PERSONAL PROJECT

How do IoT Devices impact the modern environment?

Scientific and Technical Innovation

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Grade 10 Personal Project
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HOW DO I.O.T. DEVICES IMPACT THE MODERN HOME?

INVESTIGATING

GOAL

My goal for the personal project (PP) is to **develop my skills and understanding of the Internet of Things (IoT) and electronics products engineering**. I will do this by **developing a line of custom made IoT devices**, including; a thermostat, a button, a smart outlet, a display and an easy-to-use graphical web-interface for configuring said devices. This setup will allow me to explore how **scientific and technical innovation** has changed the modern environment, meanwhile developing my skills as I build a full line of electronic devices.

I will build these products to **make an environment more practical through IoT devices** because it will develop my skills and expand what I'm capable of. Designing not only for myself but also for others, yet most importantly for a *useful purpose*, something that is often lacking with my personal hobby projects.

LEVELS OF CHALLENGE & ACHIEVEMENT

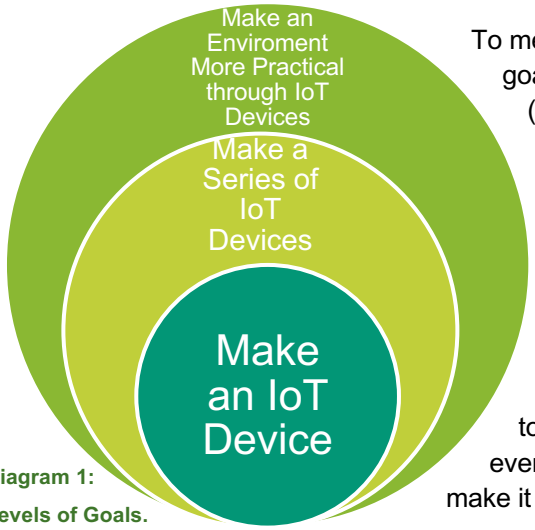

Diagram 1: Levels of Goals.

To measure my level of goal achievement, I have made SMART goals with differing levels of challenge; making an (1) IoT device (ordinary goal), making a set (5) IoT devices (challenging goal), and making an environment more practical through a set of IoT devices (**highly challenging** goal); as seen in Diagram 1. The highly challenging goal is so because it involves not only the creation of multiple electronic devices/products, but it also needs to account for its *environment*. This adds much more complexity to the project as practicality is defined *by people* and is not absolute. Now the devices truly have to work in serving their respective purpose and need to be easy-to-use for anyone. This is especially challenging for me because even if making it work with the *technology* is possible, I will need to make it work with the *people* (more effort).

GLOBAL CONTEXT

The most appropriate global context for my project is **Scientific and Technological Innovation**, because it encompasses all aspects of my project. When we observe the meanings of science and technology (Figure 1) we get a clear breakdown.

science | ˈsīəns |

noun

the intellectual and practical activity encompassing the systematic study of the structure and behavior of the physical and natural world through observation and experiment: *the world of science and technology*.

technology | tekˈnäləjē |

noun (plural **technologies**)

the application of scientific knowledge for practical purposes, especially in industry: *advances in computer technology* | *recycling technologies*.

Figure 1: Dictionary definitions of science and technology.

Diagram 2: Relation between Science and Technology.

Science is the knowledge of basic universal principles meanwhile technology is taking those principles and applying them to create practicality (Diagram 2). This deeply **connects with my highly challenging** goal, as it is gathering the scientific principles to make the products work and creating technology to increase the practicality of an environment. In context of the IBO I will be looking at "*impact of science and technology on the environment as well as communities*".

PERSONAL INTEREST & PRIOR KNOWLEDGE

Since little, I was interested in discovering how everything around me worked. Electronics always fascinated me, as it seemed almost like they worked by magic. My dad is a mechanical engineer and he could only answer some of my questions. This left me to find out the rest by myself. Over time this has led me to develop a personal connection with the topic, as it was all up to me to learn and pursue it. Over the past 5 or so years, I have gathered enough prior knowledge to start building and developing *my own products* (Diagram 3).

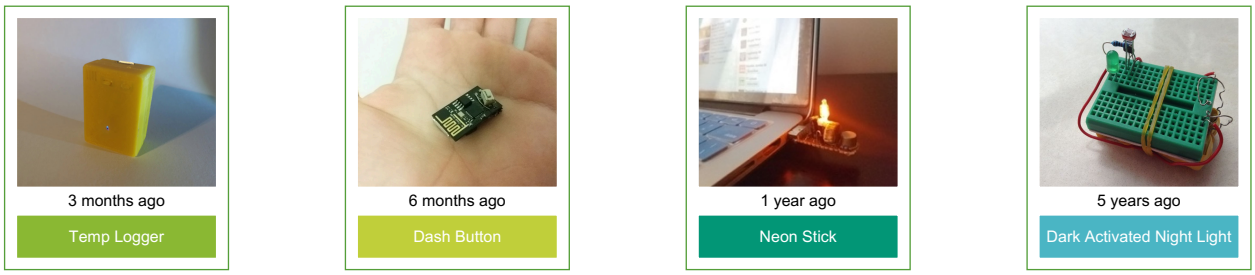

Diagram 3: Previous products I have made.

This opened up a world of opportunities as I can build whatever device I'd like learn how it works while *fully customizing* it to my needs. Getting here involved many skills like planning and design, electronics engineering, software engineering, computer aided design, 3D modelling among more. These skills will be deployed at all stages of my personal project. (Diagram 4).

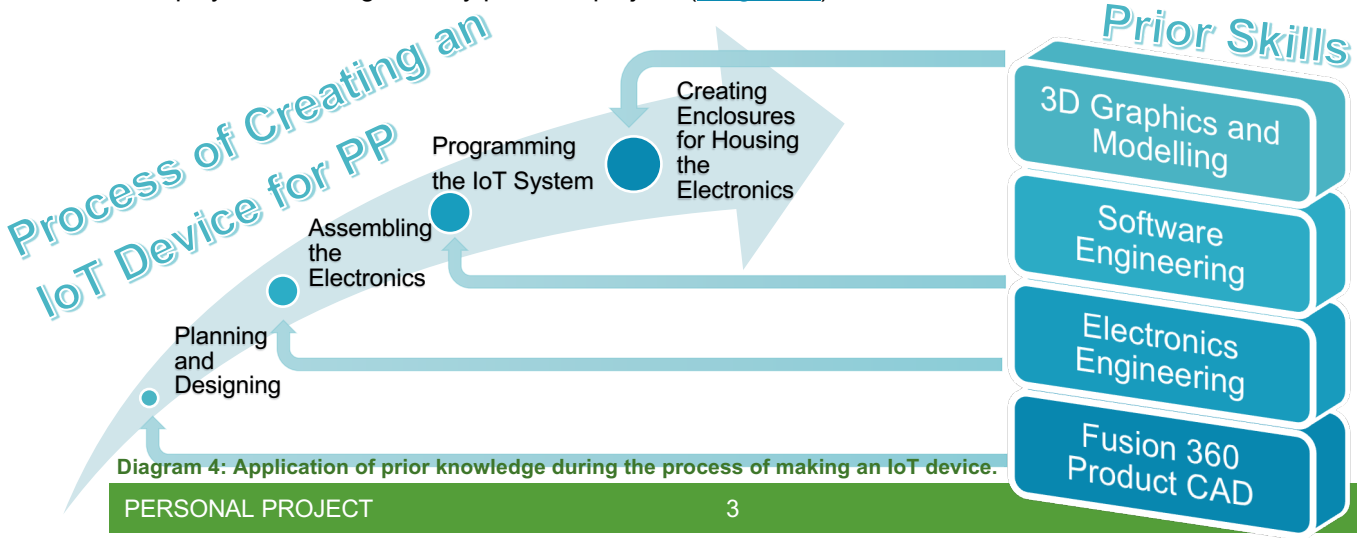

Diagram 4: Application of prior knowledge during the process of making an IoT device.

Most of this knowledge was gathered online, and through numerous guides and documentation published by me and *others* (Instructables[1], GitHub[2], etc). Some of this knowledge was also gathered from MYP subjects, design and physics were especially helpful for me when starting to create.

RESEARCH

A hierarchical outline was used to guide research (Appendix F: Building The Electronics). The many research and organisation aspects in the project challenged my research skills.

HARDWARE

Researching about what hardware to use in my products I discovered that: Wi-Fi enabled microcontrollers exist at a very accessible price[3], 3D printed cases have multiple types of joints to close enclosures like snap joints, friction fits, or screws[4], and the orientation of a 3D print can have a huge impact on the strength of the case[5] (Diagram 5).

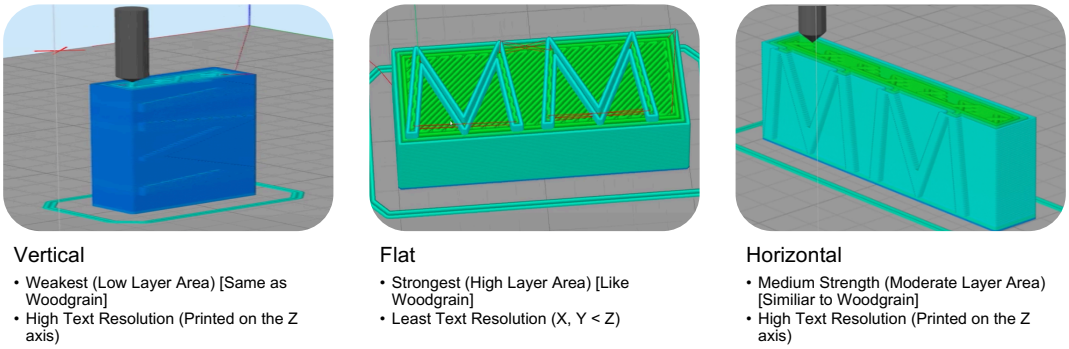

Diagram 5: Differences between orientation when 3D printing a cuboid with text.

This new learning got applied to the project, orienting me towards; using ESP8266 Wi-Fi modules, using friction fit joints for my 3D printed cases and how I should print them.

SCIENTIFIC PRINCIPLES

Researching scientific principles behind radio waves I learnt; how waves can travel, through sky wave, space wave and surface wave (Diagram 7)[6] and how link-budget[7] determines how far a signal can travel (Diagram 6).

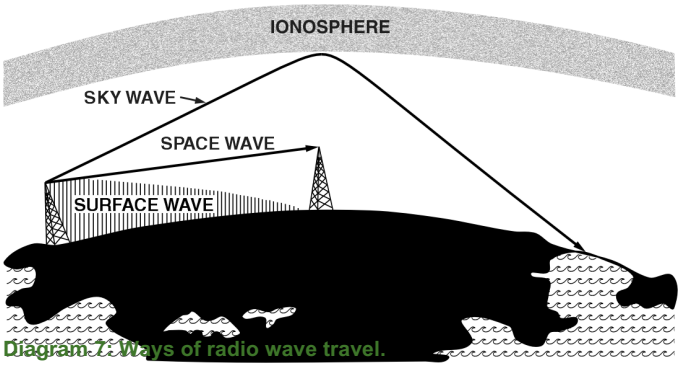

Diagram 7: Ways of radio wave travel.

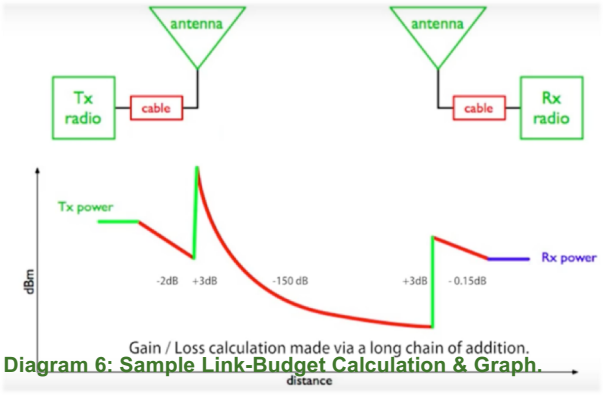

Diagram 6: Sample Link-Budget Calculation & Graph.

[1] (Pizzolito, Ploopy, 2018)

[2] (Pizzolito, Gangster45671 – Overview, 2018)

[3] (mdiaconescu, 2016)

[4] (Adafruit Industries, 2018)

[5] (Muse, 2017)

[6] (Ve6xl)

[7] (Sattel, 2016) & (MARSHALL BRAIN, 2001) & (Spiess, ESP8266 Range Test, 2016)

I also looked into different types of recharable battery technology (Appendix A: Research & Findings) which revealed which battery types could hold more charge by their size and weight[8].

SOFTWARE

While researching software my focus was on making device's software use low-power and how to make client-software easy-to-use. I learnt that the ESP8266 has deep-sleep modes that conserver power[9] and summarized key points to minimalistic, user-friendly web design[10] (Appendix A: Research & Findings).

SOURCE ANALYSIS

Three of the most valuable sources were to be evaluated; Maker's Muse[11], Andreas Spiess[12] and Autodesk[13]. They are a young, and an older youtuber, and a company; each has different perspectives on teaching what they share, yet they all succeed in different ways. An OPVL analysis was completed (Appendix B: Source Analysis & OPVL).

PLANNING

PRODUCT SPECIFICATIONS & SUCCESS CRITERIA

When creating success criteria, because I'm building a system, there are many aspects that can be assessed (Diagram 8).

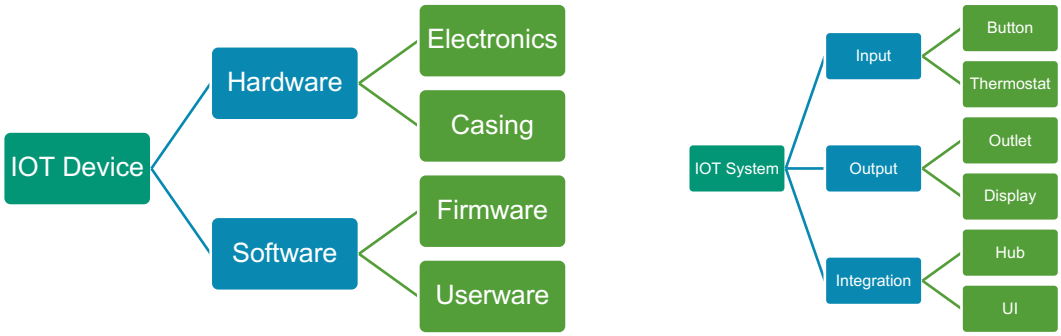

Diagram 8: The different aspects that can be assessed in an IoT system, the topics (left) and devices (right).

Noting that all these aspects should be accessed specific specifications that define characteristics of a high-quality outcome were created. For each topic, what the key research suggested was transformed into a highly-relevant question that could be assessed. Additionally, ACCESSFM was also used, which is a standard assessment for product design[14].

[8] (PowerTech Systems, 2015)
[9] (Spiess, ESP8266 Sleep Modes, 2016)
[10] (Studio, 2017)
[11] (Muse, 2017)
[12] (Spiess, ESP8266 Sleep Modes, 2016)
[13] (Sattel, 2016)
[14] (Marsh, 2017)

	Specification		Score					Average
			Button	Thermostat	Outlet	Display	User Interface	
ACCESSFM	Aesthetics	Aesthetically pleasing?	9	8	8	5	7	6.1667
	Cost	Cheap as Possible	7	6	5	3	-	4.2
	Customer	Easy-to-use as Possible	9	6	9	4	8	6
	Enviroment	Does it enhance it's area?	8	6	9	8		6.2
	Safety	How bad can it possibly go?	10	8	1	6	-	5
	Size	Small as Possible	10	9	7	4		6
	Function	Does it work?	10	9	8	5	7	6.5
	Materials	Is it robust enough?	6	5	4	5	-	4
Electronics	Is it simple to make? Not time consuming?		1	2	5	8		3.2
	Is it easily fixable / replaceable / servicable?		3	4	7	10		4.8
	Is it easy to debug / dev. Interface ?		1	1	2	10	-	2.8
	Is it robust? Or too fragile?		6	5	4	5		4
	Is it long-lasting, high quality?		8	7	5	6		5.2
Casing	Does it print nicely?		7	7	6	3		4.6
	Does it build nicely?		7	8	7	6		5.6
	Will it last long?		7	6	5	6	-	4.8
	Does it accommodate the electronics?		9	9	5	8		6.2
	Is it servicable?		2	2	6	10		4
Firmware	Can it be debuuged remotely?		4	4	2	3		2.6
	Can it be updated remotely?		8	8	2	2		4
	Is it dynamically reconfigurable?		10	10	10	5	-	7
	Is it universal use-case?		10	6	8	7		6.2
	Is it bug-free?		9	8	6	3		5.2
Userware	Does it look minimalistic and modern?		7					7
	Does have as few elements as possible?		9	6	8	4	8	5.8333
	Is it straight forward to use?		9	6	9	5	7	6
	Is it bug-free?		9	9	9	6	9	7
	Is it dynamically scalable?		2					2
		Sum Score	188	165	157	147	46	117
		Average Score	70.36%	63.46%	60.38%	56.54%	76.67%	54.57%
		Average *Science* Score	86.00%	81.00%	60.00%	70.00%	-	59.40%
		Average *Technology* Score	111.00%	84.00%	97.00%	77.00%	55.00%	70.67%

Table 1: Specification Assessment and Success Criteria.

The result was the table beside (Table 1), which shows ratings for each product against all the specifications; allowing for an average success score.

Summarizing research, each device must be:

- a good product design, as assed by ACCESSFM
- the electronics must be easy to interface/debug and repairable/durable
- the casing must come together accommodating the internals
- the firmware must be flexible for remote-reconfiguration
- the user-ware must be easy to use, and scalable.

By not only summing/averaging the scores (rated from 0-10) but also putting each score in a technology(practicality) or science(core-principle) category further insight is gained into how well aspects of the global context were used. This was a significant change of criteria during my project which delivered more perspective, other than moving away from simply using ACCESSFM initially.

This will allow me to access my product myself, however tests with other people will also be run. Asking them specific questions (like the ones in Table 2) to further evaluate my product. Including what they would use my product for, using an industry standard technique called **user-cases**. (As who I want what, so that why)[15]

User Questions
How long did it take you to setup the system?
What would you use this system for?
Is this system useful? Would you buy it?
What's good and what could be improved?
Would it make your environment more practical?

Table 2: User Assessment Questions.

[15] (Pizzolito E. , 2018)

ACTION PLAN & PROGRESS CHECKING, WORK BREAKDOWN & PLANNING SYSTEMS

At the start of the project I made an action plan and a progress checklist, however once reading up on the PP criteria. It became clear that better organisational/self-management skills would be needed. This resulted in the creation of the Work-Breakdown-System (WBS) and the Product-Breakdown-System (PBS). With such systems work that needs to be done and/or components of a product can be broken down into much smaller individual pieces/tasks hierarchically. Combined with specific deadlines and technology-aid (Excel) it is possible to automatically track progress and changes while planning short- and long-term specific tasks. With these systems I can see exactly what is the next small logical step that needs to be done to complete the larger comprehensive PP.

The WBS can be seen in Appendix C: PP & Product Plan. Combined with the process journal and the fillable columns the plan/system can keep a comprehensive record of the process. The usage of the plan shown by the "Actual End Date" and completed columns meant that any changes would automatically be flagged (as late) and would then be justified in the process journal; for example: all the lates marked after 09/09/2018 were caused by shifting the schedule back one week as an unexpected holiday occurred. This system also let me reflect-back on what I had done at any point of the project.

The PBS works much in the same way but keeps track of components of my IoT system that need work rather than work itself (Table 3).

PBS #	Name	Type	Status	Comment
#000-000	IOT System	Other	Waiting	
#100-000	IOT Button	Product	Waiting	
#110-000	Hardware	Assembly	Complete	
#111-000	Electronics	Assembly	Complete	
#111-001	ESP8266 Module	Physical Component	Complete	
#111-002	Li-Po Battery	Physical Component	Complete	Capacity?
#111-004	Voltage Regulator	Physical Component	Complete	HT-7333A
#111-003	Push Button	Physical Component	Complete	Size?
#112-000	Casing	Assembly	Complete	
#112-001	CAD Measurements	Virtual Component	Complete	
#112-002	CAD Design	Virtual Component	Complete	
#112-003	3D Print	Physical Design	Complete	
#120-000	Software	Assembly	Waiting	
#121-000	Firmware	Assembly	Complete	
#121-001	Reconfigurability	Virtual Component	Complete	
#121-002	OTA Updates / Debugging	Virtual Framework	Complete	
#121-003	Core Function	Virtual Framework	Complete	
#122-000	Userware	Assembly	Waiting	
#122-001	Scan (EZ-Link) UUID Link	Virtual Component	Complete	
#122-002	Configuration Parameters	Virtual Component	Difficulties	
#122-003	Factory Reset Parameters	Virtual Component	Complete	Store with JSON

Table 3: Product Breakdown System, breaking down individual components in the IoT system.

In summary, these self-developed systems greatly helped me effectively task and time manage independently. Other self-management skills such as auto-tracking systems helped in keeping me in check. However not all went to plan, and affective skills and perseverance were required. Such as when I had to cancel one of my products, the IoT hub. It was simply too complicated and not practical with the rest of the project logistically (See Appendix D: Issues in the Proccess). A plan does not guarantee

perfection following it. That said my self-management improved significantly through the project, through new strategies such as the breakdown systems to manage such a complex task.

TAKING ACTION

THE PRODUCT & IT'S OUTCOMES

Diagram 9: Process of creating each IoT device… (4 of them)

Once all my materials had arrived from online purchasing and I had planned the functions of each device, I was ready to begin a 9 step process to develop each device, as shown in Diagram 9. This starts with:

1. circuit design using EasyEDA, then
2. I build the circuit on a test breadboard for prototyping, once I am ensured the circuit will work, I move on to
3. making a permanent soldered version, from there
4. I develop the firmware and upload the code to the ESP8266, then
5. I write the software to run on the backend and interact with the firmware, to finish this
6. I debug the code with the help of a serial monitor until all is working, with working electronics I can
7. measure the physical dimensions of the electronics with an electronic calliper to model a Computer Aided Design (CAD) model of the enclosure,
8. this enclosure can then be turned into reality via a 3D printer, the last step is to

9. fit the electronics inside the casing.

This multi-step process that I developed by making many other electronic devices has proven to reliably deliver highly functional and high-quality products, it makes sure all aspects are worked on. In the context of my PP, it has allowed me to meet my outcome successfully; I was able to greatly *develop my skills and understanding of IoT and electronic engineering*. By creating not one, but four IoT devices, as shown in Evidence of Product. I know that I highly achieved my goal because I went from never making an internet-enabled device to making 4 fully functional ones. As proven in Product Evaluation the products comprehensively met most of their extensive criteria(s) for success;

- being small (barely fits in 3D-printed cases)
- functional (actually connects and interacts)
- easy-to-use (single QR code scan to setup [EZ-Scan]).

They succeed at developing my skills (from nothing internet connected to this feat), I managed a working system.

The goal was reached in a very complex way with such a task of building a whole line and system of IoT products, many steps were taken; however, each step can be categorized into either, scientific or technological (as seen in Diagram 9). This splendid match and categorization between steps of the project and the global context allows it to be explored in a much deeper level. By using the science in said steps then making it practical in other steps.

Perhaps the main skill exercised is thinking skills, as this is a critical problem-solving project. It required to transfer learning from other disciplines to tackle circuit design (see Appendix G: Designing the Electronics), because it has many aspects. It took creative skills to build the electronics layout (see Appendix F: Building The Electronics). Software development required the most critical thinking skills (see Appendix E: Software Development), to solve problems and get functional. This was a complicated project that offered an opportunity to practice and improve my thinking skills. Furthermore, having so many different areas within; many specific points of research were applied for each aspect/step.(Further elaborated on: Appendix E: Software Development, Appendix F: Building The Electronics, and Appendix G: Designing the Electronics)

GATHERING IDEAS AND SHARING IDEAS WORTH SPREADING

Although most of my project was just research based, after I hit the problem of having to axe my IoT hub I had to see what I could do where research wouldn't help. This lead me to talking to the school's IT department to gather their ideas on what could be done to fix the issue (See Appendix H: Interactions With I.T.). Gathering their ideas required communications skills which proved very valuable. Other's ideas can often show you something you had never even considered. Working with them I got over a major barrier.

After completing my product, I was inspired by what I had learned and *how much effort it takes to build specialized devices* but also *how rewarding it can be*; I decided this was an idea worth sharing and that I would present a TED talk. In this TED talk I will deliver a speech to a large audience (±400 people) and through online video platforms. By sharing my idea of *Learning to Make*, I will be helping others to succeed and taking responsibility for my own actions and ideas (See Appendix I: Preparing for a TEDx Talk). Planning this talk required deep thought on my personal project and many modes of communication with the TED team, including email, meetings, rehearsal and social media. I have never done any sort of public speaking before and this event shows just how much I developed my social skills from the beginning of the project. My IoT system can be configured to do anything, therefore what **people** use it for is what make it valuable; communication is a key element in making my product practical.

REFLECTING

PRODUCT EVALUATION

My goal was kept the same, except that it was expanded upon to include the improvement of my software design skills, which helped my products meet their criteria.

Since my product was not only meant for me to make but also for users to use; there were two sets of specifications. The specifications for me included things like build time, and debuggability which are irrelevant to the customer. Customer specifications are more question/prompt driven, rather than numerical.

My specifications are based odd ACCESSFM and sections of development (See Table 1). Each product has a sum score that shows not only how each device compares to other devices but also in a percentage how far they are from a theoretically perfect product. On average the five products (button, screen, outlet, temperature logger, and user-interface/backend) scored a percentage of 66% perfect, that is they are only 33% away from reaching a maximum score on all the rigorous and multi-faceted range of specifications. This is impressive as products that meet every aspect extremely well are almost impossible. This shows that the goal of *making a series of IoT devices* was met to a very high level within the categories of general product design (ACCESSFM), electronics, casing, firmware, and user-ware.

However, to meet my goal of improving my product design skills I needed to make a comparison to my previous skills. At around 50% of the creation stage, I stopped to self-reflect by pre-accessing the products I had built so far (See Table 4). Using simply ACCESSFM specifications the improvement in

		Device and Version							
		Pre-PP			Post-PP				
		Button MKI	Display MKI	Thermostat MKI	Outlet MKI	User Interface MKI	Button MKII	Thermostat MKII	Display MKII
Picture									
ACCESSFM	Aesthetics	8	2	8	7	6	10	9	3
	Cost	2	5	5	1	8	5	4	2
	Customer	9	1	7	9	7	9	7	6
	Enviromen	8	8	6	4	8	6	6	6
	Safety	8	6	8	2	10	9	9	7
	Size	10	2	10	7	8	10	9	6
	Function	9	7	6	8	6	8	7	6
	Materials	9	8	9	8	8	9	9	8
Sum Score		63	39	59	46	61	66	60	44
Average Score		7.88	4.88	7.38	5.75	7.63	8.25	7.50	5.50

Table 4: Progression table showing improvements in my products (and skills) from half-way to end of product development…

product scores (and therefor my product development skills) was on average an extra three points from half-way to end of product development. This translates into an improvement of six points from beginning to end of product development, within the context of these specifications that is very significant evidence of developing my skills, as it means that I was not only able to make functional baseline products, but also improve them by 7.5% ((3/80)*2) to form final products. In summary, I went from having medium product development skills and no knowledge in IoT to creating a high-quality system and developing advanced skills in various areas of the project. Therefore, developing my skills to a highly challenging level.

To make an environment more practical with my IoT devices, it was not enough for me so simply access my own products. I had to ask a random selection of test-users to see if it would in their minds have the potential to make an environment more practical. To do so I demonstrated, used, and interviewed my product to a wide selection of eight users; ranging from ages of 15 to 44. I guided them towards the prompts in Table 2 after they tried my system for themselves (See Appendix J: PP Exhibition

Planning & External User Feedback for raw interview data of most significant responses.). The results from this real-user testing are summarized & justified in Table 5 below.

Specifications	Achievement	Justification
Ease of Setup /Configuration	Users who had an idea of use in mind (75%) said that they would be able to in not a very long time (within 30 mins). However, others thought that the system lacked some guiding instruction or pre-sets for use-cases (12.5%).	Three quarters of the users being able to find a use shows that the product was highly successful in making itself easy to use. Meanwhile, the rest might simply not be used to this new technology or weren't able to use the product.
Usability, Commercial worthy?	50% of users were new to the technology and had some trouble finding a personal use, while 37.5% of users who have used IoT systems before were overwhelmed with the possibilities of such an open and versatile system. 62.5% found a personal use for the system as is, and 37.5% would use it with a slight tweak (eg. Bigger display, faster response). 25% of users found that the idea was viable for commercial production.	The majority of the users, even those who had used IoT before were surprised by the versatility of the system, showing the high level of innovation achieved by the system. Some users needed tweaks for their application which is inevitable for such a system, but one user even offered to (financially) support this system if it was to go into production. This demonstrates that the product has reached a level of quality that can be seriously considered for further commercial development.
Aesthetics / Build Quality	75% of users liked the prototype aesthetics and the retrofittable/universal ability of the system to work with anything. 37.5% suggested improvements to portability, usability and security.	As successful of a prototype this system has proven to be. There are still improvements to be made in security and specific user cases.
Impact on environment practicality	62.5% percent agreed that it would make an environment more practical. 25% thought that minor tweaks were needed, or they didn't find a clear enough use-case to answer.	Having a majority agree that the system would truly make an environment more practical shows that it has true potential to meet its highly challenging goal in a real-life application.

Table 5: Summary of real-user product testing sessions, with 8 users.

This real-user evaluation shows how far I've come in meeting not only my goal (developing skills) but also delivering a product that is able to make environments more practical to provide a highly successful outcome. Not only in my opinion, but also in the views of various others. This extended testing with me and other's opinions is the most appropriate manner to test a product intended for versatility and multiple users.

That being said there are improvements that could be made (as suggested above), including if this project was going to progress to mass-production and sales. The major concern brought in by my test

users was that of security; as is, anyone can access the system without authentication. This proves effective for a prototype where accessibility is more important, however for a production-run this must be changed and security must be uptight, a high priority in the reputability of such an IoT system. Other changes include shifting even further away from designing this system for myself and moving closer to designing this system for a wider user range. Increasing the size of the devices can make them more accessible to elders and other extra features can make the system more useful to more people. If choosing to repeat this project, I would work closer with my user-base to develop something that is even more useful for more users than the current outcome/system is.

REFLECTIONS ON KNOWLEDGE & UNDERSTANDING

I have substantially expanded my knowledge of electronics, product design and IoT. Before starting my project, I had to research into each specific step of product design; from planning, hardware, software, user interface to implementation. One specific example of where I learned in-depth information about the topic was when I found out the six different programming languages commonly used for frontend and backend web-design. This showed me how complex web systems can get but also the interactions needed between each 'layer' to build a functional system. Each 'layer' requires a whole different set of requirements, technique and mind-set to design (See Appendix E: Software Development). Previously I looked at systems as a whole, but this taught me to break down systems to less complex 'layers' and work from there, greatly speeding up development and simplifying the process. I will definitely transfer this idea to other areas of work.

The global context of *Scientific and Technical Innovation* played a major role within my project. This is the first time that instead of simply innovating technology for my own use, I also had a very strong focus on making it practical and usable by anyone. This opening up of my project to public/client use strongly encouraged practicality which is what turns science into tech (see Global Context). For example, if only I were to use the system I would simple have hard-coded all the parameters/configuration straight into the firmware of my devices, however this reach for usability lead me to create not only a full web-site/sever backend but also a simple-to-use and accessible online user interface. This shift to ease-of-use greatly expands the versatility of my product(s). Making both *Tech* and *Science* essential parts of my project greatly boosted my understanding of not only why these are grouped together but also the practicality and satisfaction in bringing a product to real uses and users.

REFLECTIONS ON SKILLS AS A LEARNER

Through this project I have extended my transfer skills, as while developing my IoT devices I had to gather and use knowledge from physics, design, math and many other areas to work in fields that I have never worked in a combined way before (website, web-backend, web-client, firmware, config-code, SQL). This was a major challenge and transfer skills to make these parts interact functionally was the vital solution. A weakness of mine would be that of communication and social skills, I am naturally shy; but as my project is a system for other users it was essential that I communicate with others. Through the project I strengthen my communication skills by collaborating with the IT, inviting a range of people to test my product and by sharing my ideas through a public-speaking TEDx speech (TED, 2019). My strength has always the ability to acquire and apply knowledge, however after this project and especially my public speech, I have gained more confidence to share my knowledge; something that is helpful not only for me but for others. I have the characteristics of a *thinker*, *inquirer* and *knowledgeable* (from the IB Learner Profile). In this project I have trained my skills of *communicating* (TED), *risk-taker* (TED) and *reflecting* (self-evaluating). I further exercised my skills by planning the PP exhibition night along with one other student, we collaborated and shared our organizational skills with the rest of the grade (34 students). This was in form a planning spreadsheet (See Appendix J: PP Exhibition Planning & External User Feedback).

This project has taken my skills to the next level, as not only did I conceptualize a product, I went forward to build a whole product line of prototypes and test it with actual users. This is the closest I have ever been to creating a real commercial product and the systematic approach taken in my PP is something that will be kept and impact my future in product development. This includes the use of work/product-breakdown-systems, separate user and creator specifications, definition and breakdown of steps required to reach the outcome, multi-faceted goal targets, and communication to share ideas; that

are to be used in all future projects and/or complex tasks of mine, whether for school or commercial/non-profit uses.

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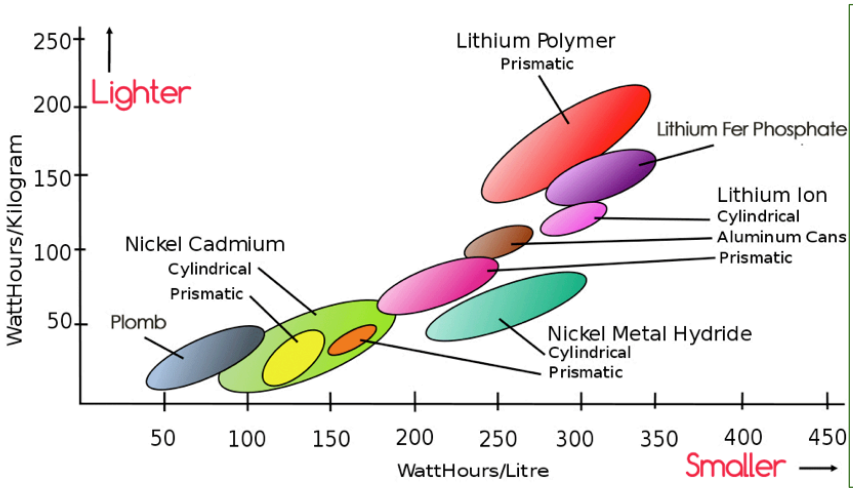
APPENDICES

APPENDIX A: RESEARCH & FINDINGS



Graph 2: Battery weight (Wh/Kg) and battery size (Wh/L) power capacity compared for different battery technologies...

Looking at Graph 1, we can see that lithium-polymer batteries have the highest power density meaning that they carry the most power per weight/size. This makes LiPo (Lithium-Polymer) batteries the best choice of my application of small, but long lasting IOT devices; according to *PowerTechSystems*'s webpage. Combined with low power microcontroller routines and sleep cycles as shown by *Andreas Spiess* in his YouTube video, I can use the information from these two sources to maximize the battery life of my IoT devices.

Journal Extract: Research: Scientific Principles

- Collecting and analyzing data to identify solutions and make informed decisions
- Comparing, contrasting and drawing connections among (multi)media resources
- Drawing reasonable conclusions and generalizations
- Make inferences and draw conclusions

Here I take information from multiple sources (Webpage & YouTube Video) and make connections between them, to make a decision to use Lithium-Polymer batteries for my IoT products.

UI (User Interface) design is going to be a main part in my PP, since the goal is to make my system so easy to use anyone can do it. When researching what a minimalistic GUI (Graphical User Interface) should and shouldn't have I boiled it down to the following key points:

Do's	Dont's
• Simplicity • Clarity • Visual Hierchy • Element Functionality • Spare Space • Typography • Flat Desgin • Limited Colour Pallete • Intuitive Navigation • Grid Adaptive Layout	• Unecesary Elements • Generic Design • Multiple Focal Points • Clutter

Diagram 9: Key points in minimalistic UI Design...

By looking at the examples below, you can see most if not all of the points from the list:

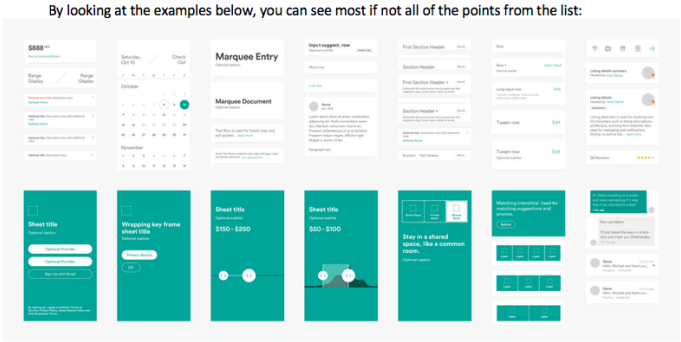


Image 12: Examples of minimalistic UI design...

The main jist of minimalistic design is to put form over function, keep the number of elements low but keep it functional.

Journal Extract: Research: Software

- Using critical literacy skills to analyze and interpret media communications
- Processing data and reporting results
- Interpreting data
- Paraphrase and take effective notes

Here I report the results from my research into minimalistic UI design. To do so I analysed and interpreted the media that I've researched and referenced in order to create a list of do's and don'ts summary for what to and not to do.

APPENDIX B: SOURCE ANALYSIS & OPVL

Source	Maker's Muse	Andreas Spiess	Autodesk
Origin	This is a YouTube channel with 350k subscribers. It is a primary source as everything was learnt 1st hand with the owner's own 3D printers.	This is a YouTube channel with 95k subscribers. It is a primary source as it is simply Andreas Spiess sharing his engineering expertise with the world, through videos.	This is a multinational American software industry with $2.03 billion yearly revenue. It supplies engineering and design software such as Fusion 360 and many educational platforms such as Instructables.
Purpose	The purpose of this channel is to educate others on 3D printing based on the owner's own experiences.	The purpose of this source is to inform not only engineering information but also to teach concepts and ways of design thinking. Andreas Spiess teaches you how to think like and engineer.	The purpose of this company other than profit is to make design achievable for everyone. Their software is awesome and mostly free for non-commercial purposes. They have a huge focus on education, and their global communities of engineers make for a very comprehensive source for anything design related.
Value	This is valuable because it is unbiased and does not intend to promote anything, just to inform.	This holds value because Andreas is an experienced Swiss engineer that has worked in the field for many years. He can be considered an expert on many topics.	Autodesk is especially valuable because they open up a door for anyone to participate in design, from beginner to expert. This means that they are rich in different perspectives, their community focused forums together with their normal pages make it a comprehensive and varied source.
Limitations	The owner has a different printer than me there for some of the things may or may not apply.	Although his design thinking lessons can be applied to anything, his solutions may not be the best for my situation. Just because someone experienced suggests it, it doesn't mean it's the best solution for my case specifically.	This is still a company that needs to make profit, any of their non-educational articles may be biased to increase sales.

Journal Extract: Research: Source Analysis

- Seeking a range of perspectives from multiple and varied sources
- Demonstrating awareness of media interpretations of events and ideas
- Evaluating sources
- Recognizing assumptions and bias in sources
- Considering ideas from multiple perspectives

Here I make an OPVL analysis out of three sources that I've used during my research. Just in this comparison table I've seeked different perspectives as they are sources from different types of people; Maker's muse being a young 3D printing enthusiast, Andreas Spiess being a n older experienced engineer and Autodesk being a multi-billion-dollar company. I also show awareness of the different interpretations of media by each source/person, especially on the 'Purpose' row. The first two YouTube channels idea is to educate with different levels of experience meanwhile Autodesk is also in for a larger profit, but also a different overall goal.

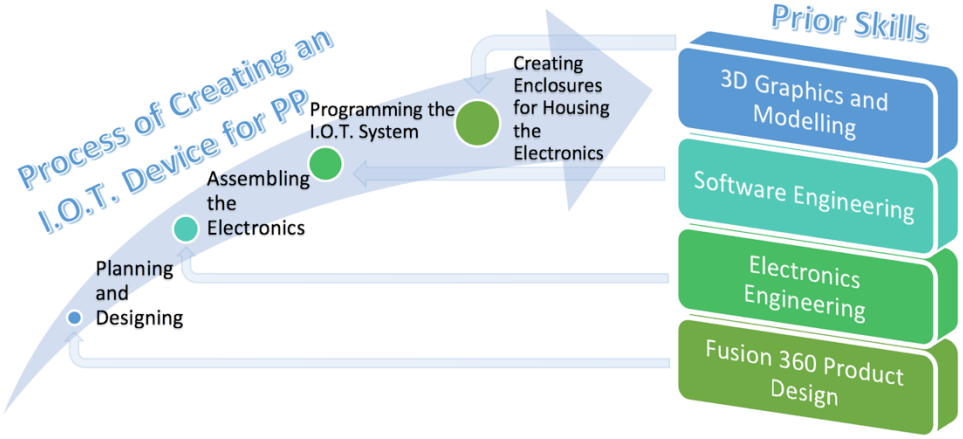


Diagram 2: Diagram showing the connections between my prior skills and the steps in the process of creating an I.O.T. within my PP...

Journal Extract: Prior Learning

- Communicating information and ideas effectively to multiple audiences using a variety of media and formats

Here I created a combination of visual diagrams/illustrations to effectively communicate how my prior skills will play a part in creating IoT devices for my personal project. By using such a visual it can be understood by a larger audience.

APPENDIX C: PP & PRODUCT PLAN

Task			Criteria				Time Constraint						Documented			
Object	Section	Task	Criteria	Strand	Self-Check	Supervisor Check	Week Number	Planned Start Date	Planned End Date	Actual End Date	Complete	Late	On GD	On Word	On MB	On Report
	PP Day				-		36		05/09/2018		1	No	Yes	Yes	Yes	-
Journal, Project, Goal	Brainstorm Ideas	Make Mind Map	B	2, 3	Yes	Yes	36	05/09/2018	08/09/2018	22/09/2018	1	Yes	Yes	Yes	No	No
		What topics can connect to subject-specific knowledge?			Yes						1	Yes	Yes	Yes	No	No
		What will maintain your interest for the next 10 months?			Yes						1	Yes	Yes	Yes	No	No
		What will expand your learning beyond the school walls?			Yes						1	Yes	Yes	Yes	No	No
		Pick Best Idea			Yes					05/09/2018	1	No	Yes	Yes	Yes	No
	Identify Prior Learning	Find Prior Learning	A	2	Yes	Yes	37	09/09/2018	15/09/2018	22/09/2018	1	Yes	Yes	Yes	No	No
		Identify and list knowledge gathered from specific subjects that relate to your topic			Yes						1	Yes	Yes	Yes	No	No
		Outline Research		3	Yes		39	23/09/2018	29/09/2018	05/10/2018	1	Yes	Yes	Yes	No	No
		Generate a list of general questions you have about this topic			Yes						1	Yes	Yes	Yes	No	No
		Research answers to your general questions and identify a clear, focused, topic			Yes						1	Yes	Yes	Yes	No	No
		Create specific questions to guide you through your research phase			Yes						1	Yes	Yes	Yes	No	No
	Define Your Goal	Sentence Form (To... By... [For...])	A	1	Yes	Yes	36	05/09/2018	05/09/2018	06/09/2018	1	No	Yes	Yes	Yes	No
		SMART			Yes		38	16/09/2018	22/09/2018	25/09/2018	1	Yes	Yes	Yes	No	No
		Basic			Yes						1	Yes	Yes	Yes	No	No
		Challenging			Yes						1	Yes	Yes	Yes	No	No
		Highly-Challenging			Yes						1	Yes	Yes	Yes	No	No
	Select Global Context	What do I want to achieve through my PP?	A, C, D	1, 1, 2	Yes	Yes	36	05/09/2018	05/09/2018	24/09/2018	1	Yes	Yes	Yes	No	No
		What impact do I want my project to have?			Yes						1	Yes	Yes	Yes	No	No
		From what perspective do I want to approach?			Yes					05/09/2018	1	No	Yes	Yes	No	No
	Investigate Defined Goal	Execute and Discuss Research	A	3	Yes	Yes	40	30/09/2018	06/10/2018	09/09/2018	1	Yes	Yes	Yes	No	No
		1 Question, Answer, Question... Cycle			Yes	No					1	Yes	Yes	Yes	No	No
		Various Types of Sources			Yes	No				01/11/2018	1	Yes	Yes	Yes	No	No
		OPVLC on all Sources			Yes	No				01/11/2018	1	Yes	Yes	Yes	No	No
	Create Specifications	Create an assesment system	B	1	Yes	No	41	07/10/2018	13/10/2018	03/11/2018	1	Yes	Yes	Yes	No	No
		What do I want my outcome to be?			Yes	No				01/11/2018	1	Yes	Yes	Yes	No	No
		How will I demonstrate a "high quality" product?			Yes	No				01/11/2018	1	Yes	Yes	Yes	No	No
		How am I going to test my product?			Yes	No				01/11/2018	1	Yes	Yes	Yes	No	No
		What is the difference between a successful outcome and an unsuccessful			Yes	No				05/11/2018	1	Yes	Yes	Yes	No	No
		Test and evaluate my product within my chosen global context			Yes	No										
	Develop a plan	Create Master ToDo Checklist		2, 3	No	No	42	14/10/2018	20/10/2018	05/11/2018	1	TBD	No	No	No	No
		What major steps do I need to take to complete my product?			No	No				TBD	0	TBD	No	No	No	No
		What resources do I need to develop my product?			No	No				05/11/2018	1	TBD	No	No	No	No
		Create Master Tracking Action Plan with Excel			No	No				TBD	0	TBD	No	No	No	No
		What is the timeframe for completing each step of my product?			No	No				TBD	0	TBD	No	No	No	No
		Is my plan logical and feasible?			No	No				TBD	0	TBD	No	No	No	No
		Which research did I use to create my plan and why?			No	No				05/11/2018	1	TBD	No	No	No	No
		Does my plan allow me to meet my evaluation criteria?			No	No				05/11/2018	1	TBD	No	No	No	No
		How does this plan allow me to develop my understanding of my Global Context??			No	No										
	Taking Action	Create a product	C		No	No	44	28/10/2018	13/12/2018	TBD	0	TBD	No	No	No	No
		Which research was applied, and how was it applied to your product?			No	No				TBD	0	TBD	No	No	No	No
		What decisions were made based on which resources?			No	No				TBD	0	TBD	No	No	No	No
		What were the solutions to problems you encountered, and how did you develop each solution?			No	No				TBD	0	TBD	No	No	No	No
		What were the results of trial and error, and how did you use this information in the development of your product?			No	No				TBD	0	TBD	No	No	No	No
		How did the research and development of your product fit your chosen Global Context?			No	No				TBD	0	TBD	No	No	No	No
		Evaluate the outcome of your product		1	No	No	3	15/01/2019	26/01/2019	TBD	0	TBD	No	No	No	No
		How did my product rate against my specifications?			No	No				TBD	0	TBD	No	No	No	No
		Was my testing method the most appropriate method for my product?			No	No				TBD	0	TBD	No	No	No	No
		If I were to complete my product again, what specific changes would I make and why?			No	No				TBD	0	TBD	No	No	No	No

Table 3: PP Work Breakdown System, used for tracking and planning...

That's the point where I opened Excel and begun making a ***Work Breakdown System***, where each item is placed with its sub-items next to it and dates can be put for the time periods, I have to complete said task. The clever part in using Excel is that I could add columns where I fill in what stage of each task I am at. I can now not only see what tasks I need to do and when, but I can see if I'm getting behind and which tasks I've completed. This has proven to have been very useful and has even resulted in me having a whole PP progress bar through my PP.

Journal Extract: Detailed Plan: PP Plan

- Having a detailed plan for the completion of the project
- Planning strategies and actions to achieve the goal
- Meeting deadlines
- Setting goals that are challenging but realistic
- Selecting and using technology effectively and productively

Here is the core of my PP, my detailed plan of everything that needs to be done, my deadlines, goals that need to be met and strategic breakdown of every task that needs to be done. By effectively using spreadsheet technology to my advantage I can automatically keep track of my percentage progress, late tasks, level of documentation or even criteria and review checks. Without this nothing would happen.

APPENDIX D: ISSUES IN THE PROCCESS

Cancelling the Hub, Starting new remote backend

Image 13: Cancelled Hub device...

Originally, I was hoping to have a hub device, this would act as a central server to communicate with and manage all the other IoT devices. This was going to be so that by decentralizing from other services the whole system would be able to be self-hosted and work more smoothly. However, this quickly proved impractical. Firstly, the C++ code running on the hub was really complex due to not only having to manage incoming connections from devices but also outcoming connections to external service websites, furthermore this was only complicated by having to manage and SD card and file system to store logs and device data. I decided to just be resilient and accept the hub as a failure without much disappointment, it could always be re-purposed later. I shifted my focus onto coding PHP, JS, CSS & HTML to run on a real webserver hosted by a free service. This way I could write higher level code to do all managing and integrate all functions into a configuration website which people can access through the QR codes on my devices. A major improvement that resulted from perseverance through a failed device/product; which I have now titled the "EZ Setup" system.

Journal Extract: Creating the Product: Issues: Cancelling the Hub

- Perseverance and persistence
- Self-motivation and positive-thinking
- Resilience – the ability to deal with mistakes, failures, disappointment, change.

Here I cancel a major part of my system a centralizing hub device, which I simply had to live with and persevere through all the changes.

Printer's Broken Heating Element

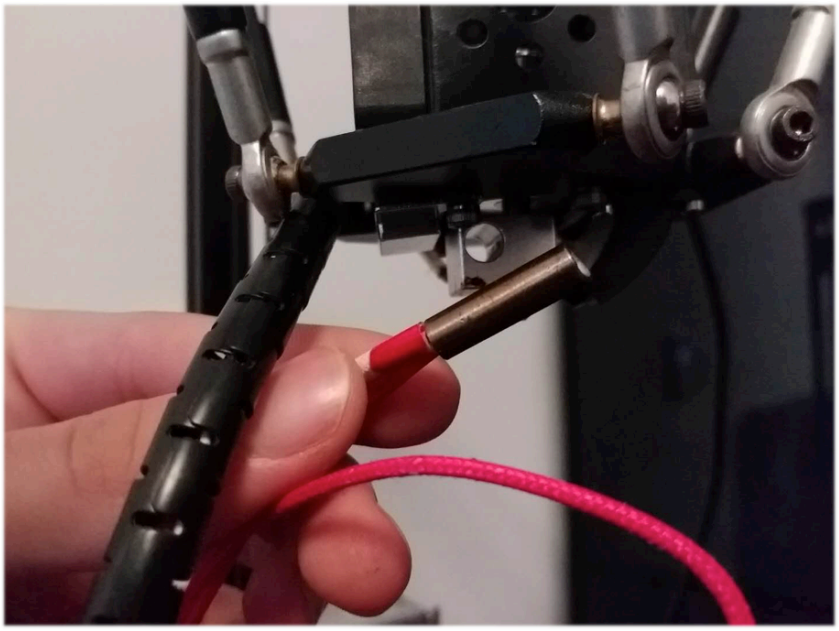


Image 14: Burnt 3D printer heating element...

Disappointingly, my 3D printer's heating element burnt out before I had the chance to printout the case for my IoT screen / info device. This was a complete halt in production as I am still waiting for another heating element to arrive through the mail.

As much of a bummer as this was, I had to keep thinking positively, as there is nothing else to do while waiting for another to arrive. Looking at this positively, with the printer being down this gave me time to work on my report and other PP documentation. Persisting from the first time I noticed the printer was losing temperature on the extruder mid print actually taught me some new skills. Before I knew it was a burnt heating element I had to trouble shoot and with a multimeter test the resistances of all the temperature sensors and heating elements to see what had gone wrong.

Journal Extract: Creating the Product: Issues: Cancelling the Hub

- Perseverance and persistence
- Self-motivation and positive-thinking

Here I had an issue where my 3D printer which is a vital tool for making the enclosures for my devices failed. After troubleshooting the printer to find the problem, it was a burnt-out heating element. Leaving me with nothing to do other than keep my motivation, while a new element is shipped by mail for replacement.

APPENDIX E: SOFTWARE DEVELOPMENT

Programming Software and Firmware (Critical)

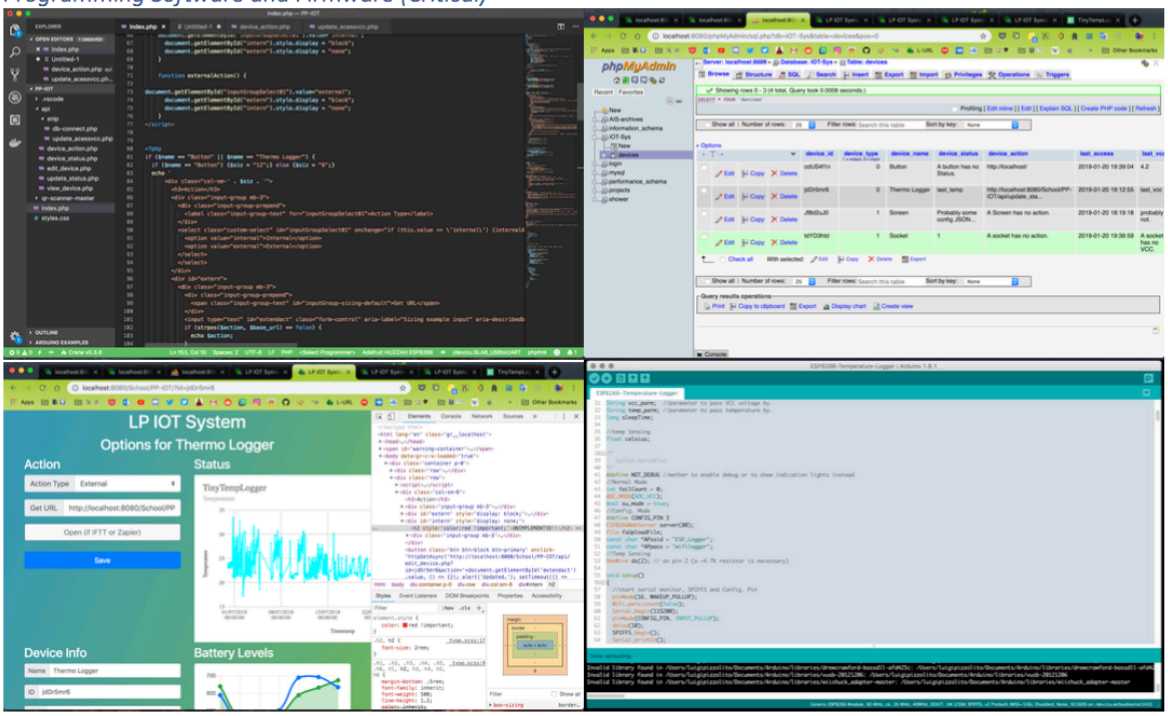


Image 16: Collection of images of Software & Firmware development... (From top left to bottom right: PHP/HTML/JS, SQL, CSS, C++)

From the software and Graphical User Interface (GUI) research I conducted, I identified that I would have to use many programming languages to bring my system to functionality; including PHP, SQL, HTML, JavaScript, CSS and C++, furthermore firmware has to be as fast as possible and go to sleep after execution to save the battery life of my devices and the backend has to interact with the devices via the technology of AJAX requests. GUI research told me that it should be simple to use and how I can make it so. However, none of this told me how to actually implement what is said above, it was up to me to revise my own understanding based on the new information I gathered from my research and to formulate questions so that I could conduct very specific searches to quickly overcome the obstacles I recognized along the process. For example, I hit an obstacle finding where in my server and how to store device information, after formulating a question I quickly found multiple solutions; creating a file on the server's filesystem, using an external service, creating a MySQL database that executes SQL code; after evaluating these solutions I choose the SQL database option. When reaching an obstacle in software design, evaluating a variety of solutions was an essential step, this is specially of great importance because there are many considerations as there is a huge difference between client code (HTML, JS, CSS)(Image 16: top-left and bottom-left pictures) that runs on a user's computer, back-end/server code (PHP, SQL)(Image 16: top-right picture) that runs on my server behind the scenes and firmware (C++)(Image 16: bottom-right picture) that runs on my actual IoT devices. User code has to load as quickly as possible, be seamless and work without glitches, Server code needs to work reliably and without fail, firmware needs to be resource-light due to the limitations of the tiny microprocessors (Computers have over 100x the processing power of an ESP8266) and has to run as fast as possible to conserve power. In summary it takes a lot of thought-driven critical thinking to bring the concepts researched into reality within software development.

Journal Extract: Creating the Product: Programming Software and Firmware

- Recognizing or identifying problems, obstacles or challenges
- Formulating arguments
- Revising understanding based on new information
- Formulating questions
- Proposing and evaluating a variety of solutions

Developing the software and firmware, also known as the code, that will run not only on my IoT devices themselves but also on the computers/phones of my clients and the back-end in my server was the part of my project that most required critical thinking skills. This is because to actually implement the concepts learned in research in functioning software a considerable amount of formulating of questions, research, evaluation of solution and implementation is needed to make it actually work. The complexity of using six programming languages heightened the importance of this.

APPENDIX F: BUILDING THE ELECTRONICS

To help me guide my research I can make a hierarchical list, breaking down the different topics in my PP and general questions which I will need to research and answer to complete my PP. By breaking down each topic into multiple smaller questions, multiple times to form multiple levels of research. This will show alternative options that could not be seen before, bringing new ideas.

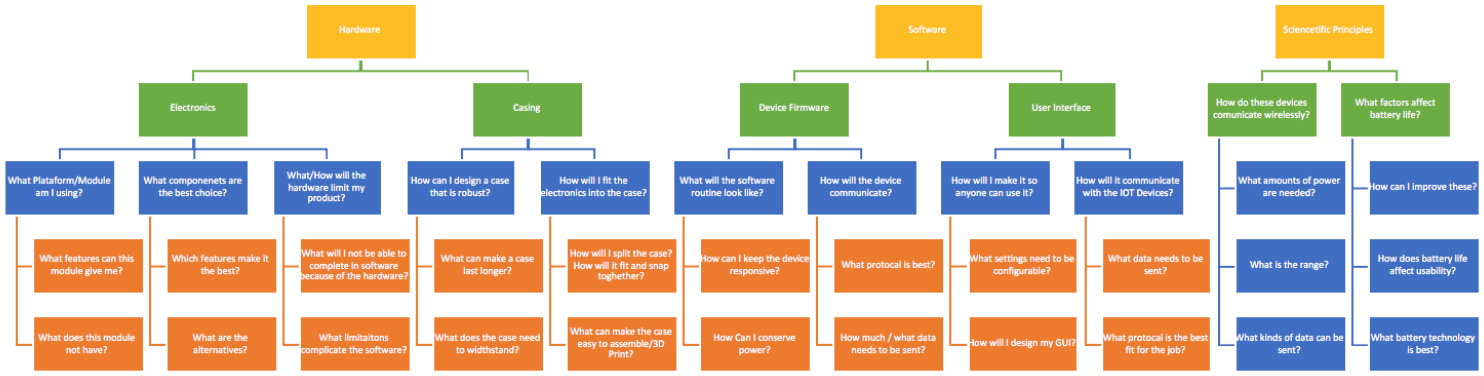


Diagram 5: Hierarchical breakdown of the topics and questions I should research...

Journal Extract: Outline Research

- Brainstorming or visual diagrams used to generate ideas or inquiries, or visible thinking strategies or techniques
- Considering multiple alternatives – even those that may seem impossible
- Organize and depict information logically

Here I brainstorm each area and sub areas of topics that I need to research, taking the form of a hierarchical list/diagram. By spreading my ideas by subtopics like this I can help myself to generate new ideas by looking at my research in a more broken down and distributed form. With this breakdown I can also help myself to consider other alternatives, that I would not have come up with without such a hierarchal breakdown.

Building the Electronics (Creative)

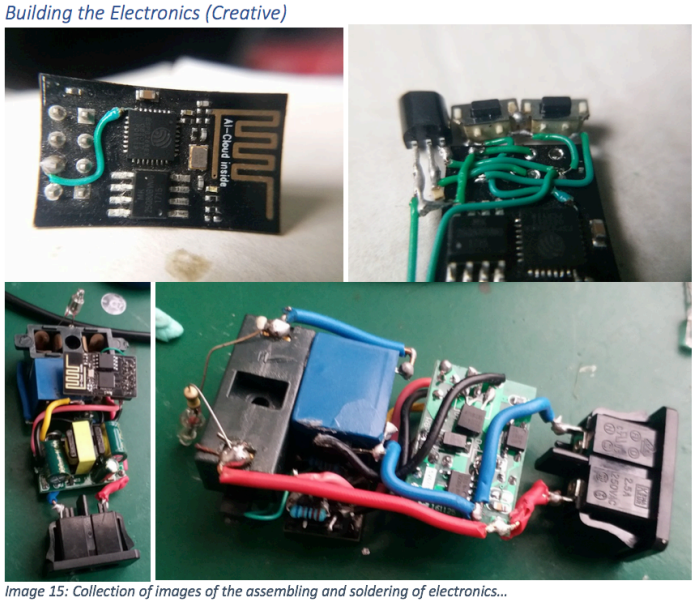


Image 15: Collection of images of the assembling and soldering of electronics...

Actually, soldering the electronics and connecting together the different components, is perhaps one of the more time-consuming aspects of this project. Not only do you have to make sure all the components have wiring as shown in the schematic, you also have to build it within a nice form factor. Usually this is done with a Printed Circuit Board (PCB), however since one of my requirements is to make the devices as small as possible, I came up with the unusual idea that I can simply solder the components with wire directly, without a board; this is called "dead-bug" style construction. I believe that it takes a lot of creativity when creating layout that's compact and a lot of skill when soldering a compact layout that still needs to be functional, you may have less than a millimetre tolerance to solder between. This intricate combination of complex assembly and delicate layout work, in my opinion creates some of the most novel solutions and original products, for example my IoT button might just possibly be the world's smallest IoT button of its kind. Furthermore, existing concepts such as logging of temperature readings can be reworked in a completely new way, with a tiny little box that is in fact an IoT device for the purpose. These decisions of compactness and novelty made on the basis of making novel and unique devices if executed without failure, can make very nice and neat products that may even be considered an improvement to existing alternatives and other technologies in the same field.

Journal Extract: Creating the Product: Building the Electronics

- Making unusual connections between ideas or objects
- Designing improvements to existing technologies
- Creating novel solutions or original works and ideas – or using existing works or ideas in new ways

Creating the electronics is a trivial part of creating electronic devices, what might not be so obvious is that creating a layout of how the electrical components will be arranged inside the device requires extensive creativity. Not only are you trying to reach the goal of a compact overall assembly for your product, but you also absolutely must meet the goal of making sure all the wired connections are made for your device to function. Doing such a feat involves keeping the wiring work within your skill level and being creative to come up with an efficient layout.

APPENDIX G: DESIGNING THE ELECTRONICS

Designing the Electronics (Transfer)

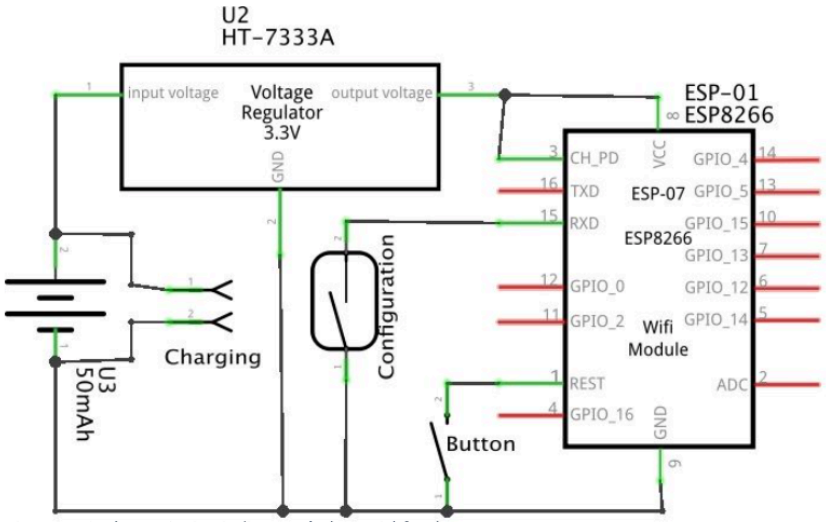


Diagram 13: Electronic circuit diagram (Schematic) for the IoT Button...

To design the electronics, I had to apply the research I did into the ESP8266, radio-communications and battery technology to an unfamiliar setting of a tiny IoT device. There are a lot of things to consider when designing electronic circuits, the small but powerful LiPo batteries which use their chemistry to create energy need to be handled properly to ensure safety. For example, voltage regulators were used to reduce the 4.7V of the battery to 3.3V that is suitable for the ESP8266. You have to take into consideration the physics behind how each electrical component will interact with electrical energy to make sure nothing goes wrong. Furthermore, to ensure a working circuit, physics knowledge can be combined with scientific knowledge of the scientific method; to run trials-and-find-errors to see if the circuit is truly functional in real life. Since I had only done simple microcontroller projects before, adding in WiFi capability really encouraged me to learn a whole new kind of technology and completely changed the context of the power a small electronic device can have in what it is capable of doing. IoT design completely changed my perspective on what small electronic devices are able to achieve. Designing electronics takes multiple skills merged from many different disciplines, including chemistry, physics, design, science among others.

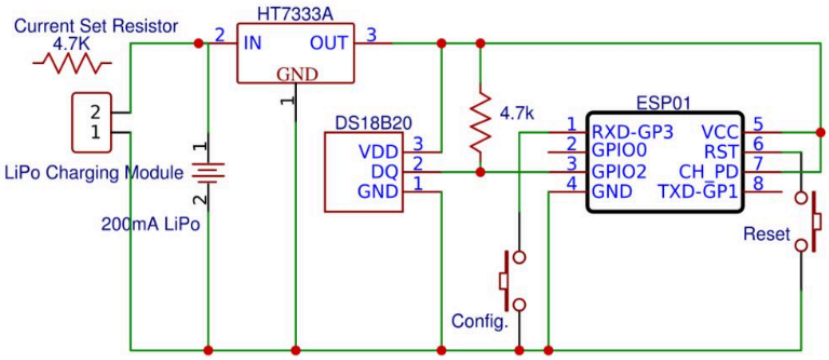


Diagram 12: Electronic circuit diagram (Schematic) for the IoT temperature logger...

Journal Extract: Creating the Product: Designing the Electronics

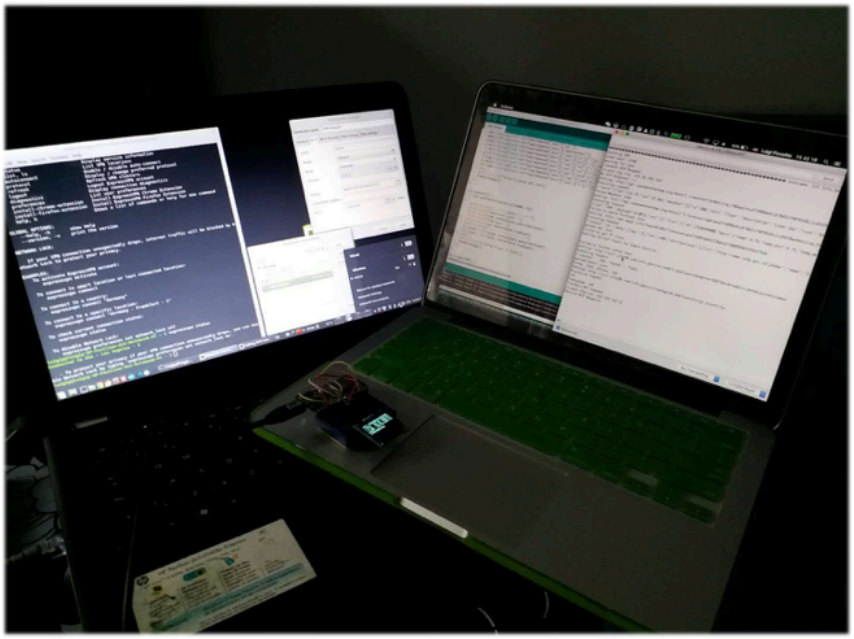
- Applying skills and knowledge in unfamiliar situations
- Comparing conceptual understanding across multiple subject groups and disciplines
- Combining knowledge, understanding and skills to create products or solutions
- Transferring current knowledge to learning of new technologies
- Changing the context of an inquiry to gain different perspectives

I used transfer skills when designing the electronic circuits behind my IoT devices because designing electrics is a very complex task; where many aspects from many different disciplines are combined into the art of electronics. Furthermore, since this project was the first time, I was working with Wi-Fi enabled electronics, I transferred all my previous knowledge into the learning a new technology. Simply changing the context of my electronic devices by adding Wi-Fi capability allowed me to gain a whole new perspective on what small electronics devices are capable of.

APPENDIX H: INTERACTIONS WITH I.T.

Interactions with the IT (Information Technology) Department (Communication)

After I decided to axe my hub device from my line of products because it wouldn't be practical, it created more problems. To replace the hub, I would use my own web server but that meant that for my devices to be able to access it they would have to connect to a wireless access point (AP). This means that wherever I want my devices to work there must be a wireless router with simple WPA2 (password only) encryption. To make this work at school I collaborated with Mr. Barder, the IT director; after I shared my ideas he gave me feedback in what I should do, program my devices to work and then later talk to the network administrator to set up an AP just for me. Later I talked to Mr. York, the school's network admin, I negotiated my ideas for a solution with him and we reached a conclusion to install a router in the place where I would be presenting my PP. With his help I was able to get a router working at school, providing an AP for my products, and there for allowing my whole system to work for demonstration and testing. My communication skills in being able to explain these technical requirements to Mr. York even with a language barrier was a major factor in the success of my product, it affected key functionality, it was make or break.



Journal Extract: Creating the Product: Interactions with the IT (Information Technology) Department

- Giving and receiving feedback (not necessarily only from their project supervisor)
- Negotiating ideas and knowledge with peers, teachers or others (possibly as part of research)
- Collaborate and share ideas (may be part of the product)
- Structure information in the written report

Here I show the process I went through to fix some of the problems cause by the cancelation of my IoT hub. Since I was now using my own webserver elsewhere as the moderator for all these devices it meant that the devices needed a wireless access point (AP) in order to connect to my webserver back-end and establish communications, furthermore it must be secured using WPA2 (simple password only) encryption in order to be compatible. This requirement led me to communicate with the IT department, including the network admin to get this AP setup.

APPENDIX I: PREPARING FOR A TED^{X} TALK

Preparing for a TED^{x} talk (Social)

Image 17: TED talk guide and TED talk stage, with the infamous red circle…

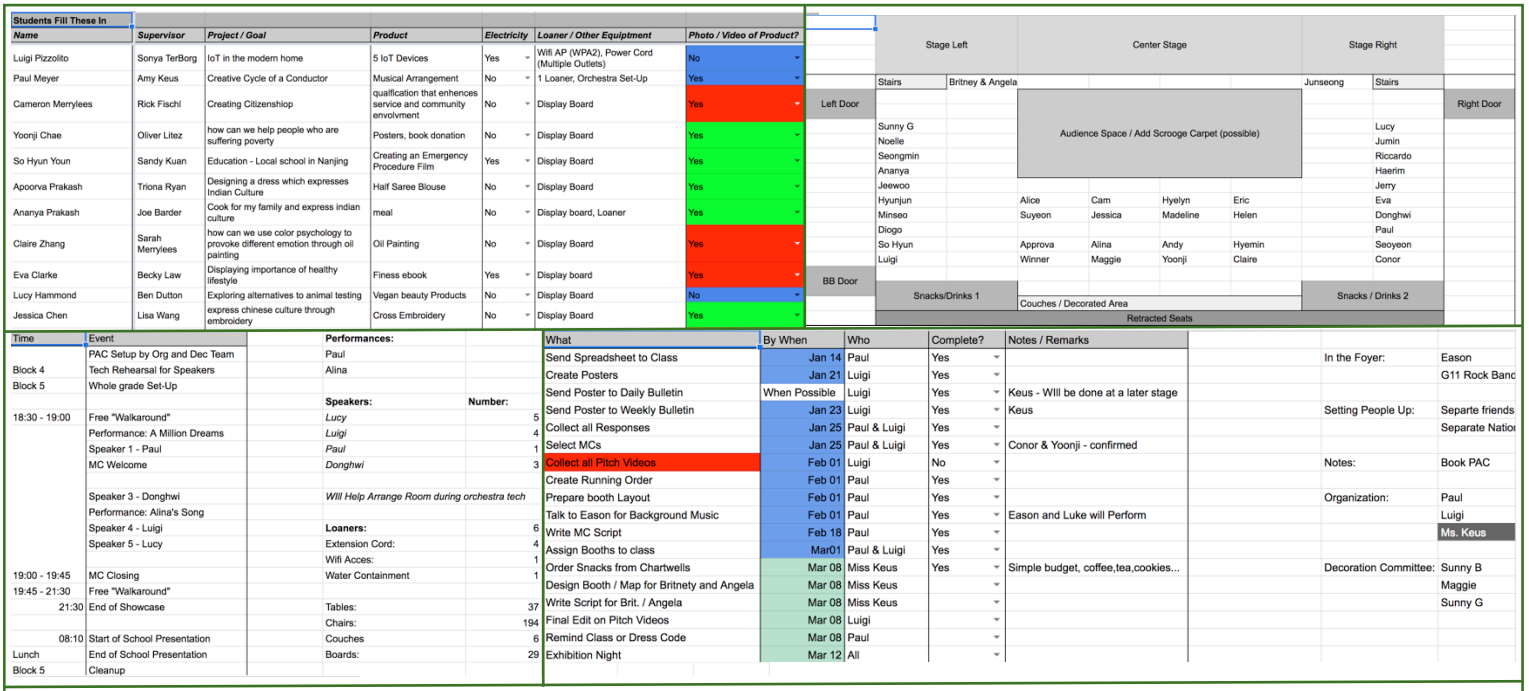
As an extension to my personal project, I will be presenting a TED talk. In this talk I wish to help others to succeed by sharing my own experiences of using learning to create things, rather than just for the sake of it with a focus around my custom IoT system and creating your own products rather than just buying them. I hope to emphasize with the audience showing them that ready-made products aren't always the best option and then have them emphasize with me when I present them the alternative; learning to create your own products. Public speaking has never really been my thing; however, I believe that I can achieve it if I put my mind to it. Another big part of TED is taking responsibility for your actions, as not only will whatever you say be recorded on the TED website and YouTube forever, if you plagiarise you will solely be responsible by contract for copyright and other kinds of disputes. This enforces upmost original and quality work to be shared. I also hope to make this talk two-way by getting the audience involved; by asking them questions and having them do quick "raise your hand if" style polls not only can I share my idea but also gather their perspectives on it. Furthermore, the rehearsal process includes practicing by presenting to the other TED speakers and receiving meaningful feedback and giving it to others.

Journal Extract: Creating the Product: Preparing for a TED^{x} Talk

- Demonstrating empathy
- Helping others to succeed
- Taking responsibility for one's own actions
- Listening actively to perspectives and ideas of others
- Giving and receiving meaningful feedback
- Using appropriate speaking and written techniques for dealing with different audiences
- Write for different purposes

During the project I sought for meaningful feedback from my supervisor many times, as can be seen by the addition of the "Supervisor Check" column back in my Work Breakdown System (Appendix C). Listening to her perspectives and ideas every time. However, I wanted to expand my project beyond simply building an IoT system for myself. I made the decision to present a TED talk, which is a short 18-minute speech given to a physical and online audience. In this speech I will talk about my experiences in learning to create things, and will focus on the compensation between buying ready made products and learning to build your own, such as my IoT system.

APPENDIX J: PP EXHIBITION PLANNING & EXTERNAL USER FEEDBACK



Students Fill These In						
Name	Supervisor	Project / Goal	Product	Electricity	Loaner / Other Equiptment	Photo / Video of Product?
Luigi Pizzolito	Sonya TerBorg	IoT in the modern home	5 IoT Devices	Yes	Wifi AP (WPA2), Power Cord (Multiple Outlets)	No
Paul Meyer	Amy Keus	Creative Cycle of a Conductor	Musical Arrangement	No	1 Loaner, Orchestra Set-Up	Yes
Cameron Merrylees	Rick Fischl	Creating Citizenshiop	qualfication that enhences service and community envolvment	No	Display Board	Yes
Yoonji Chae	Oliver Litez	how can we help people who are suffering poverty	Posters, book donation	No	Display Board	Yes
So Hyun Youn	Sandy Kuan	Education - Local school in Nanjing	Creating an Emergency Procedure Film	Yes	Display Board	Yes
Apoorva Prakash	Triona Ryan	Designing a dress which expresses Indian Culture	Half Saree Blouse	No	Display Board	Yes
Ananya Prakash	Joe Barder	Cook for my family and express indian culture	meal	No	Display board, Loaner	Yes
Claire Zhang	Sarah Merrylees	how can we use color psychology to provoke different emotion through oil painting	Oil Painting	No	Display Board	Yes
Eva Clarke	Becky Law	Displaying importance of healthy lifestyle	Finess ebook	Yes	Display board	Yes
Lucy Hammond	Ben Dutton	Exploring alternatives to animal testing	Vegan beauty Products	No	Display Board	No
Jessica Chen	Lisa Wang	express chinese culture through embroidery	Cross Embroidery	No	Display Board	Yes

	Stage Left			Center Stage				Stage Right					
	Stairs	Britney & Angela						Junseong	Stairs				
Left Door				Audience Space / Add Scrooge Carpet (possible)						Right Door			
	Sunny G								Lucy				
	Noelle								Jumin				
	Seongmin								Riccardo				
	Ananya								Haerim				
	Jeewoo								Jerry				
	Hyunjun			Alice	Cam	Hyelyn	Eric		Eva				
	Minseo			Suyeon	Jessica	Madeline	Helen		Donghwi				
	Diogo								Paul				
	So Hyun			Approva	Alina	Andy	Hyemin		Seoyeon				
	Luigi			Winner	Maggie	Yoonji	Claire		Conor				
BB Door													
	Snacks/Drinks 1			Couches / Decorated Area				Snacks / Drinks 2					
	Retracted Seats												

Time	Event		Performances:	
	PAC Setup by Org and Dec Team		Paul	
Block 4	Tech Rehearsal for Speakers		Alina	
Block 5	Whole grade Set-Up			
			Speakers:	Number:
18:30 - 19:00	Free "Walkaround"		*Lucy*	5
	Performance: A Million Dreams		*Luigi*	4
	Speaker 1 - Paul		*Paul*	1
	MC Welcome		*Donghwi*	3
	Speaker 3 - Donghwi		*Will Help Arrange Room during orchestra tech*	
	Performance: Alina's Song			
	Speaker 4 - Luigi		**Loaners:**	6
	Speaker 5 - Lucy		Extension Cord:	4
			Wifi Acces:	1
19:00 - 19:45	MC Closing		Water Containment	1
19:45 - 21:30	Free "Walkaround"			
21:30	End of Showcase		Tables:	37
			Chairs:	194
08:10	Start of School Presentation		Couches	6
Lunch	End of School Presentation		Boards:	29
Block 5	Cleanup			

What	By When	Who	Complete?	Notes / Remarks			
Send Spreadsheet to Class	Jan 14	Paul	Yes			In the Foyer:	Eason
Create Posters	Jan 21	Luigi	Yes				G11 Rock Banc
Send Poster to Daily Bulletin	When Possible	Luigi	Yes	Keus - WIll be done at a later stage			
Send Poster to Weekly Bulletin	Jan 23	Luigi	Yes	Keus		Setting People Up:	Separte friends
Collect all Responses	Jan 25	Paul & Luigi	Yes				Separate Natio
Select MCs	Jan 25	Paul & Luigi	Yes	Conor & Yoonji - confirmed			
Collect all Pitch Videos	Feb 01	Luigi	No			Notes:	Book PAC
Create Running Order	Feb 01	Paul	Yes				
Prepare booth Layout	Feb 01	Paul	Yes			Organization:	Paul
Talk to Eason for Background Music	Feb 01	Paul	Yes	Eason and Luke will Perform			Luigi
Write MC Script	Feb 18	Paul	Yes				Ms. Keus
Assign Booths to class	Mar01	Paul & Luigi	Yes				
Order Snacks from Chartwells	Mar 08	Miss Keus	Yes	Simple budget, coffee,tea,cookies...		Decoration Committee:	Sunny B
Design Booth / Map for Britney and Angela	Mar 08	Miss Keus					Maggie
Write Script for Brit. / Angela	Mar 08	Miss Keus					Sunny G
Final Edit on Pitch Videos	Mar 08	Luigi					
Remind Class or Dress Code	Mar 08	Paul					
Exhibition Night	Mar 12	All					

Figure 2: Various spreadsheets used to plan PP exhibition, from top-left to bottom-right; individuals requirements and projects, exhibition area layout, event running order, speakers and final requirements, to-do list and roles.

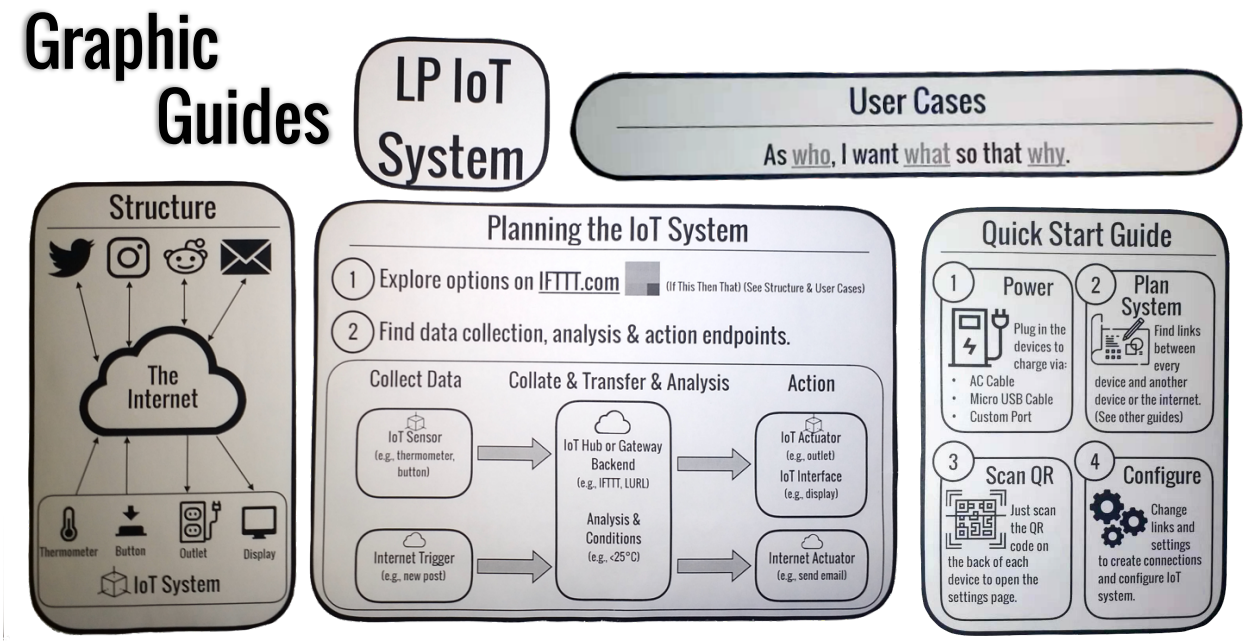
User Questions	User 1 - [redacted] G10	User 4 - [redacted] - 44Y	User 5 - [redacted] - 40ishY	User 8 - [redacted] - 31Y
How long did it take you to setup the system?	15 minutes	Lack of instruction, presets needed	Yes, pretty sure.	Not long with IFTTT
What would you use this system for?	–As a conductor I would like the tuner to turn on to tune the orchestra As I approach to conduct. – As a stage manager I want to queue actors with lights backstage	– As a busy dad I want my lights at my house to turn on when I leave my house, for safety. –As a dad I want eggs cooked in the morning.	– As a theatre a manager I want actors to be able to easily queue sound effects and smoke to relieve the tech crew.	– As a science teacher I want to be able to remotely monitor the temperature of experiments on my lab, to ensure they go to plan.
Is this system useful? Would you buy it?	Not as is, bigger display would be better	Yes, Would buy & sell.	Not as is rn.	Yes, if not get the school to buy it.
What's good and what could be improved?	Simple, and good, nice aesthetics except for screen.	Good: presentation, good demo, retro-fittable, low-cost for old devices. Bad: easier to use (bigger), simpler interface, target to wider audience, explore users, colour code guides.	-	Self hosted, more security.
Would it make your environment more practical?	If there was less lag	-	Clarity of function	-

Table 6: Evaluation and feedback of IoT system by external system users (other people), with guiding questions/prompts.

EVIDENCE OF PRODUCT

Light Box Image 1: Front view of the four IoT devices. (from left to right; display, temperature logger, button, and outlet)

Light Box Image 2: Back view of the four IoT devices, showing the QR codes used for configuration.



Light Box Image 3: Graphic guides for designing and configuring system. Custom made website and (IFTTT, 2019)

Light Box Image 4: Scanning of a QR code to quickly control and configure links/connections in IoT system.

Light Box Image 5: My custom-made website that works with backend to quickly configure IoT devices and build system.