during this project that form is sometimes as (or even more) important than the function. If the first reaction of user is that it looks difficult than they will be less confident about using the tool and they will also achieve less. Creating an interface that looks simple (or at least not more this project.

Another aspect that I experienced is that I can create over-expectations because of my enthusiasm towards stakeholders, my old ICT teacher trusted me in such a way that I felt responsible for filling his lesions. I have to communicate my goals and possibilities better to overcome this problem, and perhaps sometimes give lower expectations to stakeholders so I can surprise them, instead of disappoint them.

I have to keep optimistic, because it is also one of the core strenghts (it also forces me to learn and solve certain problems). But don't give too much expectations to stakeholders. Finding a balance between those is essential for my profesional attitude and development.

However I would like to try to put the w-esp into the market, I have to be carefull when doing an intern at LEGO at the same time.
In the future I will use the experience gained this semester to create new products and apply this knowledge and experience within LEGO the next semester.

future

When this product would really come to the market there are some things that could be improved and should be improved.

- Live debugging (in a visual way), the threshold to use the debug function is still to high. Ideally you want to see the messages, and their values flowing through the wires. Also the icons of the sensors/ actuators could show their status (in a way that you can really see the servo moving, and the pushbutton being pushed in the software)

- Larger icons and corresponding color in node-red, also connecting the visual styles of node-red and w-esp more. The w-esp software and the node-red software are still two different things, they should merge to one system node-red should also communicate what is connected to the w-esp hardware.

- More decent firmware (native c++), the current firmware is based on LUA, because it was easier to write it in LUA. But when moving to production the firmware should be based on c/c++ because then the hardware could be used optimal and memory issues are history.

- More focus on production estimates (not rapid prototyping but laser cutting/bending or mold manufacturing). The current production flow is too expensive and too slow for scaling up the production.

- Integration with other (flow chart/data logging) online services, for example If this than that (a cloud service for connecting different application programming interfaces with each other and Thingspeak (data logging service).

- More solid (and less open) course material, based on the feedback from Frank, teachers want to have something to fall back at. Perhaps this could be in combination with inspiration on different design briefs for the teacher.

- Focus more on how girls relate to this subject, using textiles/more context/less hands-on. (p180, Van Houte, Merckx, de Lange & De Bruyker, 2013)

- Try to use the hardware that is already in the school (most physics classes have banana connectors and hardware that can be connected with those banana wires.

- Also sell routers that are pre-configured for use with the w-esp and can run multiple node-red applications, so schools could easily start building.

- More hardware to connect to the w-esp (and perhaps an advanced toolkit) for example klikaanklikuit remote controlled relays, distance sensors, speakers, light sensor, temperature sensor, touch sensor.

- Running a pilot with different schools to detect practical problems.

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