Research into coding a microcontroller’s circuit to grow a plant for 30 days autonomously and more efficiently than regular watering by hand

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Experiment Report

Investigating the effect of controlled water consumption on a bean plant's growth

Problem

In a society where the need for resources such as food and water are becoming increasingly harder to sustain for the population, it is vital to be able to use the worlds resources more efficiently. It is especially agriculture which faces a lot of problems as the usage of water for growing crops is very difficult when there are not many ways of growing crops efficiently when water is scarce. In addition, it can be difficult for people to efficiently grow plants on their own to be able to sustain themselves. Therefore, there is a need for products that are able to grow plants with autonomous sensors and pumps so that this widespread issue of growing crops can be improved.

Hypothesis:

A bean plant that receives water autonomously based on its soil moisture will grow taller than one grown with regular water intake in height and have larger leaves as they will neither be over watered nor be lacking water.

Explanation of hypothesis:

The hypothesis is based on the point that a machine that is able to water a bean plant based on its soil moisture will be more successful because the plant is only being watered when it is need of water. On the other hand, when a bean plant is watered regularly by humans, the moisture of the soil of the plant is not always taken in consideration and instead it receives a regular amount per interval of watering. The problems that can arise with this includes a lack of water as the consumption of water by plants usually increase when there is an increase of growth and therefore a regular intake by humans might not be enough. In addition, there could also be a problem of over watering the plant because when a plant is watered regularly, the soil moisture again is not considered and there are periods in the growth of a plant where there is not a large intake of water. When there is a limited intake of water by the plant, the soil can remain moist for a longer period of time and hence a regular intake from humans can damage the plant by giving too much water and allowing fungi to grow on the moist soil. Fluctuations in temperature and the relative humidity at the air change the rate which the soil dries out. This is not considered with regular watering.

Consequently, it can be assumed that a machine which waters a bean plant only when there is a low soil moisture will most probably be more successful in growing because it will avoid the problems of the regular watering. A machine as such would only water the plant once the plant had consumed the water in the soil and therefore would avoid the problems of over watering which includes the growth of fungi as well as problems of under watering such as growing slower.

The object of my project was really to see whether I could construct an electric circuit to control watering, so this experiment is an initial trial to test the hypothesis. Now that the equipment works it would be important to carry out a larger trial with many more plants.

Variables:

Independent variable:

The independent variable for the experiment will be the amount of water that is given to the bean plants every day for a month. As the water that is given by the machine will not be fixed for every day and is based on soil moisture, it cannot be determined at the start. However, the plants which are grown by the machines water will be compared to the one that is grown normally with a fixed amount of water every day. Therefore, to keep the experiment fair, the plants grown normally must receive the same amount of water per day which will be 50 millilitres. If the water given per day for the plant grown normally is changed then the experiment will not be fair because then the experiment will not be comparing the difference of growth of a plant grown with regular water intakes and one with water only being given with change of soil moisture.

Dependant variable:

The dependant variable of the experiment is the growth of the bean plant in terms of height and the length of the leaves. As the independent variable (water) causes plants to grow due to it being the nutrition for the plant, the dependant variable of the experiment becomes the growth of the plant. This will be measured in centimetres with a ruler so that the growth of the plant can later be discussed and analysed.

Control variables:

To keep the experiment fair and valid, there are a number of variables that need to be controlled. Firstly, the beans that are left to grow must be left for the same length of time so that the growth of the plants can be fairly compared. For this experiment the plants are being left for 1 month so that it gives enough time for the bean to grow and be enough to compare the different methods of watering the plant.

In addition, the conditions and environment of the plant beside the watering must be the same so that the experiment is fair to compare the plants. This includes the type of soil used, the amount of soil used as well as the access to sunlight for the plants. These are all factors besides water that help the growth of beans which means that they must be the same so that the experiment is not flawed.

Other small details that must be controlled includes the type of plants used which for this experiment are lima beans (*Phaseolus lunatus*.) These need to be the same for both methods of watering or it will not be a fair to compare and analyse at the end of the experiment as different types of beans grow differently with different environments.

Method:

To be able to carry out the experiment, 4 bean seeds will be planted, which will be split with 2 bean seeds for each pot. There are 2 per pot so that there is more data to use when analysing as well as reducing the chances of losing a whole set of data due to unforeseen circumstances. Those two pots will have to be filled with the same soil to keep the experiment fair. The two pots will then be split in the way that they will be watered, with one being taken care of the automated machine that waters the soil based on soil moisture (as seen in figure 7, 9 and 10) while the other pot will need to be watered by a person once a day with 50ml being poured every day. This process will then carry on for a month and each day the total length of the plant from the soil to its top will be measured in cm with a ruler in addition to the length of its leaves. After a month's worth of data has been recorded, the growth of the 4 bean plants can be compared to see the outcome of different methods of watering the plants.

As the experiment is quite safe in regard with just watering a plant, there are not many safety precautions to take. However, the automated machine which feeds the bean with water on its own is a large circuit so one needs to be careful to not spill any water on it as one could become shocked by the electricity.

Figure 7: Image of automated plant feeder on the first day of growing 2 bean plants.

Figure 8: Image of automated plant feeder on the 30th day of growing 2 bean plants.

Figure 9: Image of creating the automated plant feeder

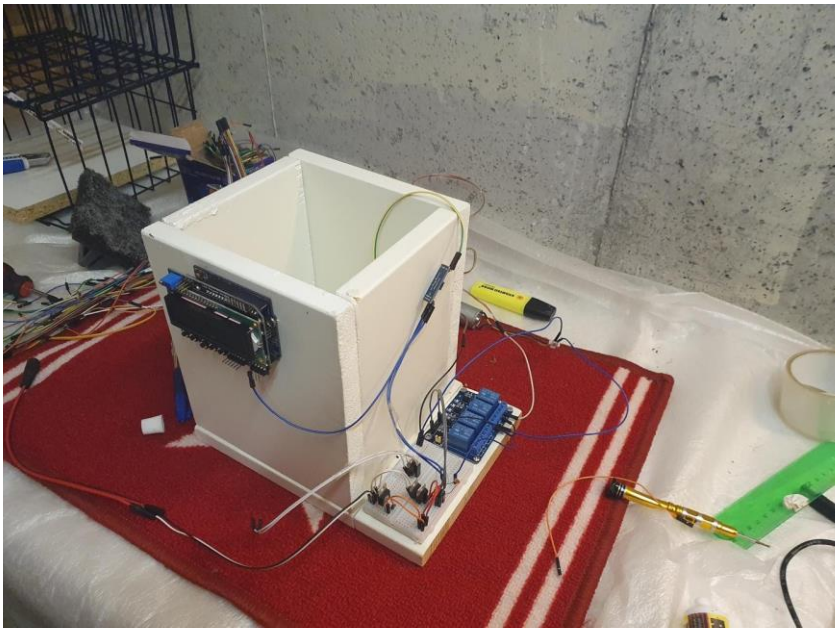

Figure 10: Image of the moisture sensor and water pump of the automated plant feeder

Evaluation of the effect of controlled water consumption on a bean plants growth

Results

Figure 1: Length of bean plants grown by automated plant grower compared to being grown normally

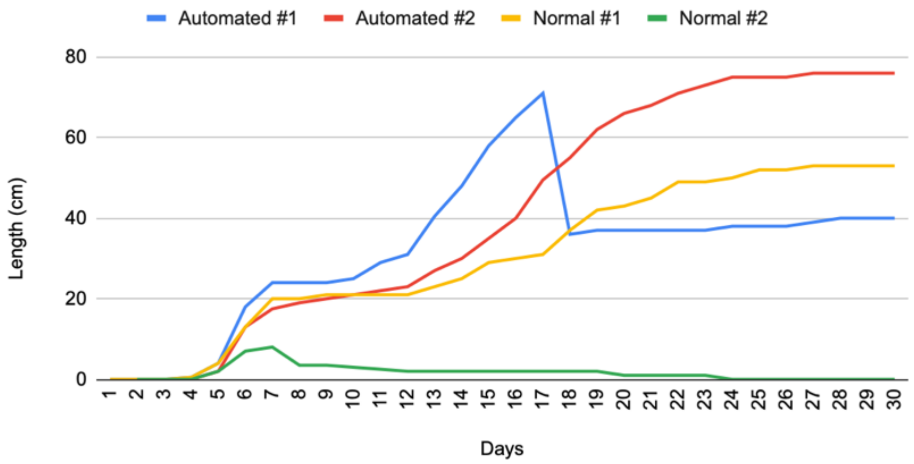

Figure 2:Length of bean plant leaves grown by automatic plant grower compared to being grown normally

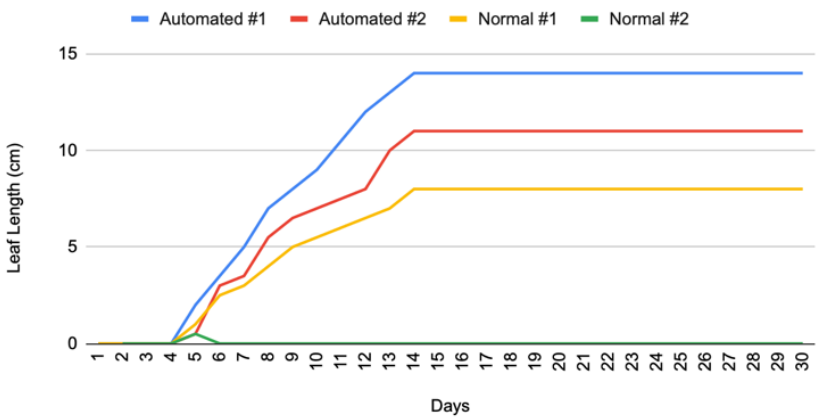

Figure 3: Water given to bean plants by automated plant feeder

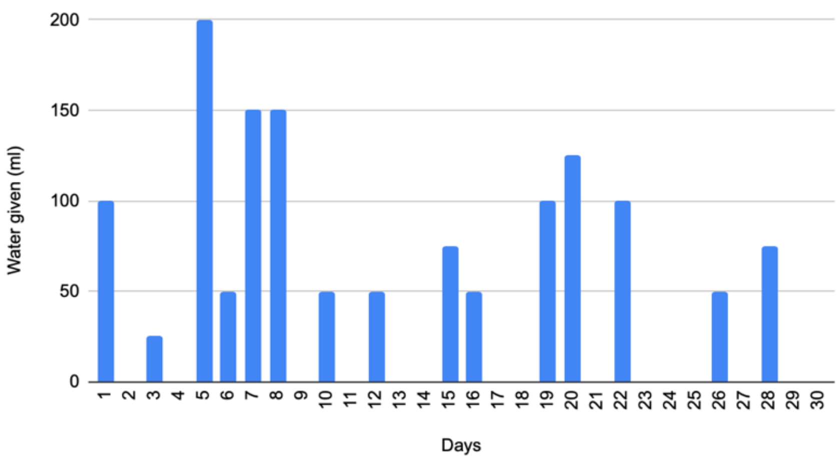

Figure 4: Quantitative data of length of bean plants grown by automated plant grower compared to being grown normally

Day	Automated #1 (cm)	Automated #2 (cm)	Normal #1 (cm)	Normal #2 (cm)
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0.5	0	0.5	0
5	4	2	4	2
6	18	13	13	7
7	24	17.5	20	8
8	24	19	20	3.5
9	24	20	21	3.5
10	25	21	21	3
11	29	22	21	2.5
12	31	23	21	2
13	40.5	27	23	2
14	48	30	25	2
15	58	35	29	2
16	65	40	30	2
17	71	49.5	31	2
18	36	55	37	2
19	37	62	42	2
20	37	66	43	1
21	37	68	45	1
22	37	71	49	1
23	37	73	49	1
24	38	75	50	0
25	38	75	52	0
26	38	75	52	0
27	39	76	53	0
28	40	76	53	0
29	40	76	53	0
30	40	76	53	0

Figure 5: Quantitative data of length of bean plants leaves grown by automated plant grower compared to being grown normally

Day	Automated #1 (cm)	Automated #2 (cm)	Normal #1 (cm)	Normal #2 (cm)
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	2	0.5	1	0.5
6	3.5	3	2.5	0
7	5	3.5	3	0
8	7	5.5	4	0
9	8	6.5	5	0
10	9	7	5.5	0
11	10.5	7.5	6	0
12	12	8	6.5	0
13	13	10	7	0
14	14	11	8	0
15	14	11	8	0
16	14	11	8	0
17	14	11	8	0
18	14	11	8	0
19	14	11	8	0
20	14	11	8	0
21	14	11	8	0
22	14	11	8	0
23	14	11	8	0
24	14	11	8	0
25	14	11	8	0
26	14	11	8	0
27	14	11	8	0
28	14	11	8	0
29	14	11	8	0
30	14	11	8	0

Figure 6: Quantitative data of water given to bean plants by the automated plant feeder

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Water given (ml)	100	0	25	0	200	50	150	150	0	50	0	50	0	0	75	50	0	0	100	125	0	100	0	0	0	50	0	75	0	0

In figure 1 and 2 one can see that the normal bean #2 did not grow much as it declined after day 7. In figure 2, there is a steady growth in the first 3 plants between day 4 and 14 but then it plateaus after that. In figure 1, the same three plants grow from day 4 to 7 where they plateau until day 12. From then on, they have a steady increase until day 17 where automated bean #1 has a drop to 36cm and plateaus around there until the end of the graph. This is because it was accidently knocked over and a major part of the plant was cut off. The other two plants continue growing but also plateau around day 20. In figure 3 there are not many connections between the data

Explanation of results

These results that show the growth of the 4 tested bean plants were done over 30 days and there are two influencing factors on the data. One of these is that around halfway through the growth of the plants, automatic bean 1 was accidently knocked over hence it lost over 20cm of its length. Fortunately bean 1 had provided useful data before being accidently knocked over. It was growing faster than all other plants at the time of being knocked over. The normally grown plants also had a problem as normally grown bean 2 died within the first few days of being grown hence there is only 1 real growth indicator for the normally grown plants which is normally grown bean 1 which survived the 30 days. It is probable that overwatering was the cause of normal bean 2 dying because at the time it had fungi growing around it which is a sign of overwatering a plant.

This is just the first trial experiment, so it is important not to put too much emphasis in such a small sample size. Nevertheless, the data that has been obtained will now be examined. These few results indicate that the plants that were grown automatically grew larger. This can be seen in both figure 1 and 2. In figure 2 and 5, one can see that both automated plants had larger leaves than the beans that were grown normally. The difference between the largest automated bean leaf seen in figure 5 and the normally grown bean leaf is 6 cm which is 75% more than the normally grown bean's leaf (not including the bean plant that did not grow.) The large size of the automated bean leaves can be seen in figure 8. In addition, in figure 1 and 4, one can see again that both the automatically grown plants had a larger length than both the normally grown plants. The exception is automated bean #1 which as aforementioned outgrew the normally grown plants but lost a significant length after being accidently hit. Nevertheless, it still grew more than the normally grown plants.

As well as that, the automatically grown beans only used 1,350ml of water during the whole experiment as seen in figure 3 and 6 while the normally grown beans used approximately 1,500ml while being given around 50ml per day. This shows that even though the normally grown plants received more water, the way that the plant feeder distributed water for the plant seemed more suitable for the plants so that they grew better. Figure 3 shows that the first 2 weeks uses much more water than the last 2. This corresponds to figure 1 and 2 because there was a steady growth seen in the automated bean plants when the water was needed the most. Figure 3 also shows that during the first 4 days, not much water was given. This also corresponds to figure 1 and 2 as the bean plants had not surfaced yet therefore there is less water used when the plant is still in the soil.

Evaluation of hypothesis

From the outcome of the experiment, the results support the hypothesis. This is seen from figure 1 and 2 where both bean plants that were grown automatically, had a longer length in addition to longer leaves than the bean plants that were grown normally. Hence the hypothesis is supported. However, a problem is that the hypothesis is only as valid as the method in which it was tested. If the method was less valid, then the results which came from it would be less valid to use and to support a hypothesis.

Evaluation of method

A sample size of 2 initial plants in each trial is too small for detailed analysis so a larger trial is important. This is the main issue with the experiment as there are not enough data that would be useful for a detailed analysis.

During the method of the experiment, several factors were kept the same. One of these was the independent variable for the normally grown bean plants. They were given 50ml every day so that it would keep the results fair and valid. The two automatically grown plants did not receive the same amount of water per day however that was the intent because it would be showing a comparison of how an automated system that relies on moisture would feed a plant compared to a human.

For dependent variable, all four plants were measured daily at the same time. This is so that the data that would be present on the graphs would be as valid as possible and not be representing different periods of time between each plant. In addition, the plants were split into two pots with the 2 automatically grown ones in one pot and the 2 normally grown plants in another pot. They were also kept in the same area of a room hence they received the same temperatures and light during the day.

However, the only problem that was present with the method of growing the bean plants was the light that was received by the plants. The automated plant feeder has its own lamp that is coded to turn on when it is very dark. Hence it received a bit lighter during the dark hours of the night. Fortunately, the experiment was done during the end of summer hence most of the day was light and the lamp did not turn on very often. The lamp was close enough that it provided light to all plants, but it was closer to the automated plants.

Improvements and extensions.

As an improvement, there could be a longer time span that the plants are left for. This is so that it can be possible to analyse a more complete comparison of the difference between growing the plants automatically and normally. Hence the data would be more valid to analyse because it would show a proper long-term comparison which is what would happen in real life as these plants are not grown in only 30 days. As well as that, the experiment could be done a couple of time so that outliers in the data could be found out and evaluated which would give a more valid set of data to analyse at the end.

Investigation Report

Investigating

Personal Interests

Throughout my life I have had an interest in different scientific and technological topics as seen in the road map in extract 4.2. This includes topics in physics such as electricity as well as technological topics such as programming. Due to my wide interest in these topics, it influenced my goal to have the implementations of it in order to make it more motivating and understanding when working on the project. By implementing my goal to have programming, circuit building and experimentation, it made the goal personal and interesting to myself thus making the process of creating the product more interesting to myself.

Goal

The goal of my project was *to code and create a circuit for an Arduino microcontroller which functions as an automated plant growing machine that can grow a plant through 30 days autonomously in a more efficient method than growing the same plant without the machine.* This goal of creating an automated plant grower was highly challenging due to its various needs of skills to create a product that uses coding, circuit creation, wire management, and another electronic module. See extract 4.1 for detailed analysis of the goal. Arduino (2019) states it is an electronic platform that uses hardware and software to read inputs in order to give outputs. Naturally, using an electronics platform as such for my goal's product made it highly challenging as one needs extensive research skills in order to understand how to code and create hardware for a machine that grows a plant autonomously. Furthermore, the challenge of the goal increased as the product's outcome of being able to grow a plant was tested against growing one normally thus it creates additional factors that must be researched.

Global Context

The global context (GC) which I chose from the International Baccalaureate (2019c) for my goal was "Scientific and Technical Innovation." It was chosen after being analysed against the other GC's for its relation to my goal (see extract 4.1). As my goal involves using circuits and programming, I chose the GC because it links to the topics which are part of science and technology. This GC and goal come with many challenges as it links to the IB subject of computer science which contains highly challenging topics (International Baccalaureate, 2019a). Choosing the GC meant that I could specify what parts of it I can use in my goal which I specified as coding and creating a circuit. In extract 4.1, I explain further why I chose which specific strands of the GC as it relates to my products ability to advance environments with its newer method of growing plants.

Prior Knowledge:

Prior to beginning my project, I had relevant information which helped me understand how to begin my goal. I had previously used an Arduino to create a small light switch and this was one of the practises which inspired me to create an Arduino based project. Using my design cycle knowledge (International Baccalaureate, 2019b), I created a research plan (extract 8.2) that helped me expand the points I already knew as well as Gantt chart for time management (extract 3.2). However, this information of Arduino was quite limited, as all my knowledge came from basic practise from 2 years prior thus, I did not have a firm understanding that would make the project easy. Hence the project stayed challenging due to my limited knowledge in how to create a large Arduino project that involved autonomation. Other prior knowledge that helped me includes knowing the basics of Java coding from design classes that helped me interpret Arduino coding better due to small similarities between them. I used relevant information from my humanities to understand that many communities have problems creating their own crops therefore it inspired me to have a goal that could help through making plants autonomously.

Research Skills

Before starting the process, my research skills consisted mainly of interpreting information hence the analysation of sources (extract 2). However, I developed this throughout the process by also organising my research for later use (extract 8.1 and 8.2) Therefore I had both interpreted the information to understand what is needed from it and what not as well as organising the information that will be helpful for later or current use. Another example of where research skills were used to interpret and organise information was the research plan where I had created exact questions that would direct my research as well as information for that question researched (extract 8.2).

In order to find out credible information, I tried to find two sources that were from contrary origins. Consequently, I could validate two different sources of information and compare them when choosing what to use. From extract 2, I researched Arduino through both a primary source, Hayer (2019) who is an experienced Arduino user as well as secondary source through a video by electronic channel called Binary Updates (2017). Overall, I could use a primary source that was regularly contactable as well as a fixed video which I would interpret myself. Binary Updates (2017) gave me the basics of using a light sensor with Arduino while Hayer (2019) was contactable to talk with if anything went wrong with the sensor or needed more information. Thus, this helped as I had a range of information to use through multiple source to see its validity.

Planning

Developing Criteria

To measure my product's success, I developed multiple success criteria from the design cycle of the International Baccalaureate (2019b) in the form of the design specification (extract 9). These were so that once the product was finished, it could be tested to see how successful the project was. Initially the criteria were made from prior knowledge as seen in the road map (extract 4.2) but these were improved with research to form the criteria in extract 9. Nevertheless, I saw that some requirements were too simple, for example the height of the plant set at 5 cm, but as I wrote in extract 9, my research said it could be grown more so I changed the criteria to make it more challenging for myself. I attempted to make the criteria as rigorous as possible by, for example, specifying what amounts of water/light needs to be given by the product and growth of a plant it completes in comparison to a plant grown normally, hence making each criterion very precise. This made it so that all actions following the creation of the criteria would reflect on attempting to make the product similar to the criteria of success because the criteria are based on research that shows that the product is rigorously designed.

Developing a Plan

One of the strategies of developing a plan was to produce both a short-and long-term Gantt chart (Extract 3.2). Having a short-term plan that established tasks at the start of the project for specific days helped to organize the start of the project. A long-term plan, however, was more useful as it distributed what task to do for each week, making my schedule flexible and easier to handle. Extract 3.2 shows that the short-term plan did not go as planned as it was only used for one month, after seeing that a long-term plan was easier to schedule with. In addition, each task was highlighted in terms of difficulty in order to understand how much time it would take to spend on personal project which would also ease my personal schedule. I met my supervisor quite often, as seen in Extract 1, and also sent emails for questions that I had. Overall, it helped organize and schedule my project because I would gain a better understanding of what is expected to occur in the future. Having multiple small meetings and deadlines with my supervisor meant I could split the task into areas that I understood to ease the process.

In addition, I created annotated drawings of my potential product (extract 5.2) that would help me decide how to make the exterior design of the product look. This worked as my final product resembled design 2 of extract 5.2. I also made small deadlines that organized the work by focusing on what particular things were left (extract 3.1). It helped me to make small completion dates because it gives a sense of how much work is left that motivates one to continue to work. This eventually worked as I had time for 1 month of testing the product's plant growth (extract 7).

Self-Management Skills

Prior to the project I already had knowledge of self-management skills hence the use of the Gantt charts and research plan to organise my work as stated previously however these were developed through the process with an example being the use of both a long term and short-term Gantt chart (Extract 3.2). As well as that I had near weekly supervisor meetings to organise with my supervisor on what is needed for the future (extract 1). Extract 5.1 shows that to speed up the process of starting the creation of my project, I created a resources list at the starting weeks of the project that had listed the resources I needed for the electronics of the product so I would not waste time finding/ordering materials. It had all products outlined in terms of if I had them or were ordering them which helped start organising the materials.

There were moments where I had to use affective skills to persevere in the project. As explained in extract 6, I have only limited woodworking skills and a part of the project involved creating wooden frames for the product. Therefore, I had a problem where it was difficult to create it due to my inexperience. However, I persevered through this as explained in the extract by practising cutting wood planks through different days until creating my final frame. This showed that even though I had a problem I went past it by practising and researching using sources such as Woodwork Boss (2018) which furthered my knowledge on something I was limited in doing.

In addition, I had to use reflection skills to move further. As seen in extract 3.2, the short-term Gantt chart was only used at the start of the summer while the long-term chart was used to the end of the project. That is because I saw that I worked better on a long-term chart which did not specify what I need to exactly do each day as the long-term plan made it more flexible to work in my own schedule.

Taking Action

Product Outcome

Through the process, I created a final product which was an automated plant grower and data that showed its ability to grow a bean plant compared to growing the plant normally (extract 7). I have here reflected on the GC that I chose at the start of my project my implementing scientific and technological innovation to it. These can be seen through the electronic circuits that run the product, the coding which controls the product and the plant that was been grown as a conclusion. Surprise outcome that came was that my product had made a bean plant 23 centimetres taller than one growth normally (extract 9) which is something my research could not predict. As seen in extract 7, there was a long process of coding, circuit building and woodwork necessary to create the physical product and then was left for 30 days to show its results of growing a bean plan. It shows that there has been a link to the GC as the technological aspects of the product such as the pump and lamp were innovative in order to grow a plant.

Thinking Skills

In taking action I was able to research critically to create the final product. In extract 7, there is a long skype call with Hayer (2019), who is an experienced user of Arduino and family member. I used this to my advantage to use him as a tutoring tool in order check any faults with my code/circuit as seen in extract 7 where I have a 40-minute call and send my trials of the product. Furthermore, I used a source that was a Norwegian Arduino book by Kjell & Company (2017) where I had to use transfer Norwegian language skills so that I could extract the knowledge into my product.

There was a clear development in my thinking skills as seen in extract 10 as I initially made small codes with the Arduino microcontroller to turn a light off but then improved that in 1 months' time to be able to have a fully functioning automotive plant grower.
There was difficulty in choosing the plant to grow as I had opposing information for what I should grow. On one hand I had research from a botanist with PhD that said that I should grow celery as that would best resemble what I am aiming however this would not work with the long period needed for celery to grow (extract 7.) Instead I used my thinking skills to come up with a solution of a plant that would be difficult to grow in order to showcase the ability of the machine which was the bean plant.

I came across multiple unfamiliar and difficult situations along the process such as creating a functioning LCD and a wooden frame (extract 10 and 6 respectively). In these scenarios, as I write in the journal entries, I had no previous knowledge of making an LCD and very limited knowledge of using tools to make a wooden frame. Thus, I had to critically analyse both scenarios to be able to make a wooden frame using only sandpaper and saw as well as a coded and functionable LCD after hours of trial and testing (extract 6 and 10).
In order to understand more completely in how my product was functioning to grow the bean plant, I recorded its height and leaf growth as well as water consumption over 30 days and compared it to a bean plant being grown normally. This way I would use models and graphs into understanding if my product effects plant growth efficiently.

Communication and Social Skills

There were multiple examples of communication and social skills being used. First of all, I used a variety of media to communicate with my resources that helped with building my product which ranged from emails, meetings, skype calls and personal chats on the codementor website (extract 7). For instance, I had multiple emails with Dr. Vrentas, a botanist with a PhD so that we could discuss what plant to grow with my machine (extract 7.) Additionally, I went to fix issues with these forms of communication as seen in the text message with coder Soni (2019) who is a coder on codementor where I discussed in a chat about how to fix an issue with the code (extract 7). I also had in person interactions such as with my supervisor where we would regularly keep track of what I have done and what deadlines to set next (extract 1). These show that I effectively communicated through different means so that I could proceed with taking action with my product.

With these various people that I communicated and socialised with, I effectively negotiated to solve issues that I was facing. For example, my texts with Soni in extract 7 show that we were collaborating to fix a code's issues by running it multiple times and even when there were issues, we kept communicating through different methods to find a solution. It was similar with the botanist, Dr.Vrentas where we had to negotiate what plant would work best to showcase the ability of the product and thus, she gave me further resources to use that could help me (extract 7). Discussing with Hayer was helpful as seen in extract 7 because I communicated with him through skype and in-person to understand more how to wire my product so that I would prevent accidents.

Reflecting

Evaluation against criteria

As seen in extract 9, all newer success criteria were met. However, there were a few close criteria such as the one where the plant grower should use less water in 30 days than growing a plant normally and the difference was only 150ml. In reality, those 150ml could vary if the experiment was done again thus it does not make that criteria entirely valid. I believe that the reason that the product did not save as much water that I thought is because it is difficult to predict a plants growth and water consumption. However, when comparing to the initial criteria that I created in the road map (extract 4.2) I was not as successful. It states how the product should run for a month without any human interaction but as seen in extract 10 problems such as overheating reoccurred therefore, I had to step into fix them. Furthermore, it stated that no more than 1 litre should be used for a month but as extract 9 says, over 1 litre was used. As the road map criteria were made before proper research, they are unrealistic while and extract 9' success criteria were made after I increased knowledge of the concepts of programming and circuits through research from extract 8.1 and 8.2.

Extension of knowledge

Through the project I have gained extended knowledge. This has happened with my project which has involved a variety of tasks under the GC of "Scientific and Technological Innovation." For instance, I have extended my knowledge especially in coding through the usage of Arduinos. As seen in extract 8.1, I created a whole table with all of the Arduino coding functions that I learned from my research that I used when writing my code for the product to run. This shows that I have greatly extended my programming knowledge so that I could create a programme that grows a plant. The same is with understanding and building electronic circuits as seen in extract 10 where I have fully developed a circuit that allows a pump, lamp and multiple sensors to run. It shows the extension of knowledge as this is a difficult task to do without knowledge of electronic.

I believe that I have also gained a larger understanding of the GC that I used. My project had elements of the GC through building electronic circuits which is a scientific process and programming my Arduino which was a technological feature. Therefore, I now have learned how to use a GC successfully with a project in order to complete it by using features that link to the GC.

By extending my knowledge on these topics I can transfer the skills for later uses. For example, the topic of circuits related to the subject of IB physics (International Baccalaureate, 2019d). Similarly, programming is a skill that can be useful for the technology-based future hence these topics prepare me for future careers and skills that I can have. The understanding of the GC also helps because it is always in the IB curriculum therefore being able to understand it will ease my future projects and tasks.

Development as IB student

I believe I have developed my skills as an IB student to be an inquirer to conduct individual research (International Baccalaureate, 2019e). The project I chose required a lot of research because it had features such as programming and circuits which are higher level topics to understand. As seen in extract 8, I researched my project's topics by extracting the information that I found to use for my later creating stages. Extract 2 shows that my research was not limited to secondary sources found on the internet because as an inquirer, I looked through a larger variety of sources such as emailing Vrentas (2019) who is a botanist with a

PhD or consulting with experienced coder Hayer (2019). These show that I have developed as an inquirer as I have been able to consistently seek information from various sources in order to complete my project. Therefore, in the future, I can find information and relevant sources more efficiently due to development from this project.

I have become knowledgeable by acquiring in-depth knowledge of concepts (International Baccalaureate, 2019e) through the link between my product and topics such as programming. The product has elements of electronics with various sensors in a circuit system and all programmed together to work (extract 10). Hence, with the creation of my product, I have practised the use of various high-level topics that require a lot of knowledge to understand. This can be seen in my research plan in where I have displayed my knowledge of the Arduino programme so that I can use the terminology for the future. Consequently, I have developed being knowledgeable and can now use this knowledge of coding and circuits for later instances in life.

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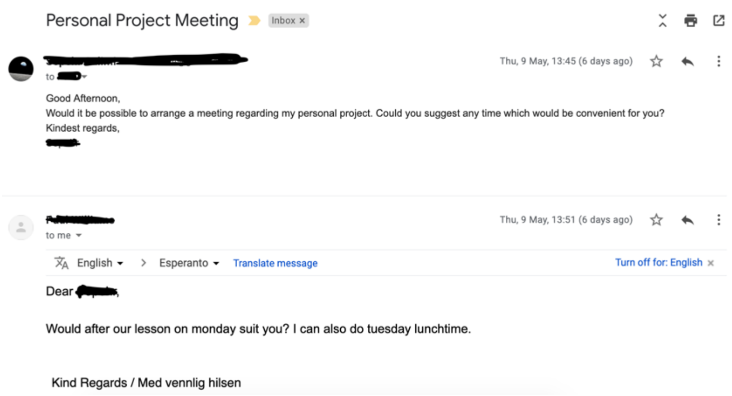
Appendices

Extract 1 – Meetings with Supervisor

13.05.19 Meeting #1

I met with my supervisor for the first time for the project. Here I discussed the choosing of two ideas I had which were to make an RC car or an automated plant grower. Through discussing together, we came to a mutual agreement that growing a plant would be a more interesting idea for myself as it is easy to relate it to a target audience and solve a problem rather than just creating a car which would not be targeted for anything. However, we decided to make a deadline until next week to come up with the final idea. I scheduled regular Personal project meetings every Monday which I will attend until the end of school. The discussion of making a RC car against a plant grower include:

- RC car does not have a specific aim or audience it could help, makes it harder to link to a global context
- Plant grower links more to the context of scientific and technical innovation, as it is an innovation which could help millions of people grow their plants without themselves doing anything
- Making an RC product will require multiple Arduino microcontrollers and more materials (as stated by Hayer, 2019) which could mean it would be more difficult and/or costly
- Having a global context being linked to the product easier would mean that it is easier to write the end report and also make it more specific for myself to create.


Personal Project Meeting Inbox ×

[redacted] Thu, 9 May, 13:45 (6 days ago)
to [redacted]

Good Afternoon,
Would it be possible to arrange a meeting regarding my personal project. Could you suggest any time which would be convenient for you?
Kindest regards,
[redacted]

[redacted] Thu, 9 May, 13:51 (6 days ago)
to me
English > Esperanto Translate message Turn off for: English ×

Dear [redacted],

Would after our lesson on monday suit you? I can also do tuesday lunchtime.

Kind Regards / Med vennlig hilsen

20.05.19 - 23.05.19 Meeting and discussing with supervisor #2

I had my second supervisor meeting. Here I finalized my project to be about creating an automated plant grower which can grow a plant efficiently. The rest of the meeting was talking about potential sources to use for the project:
The main primary source can be H.Hayer (2019) who is easily accessible through skype and has used Arduino in his free time.
My supervisor can provide secondary sources through PDFs and other media.
The meeting was short so beside that nothing else was discussed.

04.06.19 Meeting #3

I talked to my supervisor in a short meeting. Here we discussed how to keep informing each other during the summer holidays. To be able to do this, I made a google drive folder with all my work. This folder has been split into smaller subsections to make it easier for myself and my supervisor to access. The idea behind this as discussed in the meeting is for myself to add my tasks and process in there, while my supervisor annotates it with what to do and what to improve.

21.06.19 Meeting #4

I had last meeting of MYP4 academic year with my supervisor. Key notes that I got from it include:

- Record every step taken in the process and put it in the journal
- Use a variety of ways to record the process (video, images, screenshots)
- This will help for evidence for the final report and the personal project evening presentation

20.08.19 Meeting #5

I met with my supervisor for the first time since the summer holidays. The meeting consisted of explaining everything that I have completed in the summer holidays. We agreed to meet around the same time next week. I found out that because I have completed my product, I should start locating 10 extracts which I can potentially use for my report. As well as that I should begin testing specifications just as I had planned out in my Gantt chart. By the next meeting, I will discuss again with my supervisor about the same matter but with the extracts which I have found.

24.09.19 Supervisor meeting #7

I met with my supervisor to discuss the open evening next week. We spent 10 minutes discussing what to show on the boards that I have, and I decided to have my product alongside with a time-lapse of plant growth which will be next to the board that will contain a summary of my process. As I have finished my product for some time now, all I need to focus on is creating my board for the evening by organising my product and information about the process.

Extract 2 – Analysation of Sources

Vrentas, C., 2019. *Growing a plant for a school project*. [email].

Origin: This source is one of the members of the Botanical Society of America which makes her a credible source as she has a PhD in botany, so she is knowledgeable on her topic.

Purpose: The purpose of contacting her was to find out what is a challenging plant that can be grown indoors for my product to be able to test its functionality. She is able to inform me on the matter and can guide me to other potentially useful sources.

Values: The source was able to guide me into the direction of finding a challenging plant to grow with my product by giving sources about different plants such as celery to grow. Even though I did not use her idea, I used the information she wrote to choose beans instead.

Limitations: Due to time limitations I did not use most of her information of plants such as celery to grow because it would take too much time to grow. That is why I had to look to other sources for choosing a plant.

Hayer, H., 2019. *Discussion of coding Arduino and assembling modules*.

Origin: This source is my uncle who resides in Iran. He is an engineer and often uses Arduino to create projects and works with coding daily. That makes him a reliable source as he knows the subject which he discusses about. He uses Arduino occasionally for his work in the oil industry to make systems therefore his extended knowledge is credible and valuable.

Purpose: The purpose of talking to him as a source is to retrieve information about how to use Arduino and where to get parts for my project. He will be used to inform me on various ways of using Arduino as well as how the science behind works in order to make the project safer because it deals with electronics.

Value: He is valuable as a source because he has prior knowledge on using Arduino so he can tutor me to understand how to write my code. As well as that he will be useful for collecting parts for the project as his knowns which parts are needed for a plant grower and has access to them where he is. He can be easily accessible through calls thus can be used for finding information regularly to find information that can be contradicting.

Limitation: A limitation with him as a source is that he lives in Iran which means that I only see him in person only during the summer holidays and that there is a time zone difference when communicating with him.

Binary Updates., 2017. *LM35 Temperature Sensor with Arduino Uno*. [video] Available at: https://www.youtube.com/watch?v=3Xc2sPhwWEc [Accessed 26 Jul. 2019].

Origin: The source is a video made by a channel called binary updates which uploads electronic based videos.

Purpose: The video is supposed to show how to set up the LM35 sensor with your code in order for it to convert its data into Celsius.

Values: This source would be useful to use to set up my own sensor which would put the information on my product so that the product is able to show multiple data points instead of only a few.

Limitations: While using the information from the source, I could not retrieve the result which the video claims to receive by converting it. As well as that, due to poor mic quality, the source is difficult to understand and interpret.

Beetlebrox, Z., 2015. [online] Instructables.com. Available at: https://www.instructables.com/id/Light-Seeking-RC-Car-Hack-with-Arduino/ [Accessed 8 May 2019].

Origin: This website will be useful for my project as it features an abundance of tutorial guides on using the Arduino coding language on different electronic modules. I can see that this is a trustable and credible source because it is on Instructables where different authors write articles which they have knowledge on, and these authors have a history of the knowledge they spread as they also make more articles on the same topic.

Purpose: This specific article shows how to use coding on an Arduino to control a light sensor for a RC car. There does not seem to be a specific target audience as the layout of the article is set in a mixture of a report and instruction which makes it suitable for anyone to read who does not have knowledge in the topic.

Value: An RC car was my previous personal project idea however I can still use this source because it explains how to use a light sensor which I will need as I need to use a light sensor so my microcontroller can decide to give light or not to the plant. That means I will rely on this source heavily when learning and analyzing how to code a photocell sensor which detects light so that I can develop my own code for my own system.

Limitation: A limitation is that the coding that is taught here is specified for use on an RC car so it might not be relevant or functional with my plant grower project.

Extract 3.1 – Time Progress Chart

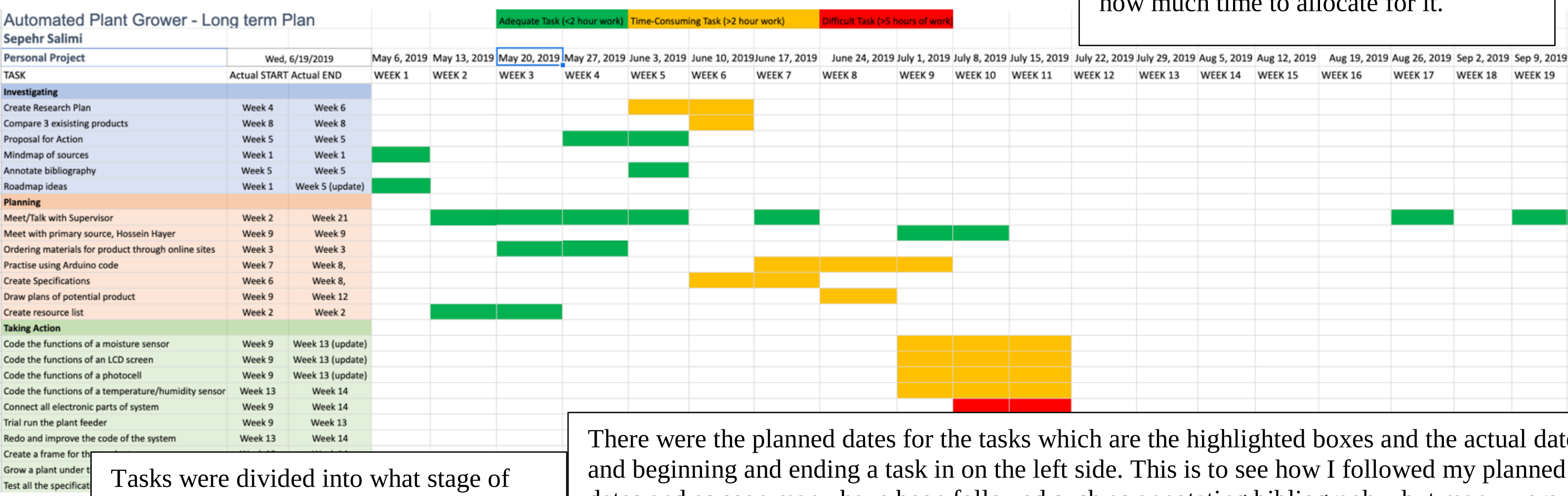
Progress List from 22.07.19

Completed:

- Mind Map sources (May)
- Roadmap (May)
- Proposal for Action (May)
- Resource list (May)
- Annotated bibliography (June)
- Research plan (June)
- Practise coding Arduino (June)
- Order/gather all materials (July)
- Create Specifications (redone July)
- Assemble the electronics (July)
- Trial run the system (July)
- Create drawings of the product (July)

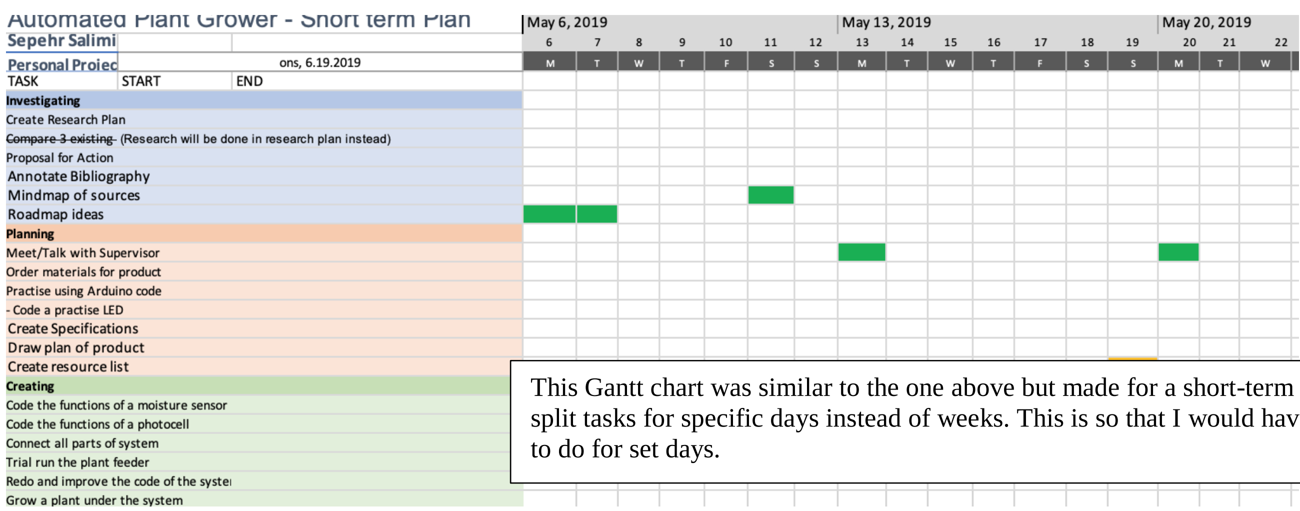
Extract 3.2 – Gantt Charts

The work was highlighted into difficulty so that it would be easier to know much time to spend working on the task and how much time to allocate for it.



There were the planned dates for the tasks which are the highlighted boxes and the actual dates and beginning and ending a task in on the left side. This is to see how I followed my planned dates and as seen many have been followed such as annotating bibliography, but many were not such drawing the plan of the product.

Tasks were divided into what stage of the process it was part of which helps to know what to expect from the task.



This Gantt chart was similar to the one above but made for a short-term use, it would split tasks for specific days instead of weeks. This is so that I would have a set thing to do for set days.

Extract 4.1 - Choosing Smart Goal and Global Context

Goal: To code and create a circuit for an Arduino microcontroller which functions as an automated plant growing machine that can grow a plant through 30 days autonomously and more efficient than growing the same plant without the machine.

Specific: The product will be run by an Arduino microcontroller which can be used to control a circuit by coding. With the Arduino, one can attach multiple electronic parts using breadboards, wires, regulators and etc. Using the abilities of circuits with Arduino, I will create a system of different electronics such as lamps and a pump in order to make an efficient and good environment for a plant to grow so that it grows better than it would normally do without the machine.
Measurable: The success of the product by the plant that it has produced after 30 days and compare it to a plant grown normally. The success can be measured by comparing the height and leaf growth of the plants by seeing which has grown more as well as creating criteria for the functions of the machine on how that should work.
Attainable: The goal can be attained through researching the Arduino coding language in order to make the machine work the way I want it. Then researching the science of electronics and circuits will allow me to create a circuit that can withhold and function a multifunction able plant grower.
Realistic: The product is possible because Arduino allows one to connect multiple electronic parts such as a lamp and pump which are elements of a plant grower and then allows the user to customise its functions with a circuit and coding.
Timely: The finished product of plant and machine must be complete before October when it is presented in an exhibition. As well as that the plant will be given 30 days to grow as an experiment to see its success against a normal plant growing.

Global Context	Why it relates to my project	Why it does not relate to my project
Identities and relationships	Does not have much relations to my project as it deals with relationships rather than innovation.	Does not have relations to the scientific aspects of my project
Orientation in space and time	Connects to how methods of growing plants have evolved and changed over space and time.	This GC does not have relations to the scientific and technological aspects of my projects like the coding.
Personal and cultural expression	Project has relation to nature therefore there can be expression with it.	Product does not express much culture as it does with expressing technological innovation.
Scientific and technical innovation	My product involves circuits and coding which are all scientific and technological topics. Also, looking into growing a plant has elements of biology which is scientific.	Does not have any irrelevancy to the goal of creating an automated plant grower.
Globalization and sustainability	My eventual product at the end of my goal could be something that could help sustain global environments as it helps to grow plants with no human intervention.	It does not relate to the scientific and technological aspect of my project including the electronics.
Fairness and development	As this GC looks at an inquiry in sharing finite resources, it links to my goal of creating a product that could provide resources of plants without humans working on it.	It does not relate to the scientific and technological aspect of my project including the electronics.

Overall: From this I can see that scientific and technical innovation is the most connected GC to my project because it involves the aspects I will be researching and implementing which is electronics and coding which are all part of science and technology. I choose the "impact of scientific and technological advances of communities and environments" part of global context because my product could be an advancement to a way that plants are grown normally in environments.

Extract 4.2– Initial Roadmap

Topic state global context	**Goal** Show your personal interest	**Specs** Success Criteria	**Process**	**Product Outcome**
The global context is Scientific and Technical Innovation. The specific strands that can be used are "the impact of scientific and technological advances of communities and environments"	The goal of my project is to code and construct an automated plant growing system which provides the necessities of a plant without a human checking on it. I have an interest in science and technology due to my background of family members who mostly all science or technology related jobs. That is why I have chosen to have such a project that requires programming and other technological/scientific aspect as it is something that I take interest in and find enjoyable.	1. Controlled amounts of water must be released into the plants soil 2. The Arduino must be able to measure the moisture of the soil. 3. The product should work for a month without needing someone to help it. 4. The Arduino must be able to measure the light surrounding the plant. 5. The system should not use more than 1 litre for a whole month of use.	The process will begin by using the design cycle to conduct my research through tasks like the research plan. Once I find enough research to understand how to create an automated plant grower, I will have to gather all of the parts for the product which includes pumps, wires, an Arduino microcontroller, photocell and moisture sensors then practise coding them. Once I understand how to code it well, I can code the systems functions and construct product by attaching all the parts together. After finishing making the product, I will check if it works by trying to grow a plant over a 1-month period using the product.	The final product will be set of electronical devices and modules connected to a microcontroller which in the end will be connected to a pot of a plant. The microcontroller will have access to information from the plant which include the light levels of the surrounding area and the moisture levels of the plant which will make the product give water through a pump to the plant when the moisture is low and turn on a LED when the light is low. Altogether the product should be able to grow an indoor plant.

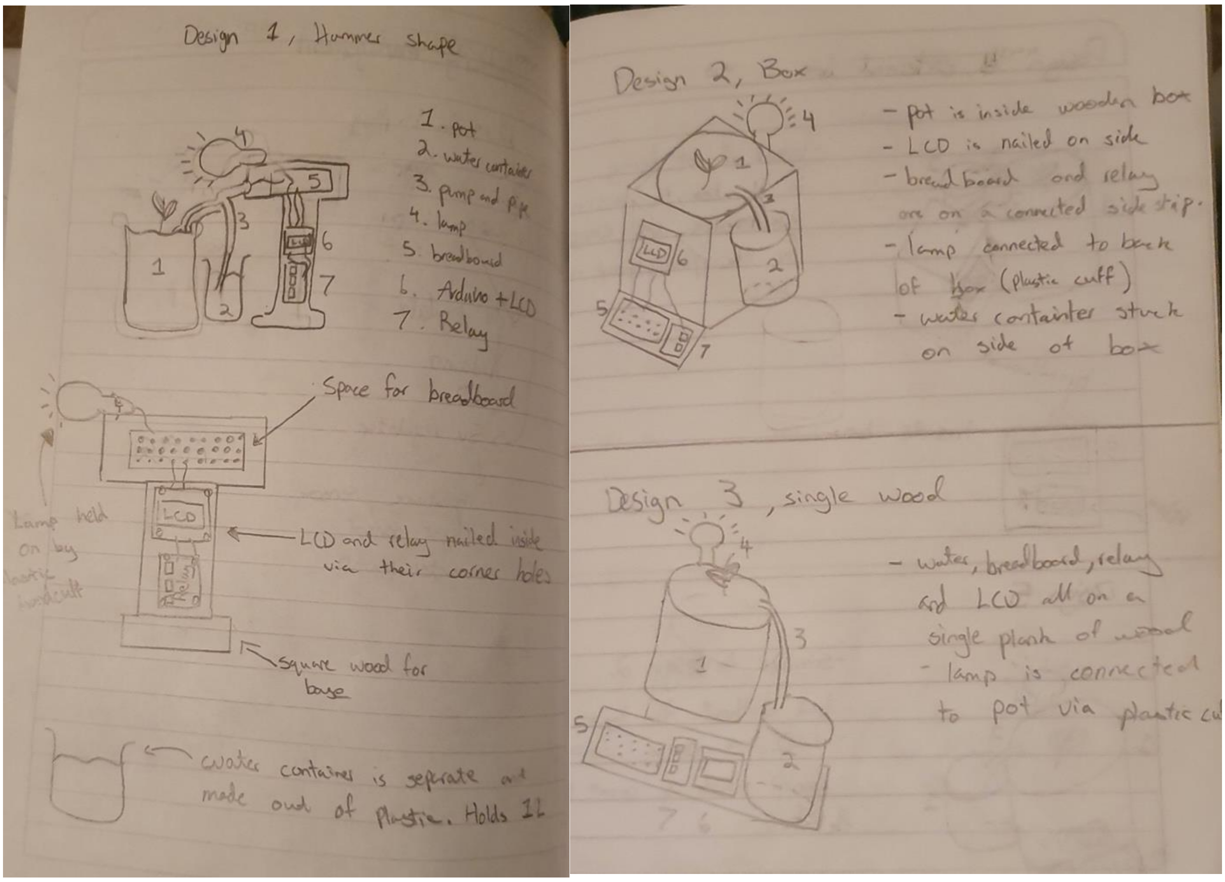
Extract 5.1 – Material List

19.05.19 Listing materials

I found a primary source which was Hayer (2019.) He has a background in programming and has experience in Arduino coding. I discussed my project about making an automated plant grower so we could list materials which would be needed. I then used this research I got to create an excel table which shows all the materials
needed and if I have it or not. This way I am able to research and gather all my materials before constructing the product.

Things to Get	Its Use	Do I have it or not
Arduino Uno	Controls whole project	Arrived
Breadboard	Solderless and for prototyping the circuit	Arrived
Jumper wires (MM and MF)	For connecting the circuit together	In Iran
Soleroid valve	Opens water for plant	Not obtaining
Potentiometer	Controls voltage that is given	Need to obtain
Air moisture sensor	Reads the moisure level of the air	In Iran
FC28 Moisture sensor	Reads the moisure level of soil	In Iran
(2x) 5v Relay	To control high voltage currents that arduino cant	In Iran
pump 12v	Pumps water	In Iran
12v lamp	To provide light for the plant	In Iran
Soldering Iron	To stick jumper wires together in breadboard	Need to obtain
Digital Multimeter	Measures voltages for safety	Need to obtain

Extract 5.2 – Design drawing plans



Extract 6 - Woodwork

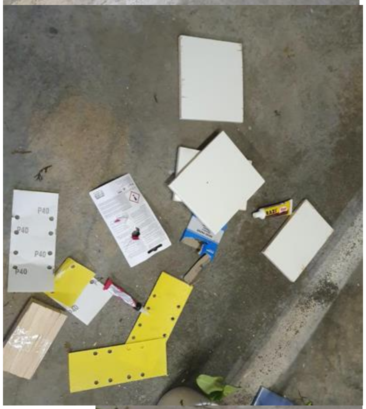
27.07.17 - 08.08.19 Woodwork and assembling final product

GC link: Just like drawing the designs, I thought of my global context and its relation to being innovative so that my sawed woods would connect to the global context when it would be put together.

Goal: To use bring together the electronics and wood frame together for a final product.

I began practicing woodwork by making a box shape using wood I had in my garage. I myself am not very experienced in woodwork as I have only done it during design in MYP5 thus I focused most of my project on electronics. I will continue practicing until I shop for more wood and sandpaper for my final product. I used transfer skills by remembering the skills of woodwork I learned in design in MYP3. With this method of thinking, I applied the skills which Mr Gibbs taught use such as doing long strides with the saw to be able to cut my wood. I also used sandpaper to smoothen the wood. I spent time practicing woodwork until the 29th where I will shop for more materials before

I bought more wood as I ran out of the one, I had at home and began using the same skills I practiced before with woodcutting to create more slabs of wood. I also transferred some mathematical skills as I drew and planned out a net diagram of the box with dimensions to help myself cut the wood. I spent 1 day everyday doing a task related to creating the box by cutting the wood into slabs, painting the wood, sandpapering the edges, gluing the slabs together and then attaching the electronics to the box through drilling and screws. By 03.08.19 I had attached most of the electronics with the exception of the lamp and pump to the box by creating a side slab to the box which would hold the breadboard and relay. I spent a lot of time reassembling and reworking the wirings to tidy up the product to make it look more aesthetically pleasing.



Doing woodwork also had issues because I had no power tools, so I relied solely on sandpaper and a saw to be able to create clean cuts of wooden slabs. This made my work much more difficult and required much more care and effort to be able to achieve exact measurements and cut.

I came across issues with the electronics as well such as nearly having a short circuit in my relay module as my pump and light would not turn on which happened on the 1st of August. However, by reassessing and using diagrams I created prior of my electronic mapping, I was able to fix the issue with rewiring.

7th to 8th of August I started assembling parts for the water pump and lamp by drilling through wood and a plastic water container so that the lamp and pipe would fit in respectively. I had a few issues such as accidently breaking my temperature sensor, so I had to buy a new one. Drilling was difficult due to the sizes and measurements needed so I had to practice and try many times.

Challenges:

It was difficult performing the task of creating a wooden frame as I had limited woodwork skills therefore, I had to transfer skills from my MYP3 design classes.

I had to cut wood several times due to the problems of cutting wood with sandpaper and saws and no power tools. Therefore, it was much more tedious to perform and used a lot of time.

The electronics of the system failed multiple times as various electronics such as the relay module overheating which meant that the pump and light would not work.

Painting the wood took a whole day due to the paint drying therefore it slowed the process down.

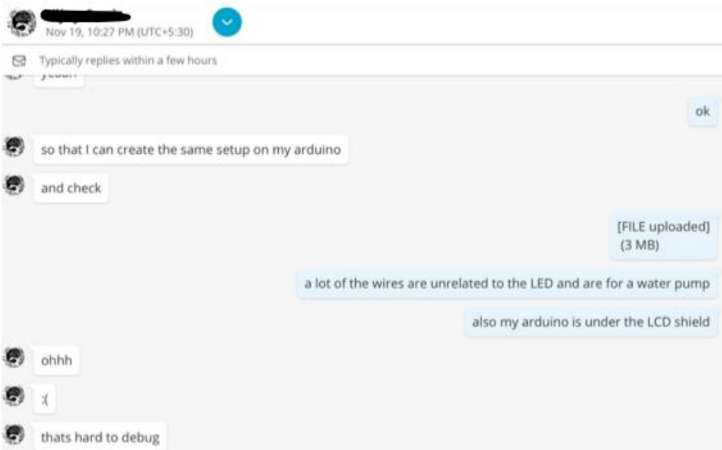
Solutions:

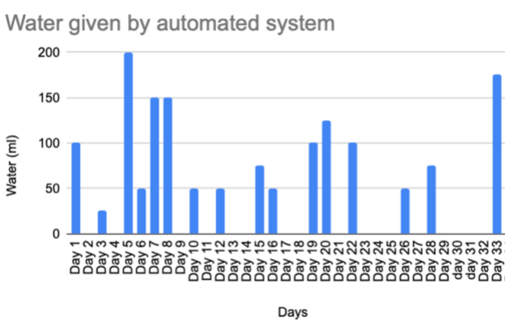
Used multiple types of wood to find the one that would work best for the project.

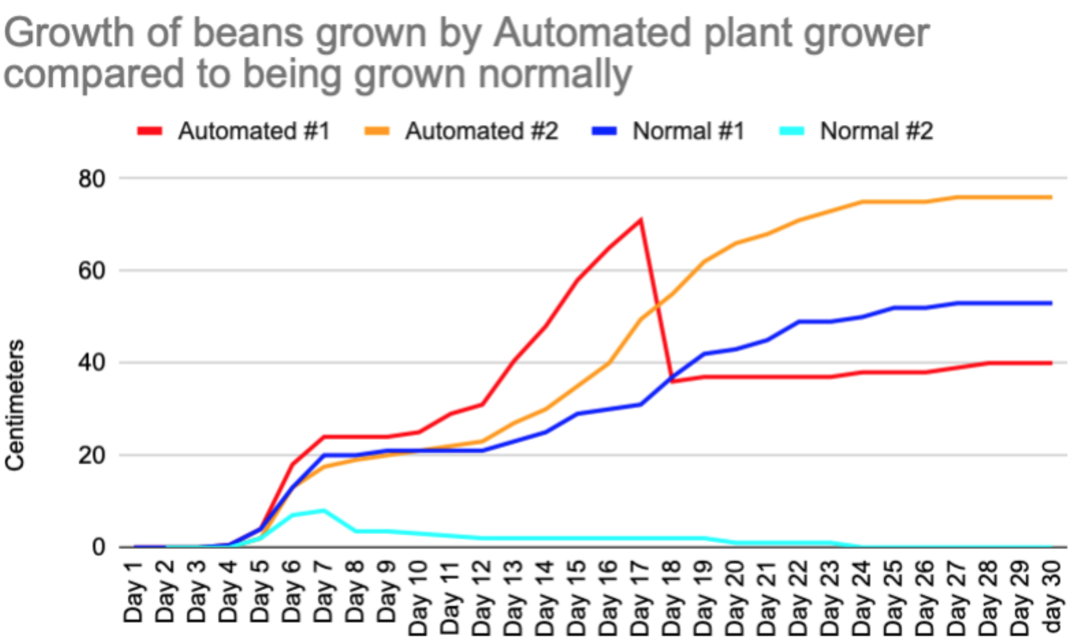
Practicing the skills of using saws, drills and sandpaper through various days meant that my precision using them at the end was much better and therefore the wooden frame turned out better.

Measuring the sides meant that the wooden slabs for the frame were more precise and made a better design.

Extract 7 – Images of researching and building product







[redacted]
to me

Tue, 6 Aug, 05:57 (1 day ago)

Hi [redacted]
Thanks for sharing a bit about your device--it sounds very impressive!
I've been spending time thinking about this, in terms of what might work for your experimental testing--while I have lists of plants that are adapted to a bog environment, they aren't really a great fit for your project since most are larger plants. I also have some lists of prairie seeds that grow in wet environments. That might be relevant, since that would be more feasible to grow in the type of device you describe. The challenge there can be that germination of prairie seeds can be tricky (for reasons outside the moisture/light parameters). But you could utilize sites that sell prairie seeds as an option: https://www.prairiemoon.com/carex-pellita-broad-leaved-woolly-sedge-prairie-moon-nursery.html to select some seed options.

What I think might be a more feasible option (just in my opinion, based on my understanding of your project) is to select a vegetable/crop seed to grow. One of the possibilities that I think might be a fit for what you are looking for (more challenging to grow--requires high levels of moisture) is celery. Celery seeds are known to be difficult to cultivate (at least, difficult as compared to other vegetables) and require high levels of moisture. Some additional cultivation conditions are provided here:

https://www.canr.msu.edu/resources/how_to_grow_celery

Let me know if this is helpful--I want to make sure we can find the right match for your project! There are some other vegetables that require high soil moisture for germination, but celery (as well as celeriac) is probably the most common example. One disadvantage is that it takes a while for celery seeds to germinate (at least 2 weeks), so if you have time constraints to your project, that could prove to be a challenge.

Sincerely,
[redacted]

[redacted] Vrentas, Ph.D.

Hossein Hayer
Seen 1 hour ago

19 June 2019

17:51
No answer

17:52
No answer

19:50
Call 47m 20s

27 June 2019

18:03

19:44

28 June 2019

Extract 8.1 – Arduino Research

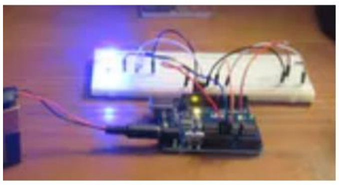
delayMicroseconds() = same as delay() but in microseconds	Arduino
millis() = gives the amount of milliseconds that have past since the code was started	Arduino
random() = this gives a random number, numbers can be put in () to give a minimum and maximum	Arduino
HIGH and LOW = When a digital pin is set to HIGH, 5V is given and when LOW is set, 0V is given.	Arduino
Analog Input Pins = These are pins that are marked A0 - A5, and can detect volts in between 0V-5V. This is useful for sensors that want specific voltages. Analog pins can be used as digital pins if one runs out of one.	DIYGeeks
Digital pins = these are 13 pins that can be put as either an input or output. They can only be set as HIGH or LOW which gives 5V or 0V respectively.	DIYGeeks and Hossein Hayer
Putting () next to a data type = makes the value put in the () converted into the data type	Arduino
Assigning variables = example, **int** var = val; , where var is the variable that is being made and val is the value being given to it	Arduino
float = data type with decimal point	Hossein Hayer
long = data type with many digits	Arduino
int = data type that is an integer	Hossein Hayer
Char = data type that holds single characters. The value is written with single quotations, Example is, **char** example = 'A';	Arduino
Array = this is a collection of variables that can be accessed with an index number. Example of creating is, **int** example[5] = { 3, 1, 5, 6 }; Note that when declaring the number of variables (in this case [5]), an extra variable is set to take in account in automatic null value.	Arduino
String = data type that is a string of characters or can also be all the other data types using the conversion. Example, **string** example = "this is a string";	Starting Electronics
Void = this word declares a function in the form of either setup or loop	Arduino

Product #1 Automatic water system by Learn by Watch

Inspiration: This product has one of the elements that I will have in my product which is to have a water pump and moisture sensor. That is why I want to use this as inspiration of how an example water system works so that mine can do same functions while aiming to link to my global context and my success criteria.

Limitations: The problem with this product is that it takes too much space by having large spaces between wires and using too large tanks. For a product which I am trying to make, that would make my system near unusable if it its area is going to be over 3 times the size of the plant pot. As well as that, the pump has too much power with less than a second of it being turned on fills up the pot. For my own product, the idea is to preserve efficiency so that it links with the global context of scientific and technological innovation, or not what I am creating is not an innovation and has no way of having a real life use.

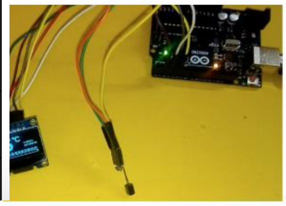
Product #2 LED turning off and on with photocell readings



Inspiration: As the creator of this product was able to use the voltage readings of a photocell to be able to make a normal LED turn on, I should take that sort of idea and the way they have listed how their code works to be able to function my own plant specific LED.

Limitations: Of course, the goal of this persons product is very different to my own specific product which is set against a global context, as the overall function achieved in this product is only a small part of my larger plant grower. As well as that my product will have a much different layout and usage of LEDs and parts to be able to link to my innovation part of global context and be able to grow the plant under efficient usages.

Product #3 Arduino OLED temperature display



Inspiration: I want to use the idea of creating a compact LCD system like in this product which does not take up much space. That would be useful to my product as my global contexts point of being innovating would mean that the product should be compact and energy/space efficient so that it would be applicable for real life use.

Limitations: This product is quite different to my own which is aimed for growing a plant while this is based on making an LCD screen showing temperature. That means there is not much I can inspire from the product beside the layout of the display and its jumper wire use.

Extract 8.2 – Research Plan and Findings

Electronics

1. How do relays function?

Aqib, M. (2019). Relay Module interfacing with Arduino - Arduino Relay Module. [online] Electronics Hobbyists. Available at:https://electronicshobbyists.com/relay-module-interfacing-with-arduino-arduino-relay-module/ [Accessed 19 May 2019].

Relays are a device which turn off and on voltages for a module, by either giving 0V or 5V. This can be used for turning off and on the different 5V modules such as a valve.

2. How do voltage dividers work?

Learn.sparkfun.com. (2019). *Voltage Dividers*. [online] Available at: https://learn.sparkfun.com/tutorials/voltage-dividers/all [Accessed 5 Jun. 2019].

A voltage divider is a circuit that can turn a larger voltage into a smaller one. By knowing this I know that I can use this so that the correct amount of voltages is being outputted for a specific module so that it can function properly. It is important to know about dividing the voltages or not too much voltage or too little would either make the modules not function or break.

3. What instruments and devices will be needed for safety and assembling an Arduino project?

Hayer, H, (2019)

The following devices are what I believe I will need by discussing with my uncle:

- Potentiometer, acts as a voltage divider so that it can turn off and on voltages
- Soldering iron, to mend together jumper wires into the breadboard and Arduino
- Digital Multimeter, measures voltages

Research Question	Justification	Suggested Source	Is it a Primary or Secondary Source?
Approximately how much water does a plant need daily and weekly?	This is important to know for my product because then I will know exactly how much water every discharge of my systems pump will give to the plant. As well as that I will know how much water will be needed in the reservoir. The overall importance is that this will lead me to interpreting how much water would make an efficient system which will not waste any materials.	As this information can vary for different plants, I could potentially use old science experiments found on YouTube or on a PDF where one works to find the mean amount of water needed for a plant as this is a topic that could be done as an experiment. Otherwise, I could visit gardening websites such as Dave's garden where it guides the user to information considering gardening.	Secondary
What plant needs daily water and sunlight over a 4-week growing period?	The answer for this question will be necessary after my product is completed because I will have to try to grow a plant using my system. However, I need to find a plant which needs daily water and sunlight otherwise my system will have no use on it and the plant just grows on itself.	A primary source that I could use to understand which plants need daily amounts of water and sunlight would be to talk to plantasjen workers. Plantasjen is a local store that sells gardening materials so visiting there by talking to the workers and looking at their plants, I can understand what to use for my project.	Primary

Extract 9 – Success Criteria and testing

Succes Criteria (Created in 04.07.19 after researching information and expanding road map)	Was it met? (Tested on 07.09.19)
The system and its modules must operate on 12V or lower	**Yes:** Voltmeter showed all ran 12v or lower.
When moisture levels are read low, the system must provide water for the plant through a pump	**Yes:** The function is performed by the system.
When light levels are read low, the system must provide light for the plant through a lamp or LED light.	**Yes:** The function is performed by the system.
The plant grower must make a plant grow at least 30cm high or gain a 40cm squared surface area after 30 days. * changed on 07.07.19 from 5cm because research said that beans can grow more than that in 30 days.	**Yes:** Plant 2 grown by the product grew to 76 cm while the first plant grew to 72 cm. Both significantly higher than the expected 30cm.
The plant grown by the system must grow past the stage of germination	**Yes:** The plant grew beans by ¾ of the growing process.
The system must operate as functioned for 24 hours without any human interference	**Yes:** Ran for 30 days with little human interference.
The plant grower must not exceed 1 meter in any dimension	**Yes:** Measured 40cm at widest.
Information that is read by the system must be displayed through an LCD that is not connected to a PC	**Yes:** Had an external LCD attached to Arduino that was not connected to a PC.
The system must have the ability to show the data of the sensors through a PC.	**Yes:** Showed the data through a serial monitor
The system must operate its functions of watering, giving light and have an LCD without being connected to a PC	**Yes:** All functions worked without being connected to a PC but was connected to power brick.
The entire plant grower must be controlled by a single Arduino Uno microcontroller	**Yes:** It was run with a single Arduino
The plant grower must have at least a 1-liter reservoir to use for watering	**Yes:** Reservoir had space for 3 liters of water.
For every time the water pump is running, at least 30 milliliters must be given to the plants soil.	**Yes:** Water data shows minimum was approximately 50ml
The light that is provided by the system should not operate for more than 10 hours a day.	**Yes:** Maximum that it was on for was 7 hours.
The system must not use up the whole reservoir in a 7-day week.	**Yes:** Used 1350 ml for 30 days out of 3L storage.
The plant grower should use less water than the traditional way of watering a plant manually.	**Yes:** Used 150 ml less than plant grown normally.
The system should make a plant grow more in height or surface area compared to the same plant being grown in the traditional way of manually watering and providing light.	**Yes:** Grew 23cm more than a bean plant grown normally.
The LCD of the system must be able to change its interface through pressing buttons.	**Yes:** Up button made the LCD show temperature and humidity.
The LCD should contain simplified information by saying what it's doing and the sensors information through numerals and percentages.	**Yes:** Data was in percentages for the humidity, water level, and light level and in Celsius for temperature
The entire systems frame should be a combination of wood and plastic to be able to hold together all the electronics and contain the water.	**Yes:** The frame of the product was made up of wood while other parts such as tank of water and tube for watering was made up of plastic.

Extract 10 – Circuit Building and Coding

04.07.19 - 07.07.19 (Coding and assembling trial product)

GC Link: The whole 4 day assembling task required thinking about the global context strand of advancements into communities and environments because I needed to create functions and codes which would revolve around it, based on how the plant grower works in correlation to the global context.

Goals: My goals after the coding and making electronics will be to make the frame of the product once my drawings plans are done.

This whole process of coding and assembling furthered my social and communication skills while working with Hayer as he has extended information into electronics and arduino so it was very important for me to always listen and ask questions to further my information as well. By working with someone who is experienced while I am not, I learned to use different methods of obtaining information that would further my knowledge into my project.

Gathered most of the parts I need for my project. Used primary source, Hayer (2019), to understand basic electronics which will be used in my project. I learned ohm's law, voltage resistors, direct voltage, alternate voltage and regulators.

- Regulators, reduces a voltage to a smaller one
- Ohm's law, how voltage current and resistors connect together

Using this source Konica Minolta (n.d) and Hayer (2019), I found out that purple light is most effective for plant growth as green is not needed for plants and when removing G from RGB you get red and blue which is purple. That is why i am going to use a custom lamp which uses only 12v and emits purple light so it is effective for growing and efficient in using electricity.

I created a prototype of my plant grower system by using 5 hours to assemble the electronics and writing the program. The prototype is just wires laid out and connected to the LED and pump. The system now pumps water when moisture is low and turns on the purple LED when light is low. The LED lamp was customised to run at 12v instead of originally being 220v to preserve safety and to connect better to my global context by not wasting too much electricity. However, there is still work to be done to find out the correct readings for when the pumps and LEDs should turn on as well as making the product work on a plant and attach to it.

I have also decided to change my success criteria for my project to redesign them and make them more rigorous so that it meets personal project. I am doing this while realising my criteria do not completely relate to the global context of scientific and technical innovation as well as my specific strand. That is why over the next 2 days I will new criteria as well as reuse a few old ones so that my project can be more rigorously tested.

I continued my work from yesterday by working on an LCD which will be connected to my system. I spent 6 hours dissembling and then reassembling the whole system so that I would understand what I have done better. I went through a few issues such as my voltage regulators burning which meant I had to redo how I laid my system. I created different areas for things that relied on 5v, 8v or 12v so that none of the electrical parts would be overworked and burned.

I made the LCD work after a few hours of coding and debugging the system so that it now displays light and moisture levels in terms of percentage which has been obtained by tests I did on the sensors. I would put the sensors in two varying environments which differed from each other to see what the maximum and minimum value it would give is, so that I could calculate it as a percentage.

The overall electronic and coding part of the system is nearly done however it still does not have a "chassis" to be a plant grower. That means I will have to create a framework or layout which would hold water, be next to a plant and have the system next to it once I arrive back in Norway. I also made a complete map and drawing of the electronic parts of the system on paper.

I faced a lot of problems this time with the sensors giving data, so I had to remake the electronics by disassembling then reanalysing where I put everything. Then I used the Arduino IDEs to make a data graph of the sensors data which I used to debug and analyse how light and water is being recorded.

Challenges:

Overall the task was very time-consuming and difficult due to the coding and electronics needed in the task.

The coding had various issues because there would be contradicting data being sent from the sensors and what is wanted by the code due to mistakes made in the circuit. This problem reoccurred during the growing of the plant in the later weeks.

The circuit had various overheating instances and several regulators broke during the construction. This is because of single misplaced wires that can drastically affect the flow of the electrons in the circuit and overheat the regulators.

LCD had issues because it needed a long set of code to function and took up too much space on the Arduino. I needed to conduct more research to understand how to make it write what I want because it was much more complex than the pump and lamp.

Solutions:

I solved issues with the circuit overheating by taking it all down and drawing where everything should go. Therefore, my plan would see what issues came from where when rebuilding.

The LCDs issue of taking up too much space was fixed by soldering extra rods to it which would allow more jumper wires to flow through it.

Putting sensors into different scenarios fixed the issues of contradicting data coming through.

```
//libraries included
#include <LiquidCrystal.h>
#include <Adafruit_Sensor.h>
#include "DHT.h"

#define DHTPIN 11 // temp/humid sensor is connected to pin 4
#define DHTTYPE DHT11 // the model of the sensor
DHT dht(DHTPIN, DHTTYPE); //turning it on

//LCD pins connected to Arduino
const int pin_RS = 8;
const int pin_EN = 9;
const int pin_d4 = 4;
const int pin_d5 = 5;
const int pin_d6 = 6;
const int pin_d7 = 7;
const int pin_BL = 10;
LiquidCrystal lcd( pin_RS,  pin_EN,  pin_d4,  pin_d5,  pin_d6,  pin_d7);

// determining the pins of the pump and lamp
int pump = 3;
int light = 2;

void setup() {
Serial.begin(9600);

pinMode(light, OUTPUT);
pinMode(pump, OUTPUT);

//turning on LCD
lcd.begin(16, 2);
//beginning temp/humid sensor
 dht.begin();
}


void loop() {

 // delay per reading
delay(1000);

// assigning the sensors
float watersensor = analogRead(A1); // water sensor to pin A1
float lightsensor = analogRead(A2); // light sensor to pin A2
int buttonreading = analogRead(A0); // button data to pin A0
float temp = dht.readTemperature();
float humid = dht.readHumidity();

// turning data into percentages
int lightpercent = map(lightsensor, 130, 950, 1, 100);
int waterpercent = map(watersensor, 1, 800, 1 ,100);

Serial.println(humid); // IDE serial plotting

//when moisture is above 500, the pump turns off
if ( watersensor>=500) {
  digitalWrite(pump, HIGH);
  lcd.setCursor(0,0);
  lcd.print("Water Level: ");
  lcd.print(waterpercent);
  lcd.print("%");
}
//when moisture is lower than 500 the pump turns on
if (watersensor<=500 ) {
```