International Baccalaureate
Baccalauréat International
Bachillerato Internacional

For first use in 2016 assessment

4/ICCSDT

Group 4: Individual candidate cover sheet (design technology)

Arrival date: **20 April / 20 October** Session: May 2016

School number: School name:

- Complete this form in the working language of your school (English, French, Spanish).
- The form must be signed by the teacher and candidate.
- A completed copy should be retained by the school

Subject: Design technology Level: SL

Candidate name: Session number:

Candidate section:
To be completed by the candidate.

Title of the group 4 project: Survival

Write a reflective statement of about 50 words outlining your involvement in the group 4 project:

My greatest involvement throughout the group 4 project was my leadership skill with which I was able to lead our group to create a successful presentation and prototypes. I also used my creativity and critical thinking to overcome challenges that we were confronted with, such as when the geophone or glow sticks didn't work the way we wanted them to.

Title of design project: Rooftop Garden Compost Tea Collector

Candidate declaration: I confirm that this investigation is my own work and is the final version. I have acknowledged each use of words or ideas of another person, whether written, oral or visual.

Candidate's signature: Date: 1st March 2016

Please turn over

Teacher section:
To be completed by the teacher.

Design project marks awarded by assessment criteria

SL and HL assessment criteria				HL only assessment criteria	
A	B	C	D	E	F
9 /9	9 /9	9 /9	9 /9	/9	/9

Total (this total must be entered on IBIS): 36 (SL max: 36, HL max: 54)

Teacher declaration: I confirm, to the best of my knowledge, that this work is the candidate's work and this has been verified by me at each stage of its development, from the initial selection of the investigation, through the draft and the final version submitted.

Teacher's name:

Signature: Date: 1st March 2016

For completion by the examiners only

Moderator

A	B	C	D	E	F
/9	/9	/9	/9	/9	/9

Senior moderator

A	B	C	D	E	F
/9	/9	/9	/9	/9	/9

IB Design Technology

Design project marks awarded by assessment criteria

Candidate Name:	
Candidate Number:	
Centre Name:	
Session:	**May 2016**
Teacher:	

Overview of marks awarded

SL and HL assessment criteria				HL only assessment criteria	
A	**B**	**C**	**D**	**E**	**F**
9 /9	9 /9	9 /9	9 /9	/9	/9

Total (this total must be entered on IBIS): 36 (SL max: 36, HL max: 54)

SL Design Project No of pages 36 + Front Cover + contents page. Candidate has met the page requirements. Appendix at back

Justification of marks awarded

Criterion A: Analysis of a design opportunity			
1 - 3	4 - 6	7 - 9	Justification Pg
identifies a problem ☐	**identifies** an appropriate problem, which leads to a design opportunity ☐	**describes** an appropriate problem, which leads to a design opportunity ☒	pg 2+3
states the key findings from relevant market and user research ☐	**describes** the key findings from relevant market and user research ☐	**explains** the key findings from relevant market and user research ☒	pg 4, 6-11
develops a **simple** brief, which identifies few relevant parameters of the problem ☐	develops a brief, which identifies **some** of the relevant parameters of the problem ☐	develops a **detailed** brief, which identifies the relevant parameters of the problem ☒	pg 5
develops a marketing specification, which **states** the requirements ☐	develops a marketing specification, which **outlines** the requirements ☐	develops a marketing specification, which **justifies** the requirements ☒	pg 11 - 12
develops a design specification, which **states** the requirements ☐	develops a design specification, which **outlines** the requirements ☐	develops a design specification, which **justifies** the requirements ☒	pg 12 - 13
		Section A mark awarded	9 /9

The work achieved this mark because: pages 2 - 13

pg 2+3. · Thorough analysis of all issues for design need + all points identified with client. Evidence of further investigation + breakdown of all issues.

pg 4, 6-11. · A range of extensive research including looking at existing solutions, market research and further Key findings of the environment. Market + user research is helpful in the identification of the problems.

pg 5. Both feasibility + design brief outline all relevant parameters to the problem, target market group and scope

pg 11 - 12 +12 -13. Both Design + Market spec have detailed + relevant justification for each Criteria which are based on the Key findings from the research

Justification of marks awarded

Criterion B: Conceptual design			
1 - 3	4 - 6	7 - 9	Justification Pg
demonstrates **limited** development of **few** ideas, which explore solutions to the problem ☐	develops ideas with reference to the specifications, which explore solutions to the problem ☐	develops feasible ideas to meet appropriate specifications, which explore solutions to the problem ☒	pg 14 - 18
selects the most appropriate idea for detailed development **with no justification** ☐	uses concept modelling with **limited analysis** ☐	uses concept modelling to guide design development ☒	pg 19 - 21
☐	selects the most appropriate idea for detailed development **with limited justification** ☐	**justifies** the most appropriate idea for detailed development ☒	pg 18 - 21
		Section B mark awarded	9 /9

The work achieved this mark because: pages 14 - 21

- Candidate has used a range of design strategies to come up with a range of ideas which are innovative in each way. Project does limit the scope for creativity & candidate has done well with coming up a range of ideas.
- Ideas are detailed and all aspects of materials, manufacture, user / function has been considered.
- A good range of prototyping / CAD / physical / Graphical has been used to explore the design ideas further.
- Development also considers construction and reference to testing to specifications has been carried out to see the strengths & weaknesses of each idea.
- Candidate could have done further review from target user / audience. to see thoughts on proposals.

Justification of marks awarded

Criterion C: Development of a detailed design			
1 - 3	4 - 6	7 - 9	Justification Pg
lists some appropriate materials and components for a prototype ☐	**outlines** some appropriate materials and components for a prototype ☐	**justifies** the choice of appropriate materials and components for a prototype ☒	p 23-26
lists some appropriate manufacturing techniques for prototype production ☐	**outlines** some appropriate manufacturing techniques for prototype production ☐	**justifies** the choice of appropriate manufacturing techniques for prototype production ☒	p23-26
develops a design proposal **that includes few details** ☐	develops a design proposal that **includes most details** ☐	develops an **accurate and detailed** design proposal ☒	p27-29
produces an **incomplete** plan that contains **some production details** ☐	produces a plan for the manufacture of the prototype ☐	produces a **detailed** plan for the manufacture of the prototype ☒	p29-30
		Section C mark awarded	9 /9

The work achieved this mark because: pages 22-30

p23-24 · The use of CAD + further physical modelling has allowed student to refine the construction and assembly of the chosen design proposal.

p24-26 · Candidate has explored + analysed the most suited method for manufacture using the best materials available.
- The manufacture + materials selected are for manufacture of a fully functional scaled model. The decisions are all justified through the additional research carried out.

pg 27-29 - Accurate + detailed Orthographic / CAD + assembly are shown. List of materials is detailed coinciding all parts including assembly method.

pg 29-30 - Extensive manufacture plan for the prototype

Justification of marks awarded

Criterion D: Testing and evaluation			
1 - 3	4 - 6	7 - 9	Justification Pg
evaluates the success of the solution against **few** aspects of the marketing specification **with no evidence of testing**	evaluates the success of the solution against **some** aspects of the marketing specification	evaluates the success of the solution against the marketing specification X	pg 31-33
evaluates the success of the solution against **few** aspects of the design specification **with no evidence of testing**	evaluates the success of the solution against **some** aspects of the design specification	evaluates the success of the solution against the design specification X	pg 33-35
lists how the solution could be improved	**outlines** how the solution could be improved.	**explains** how the solution could be improved. X	pg 35-36 33-35
		Section D mark awarded	9 /9

The work achieved this mark because: pages 31-36

pg 31-33 Testing carried out with evidence. Trials + interview with client / potential user. Target market also gives suggestions + constructive feedback

pg 33-35 Both Design / Market specifications are well analysed with detailed purpose + evaluations carried out for each section of the market spec + design spec

Design has also been rated + suggestions are made to the strengths + weaknesses of the final design.

pg 35-36 A range of modifications suggested using CAD to illustrate. Please note that improvements are also suggested for each design spec requirements on p33-35.

IB Design Technology

Design Project

Candidate Name:

Candidate number:

Session: May 2016

Centre Name:

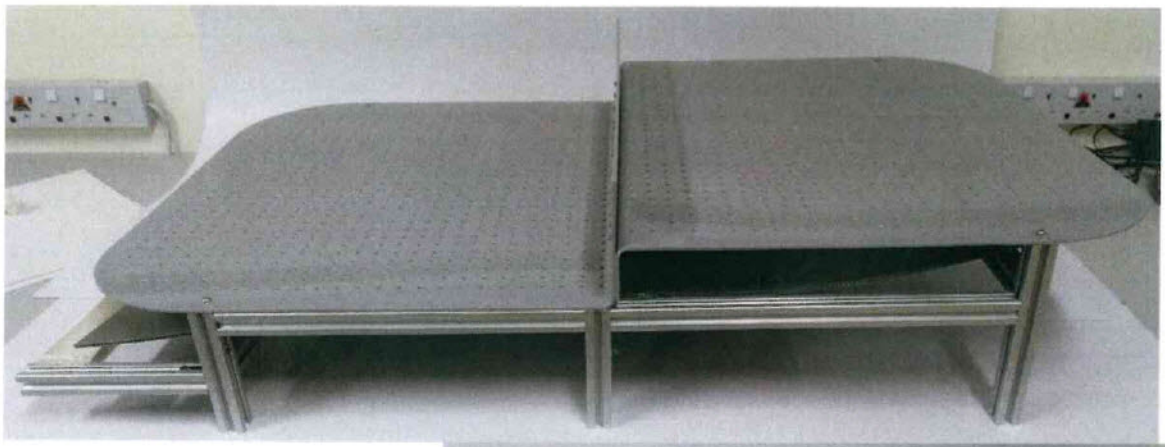
Centre number:

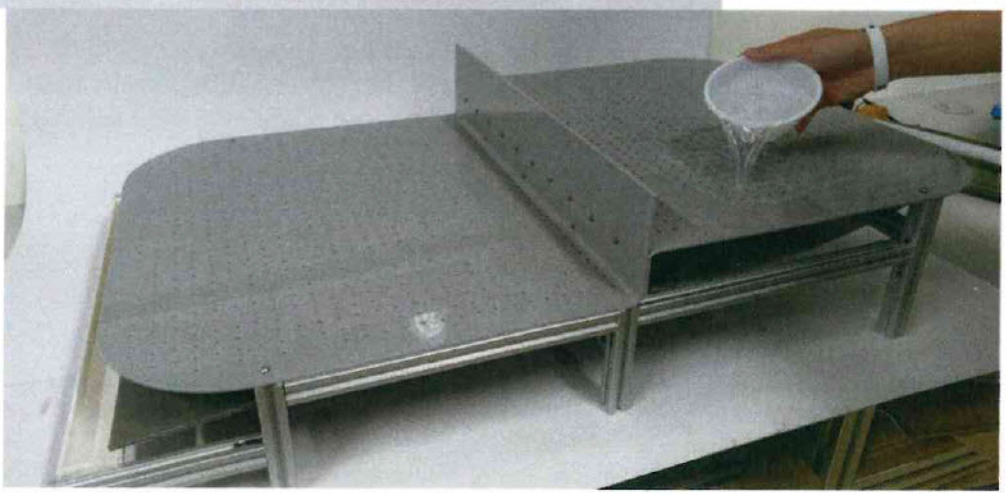
Subject: Design Technology

Level: SL

Date: 1st March 2016

Word Count: 21,471





Compost Tea Collector

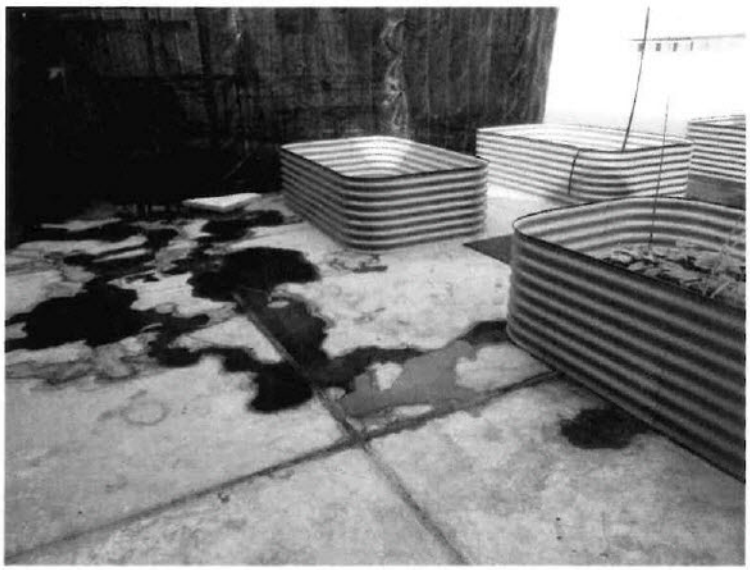
Table of Contents

Criterion A: Analysis of a design opportunity

Design need

After touring around the school and having a look at various issues, I have chosen to create a catchment system for compost tea at the rooftop garden. This catchment system is needed because compost tea is currently leaking out of the gardens, while it should be caught and reused as it is very good for fertilization. The compost system could also be used to elevate the soil currently in the bins, as it is not necessary for the bins to be filled up all the way.

The rooftop garden is located on top of the C block at school. The garden features many things such as a plant nursery, a mini garden in galvanized tubs, as well as a rainwater collection system. As the roof is made out of concrete, and it would be too expensive to fill the entire area up with soil to plant, the school had to purchase these galvanized tubs from Australia to farm in. However, after my interview with Adam Erickson, the man in charge of the garden, I found out that these tubs have a number of problems associated with them. Of course, the first question I asked him was to describe the problem. He told me that there are multiple issues they are having with the tubs. Firstly, there is precious compost tea leaking out from the tubs that could be caught and reused in the garden. As these galvanized tubs do not have anything underneath them to prevent the compost tea from leaking out, it just drains out the bottom. Secondly, Adam told me that the tubs are too high and that the amount of soil that the tubs can hold is not required, so they do not end up filling them up completely. From the interview, I also found out that the people that use the garden most are high schoolers and middle schoolers. There is a high school service that tends after the garden after school each week, so high schoolers are the ones that end up visiting the garden space the most. However, primary schoolers also visit the garden sometimes to learn and get ideas for their own garden. Every once in awhile, when more professional services or heavy lifting are required, the facilities or gardeners are required to use the space as well. However, Adam told me that high schoolers are able to do most of the stuff related to the garden, from planting to fertilizing to harvesting the products.



One of the first thing one notices when they go up to the garden on top of the C block is the giant dark stains on the garden floor. These stains are caused by compost tea leaking out of the farming tubs and onto the garden floor. Currently, the primary issue is that potentially useful compost tea is being leaked out of the bins instead of being collected and reused. The compost tea itself can be reused as a fertilizer in the garden to enrich the soil in which other plans are growing with minerals. It can also be used to boost the growth of smaller plants and seedlings, as they need the fertilizers most. However, as this compost tea is quite dense with minerals and fertilizer, it leaves dark stains on the floor after it leaks and evaporates. Specifically, it leaks out after heavy rains or after the plants are watered. As there is no base or waterproof surface underneath the tubs, the compost tea is able to freely leak out of the galvanized tubs and onto the floor. This ruins the aesthetics of the floor, which could be displeasing to the gardeners and anyone visiting the school. The reason this happens is because the water they use to water the plants or after any rain drains from the bottom of the galvanized tubs. On the way, it picks up nutrients and materials from the soil, which then comes out the bottom. Thee nutrients leave a dark stain on the floor, which the cleaners have to clean every once in awhile. It also creates a walking hazard as it creates a wet floor on which the people maintaining the garden could slip on and potentially hurt themselves. Specifically, as the garden is most used by primary schoolers, who are many times careless in where they walk or run, they could slip on the still wet floor and hurt themselves.

A solution to this would be something that is able to solve all of the above issues mentioned. The first thing it must do is catch the compost tea and prevent it from leaking onto the garden floor. A drainage system would then have to redirect the compost tea into a catchment tub where it would wait to be reused. By preventing the compost tea from reaching the ground, it would solve all of the issues mentioned above. For example, it would remove some of the hazards of working on the garden for, not only primary schoolers, but gardeners and anyone else in the area. Next, it would also make the cleaner's jobs easier by giving them one less thing to have to clean, allowing them to focus on other parts of the school as well that might also need their attention. Lastly, if the catchment system efficiently collects the compost tea, it would give the gardeners another mean to fertilize the garden. This is

useful as it would reduce the cost of the garden, as the school does not have to buy nearly as much fertilizer as before as well as making the garden more sustainable.

Another issue that Adam Erickson told me about was that the tubs are able to hold much more soil than the plants require. This means that they do not end up filling the tubs up all the way with soil as shown with the image to the left. As the plants have quite shallow roots, they do not require nearly as much soil as the galvanized tubs are able to hold. Naturally, to reduce costs of soil and to be able to use the soil elsewhere, the school would not fill up the tubs completely. Currently, the main issue is that it is much more difficult to tend to the garden when everything is much lower than it should be. As many of the plants require being planted by the roots, people must bend over a lot to be able to tend to the plants.

This makes the process much more uncomfortable and inconvenient to the people managing the garden. In this instance, the middle schoolers, who are some of the users of the garden, Adam told me that this could lead to some back pains to anyone who uses it, from middle schoolers until full grown adults. From a distance, this could also lead to people not seeing what is inside the tubs as the majority of plants are covered. By elevating the soil, people would be able to farm in the tubs much easier, requiring them to lower the shovels less and making it much easier to gain leverage while shoveling the soil. Maintaining the plants would also be much easier as the users would not have to bend as low, giving their back some relief. For this issue, I believe that users would either be high schoolers or grown adults as it is their backs which are more susceptible to back pains. Raising the elevation of the soil would allow them to garden for longer and with more comfort. In the long run, this would also benefit middle schoolers or any of the younger kids, who may get pains if incorrectly lifting heavy loads. In the long run, this a product that would deal with these issues could reduce people's back pains or other physical issues.

Client

In this section, I will briefly discuss my client, Adam Erickson, in a bit more detail and his involvement in the school. It was also contain several of the requests he made while we were discussing the issues at hand at the gardens.

Adam's official role in the school is Head of Middle School Spanish. However, he is very passionate about the environment, specifically, gardening and rainforests that he has undertaken a leadership position at the Rainforest Restoration Project at the school. This project is not the same as gardening and growing the vegetables, however, he and the students that are involved in one are also involved in the other.

All of the information that was in the design need came directly from my interview with Adam Erickson himself as well as simply being present at the garden and seeing the issues for myself. Here I will summarise what the main issues Adam described to be were. He told me that the primary issue, the one that needed solving the most was the leaking compost tea. This was because whenever he carried out tours of the garden for visiting parents or students the reputation of both the school and Rainforest Restoration Project were slightly hurt. The leaking compost tea further had issues with danger as people could slip on it. Or if a person were to step in it, they could potentially carry remnants of it into the school itself which also has carpets. Although this was the primary issue he described to me, another one was how low the soil level was in the gardens. He stated that the gardens did not need to be filled to their maximum height as that would be wasting soil, therefore, they simply have all the soil resting at the bottom. While describing these issues, Adam Erickson gave me nearly full control of the product as he did not give any specific requests apart from it collecting the compost tea. From this, I will have to come up with the rest of the design specifications which I believe will solve these issues as well as being a usable and simple product to use.

Similar or competing products

In this section I will look at various attributes of similar or competing products existing on the market. However, as there are no similar products or solve the same issue, I will be looking at various components that I believe could be used in the product I am designing.

Feasibility Study

In this section I will be discussing why I believe it is possible to produce this product considering things such as time restraints and the materials I would use in the product.

Client Base: Although the client base for this project is not enormous, it is significant enough for Adam Erickson to believe it is an issue. This would include anyone maintaining the garden such as the high schoolers that use it after school. Currently, there is a lack of such products in the market, meaning that this product could be used others who have a mobile garden such as the one shown in the images. A solution to this problem could be used by anyone experiencing this issue. As the product will not be used directly by most people and most surely not on a daily basis, this would mean that most people do not interact with the product itself. Although this problem might affect multiple people, the solution would be used very rarely by a few people, therefore, the user base would be small.

Completion: This project must be completed by February 2016, which includes everything up to the completion of the final product. This means research, design, and development of the product. This will also include production of jigs and formers to be able to allow for batch production in the future. After consulting with my teacher, this completion date should not be an issue for this project.

Materials: The materials needed for the manufacturing of this product are available at school. However, if any other standard components are required, they can be purchased from sellers in Singapore.

Facilities: The entire manufacturing process of this product will be carried out in the Design Technology labs provided by the school, meaning that facilities will not be an issue. As the facilities also include equipment, all the equipment will be available for me to use.

Safety: The majority of the people benefiting and using this product will be of the age of 13 or above. However, as the majority of this product will be concealed, the only safety requirements are that it should not collapse during use. However, the parts where user interaction is required must not fall apart or injure the user in any way during use. Making the product safe to use should not be a problem in any way.

Required Skills and Experience: As I have been taking Design Technology for the past 3 years, I believe I have the required skills and experiences to use all of the machinery in the labs. I also believe I have the knowledge to make the right choices of materials to be used for production.

Cost: As there are no other products on the market like it, it is impossible to accurately judge what the cost of such a product should be. However, given that the materials and equipment for production will be provided by the school, the production costs of the product itself should be very small unless other parts are needed to be bought.

Sustainability: The product must be made out of rigid and durable materials to extend its lifespan. This is because it will have a constant mass of dirt placed on top of it, meaning the beams and supports must all be strong not to break. As this product will be collecting compost tea which will later be reused in the garden, the materials used will be non-toxic and will not leech any harmful substances into the compost tea. Most of the joints will be temporary for any repairs the product would have to undergo if anything were to break.

Design brief

In this section, I will be outlining the design brief, which gives the overview of things such as the design goal and target market this product will be made for. It also discusses the constraints and criteria I must consider while designing this product.

Design Goal

The goal of this project is to produce a fully functional scale prototype of the final product. The scale of this product will be a 1:3 scale where all of the materials and thicknesses will also conform to this scale. It will be produced with materials exactly or as close as possible to those which would be used in the full scale batch produced product. Although the scale model would not be the size used for production, however, it must be of quality that if given to a producer, they could reproduce and make a full scale working prototype. If it were a full scale product, it would have to solve the existing problem of compost tea leaking onto the floor of the rooftop garden. However, it will be able to store this compost tea for later future use in the garden.

Constraints

The following are some constraints I will have to keep in mind while designing this prototype:

-Aesthetically, must look exactly as full scale prototype would
-Must be a 1:3 scale prototype
-Provide a guard preventing dirt from clogging
-Be rigid and strong as will be under constant strain of soil placed on top of it
-The maximum height of the galvanized tub prevents from going higher

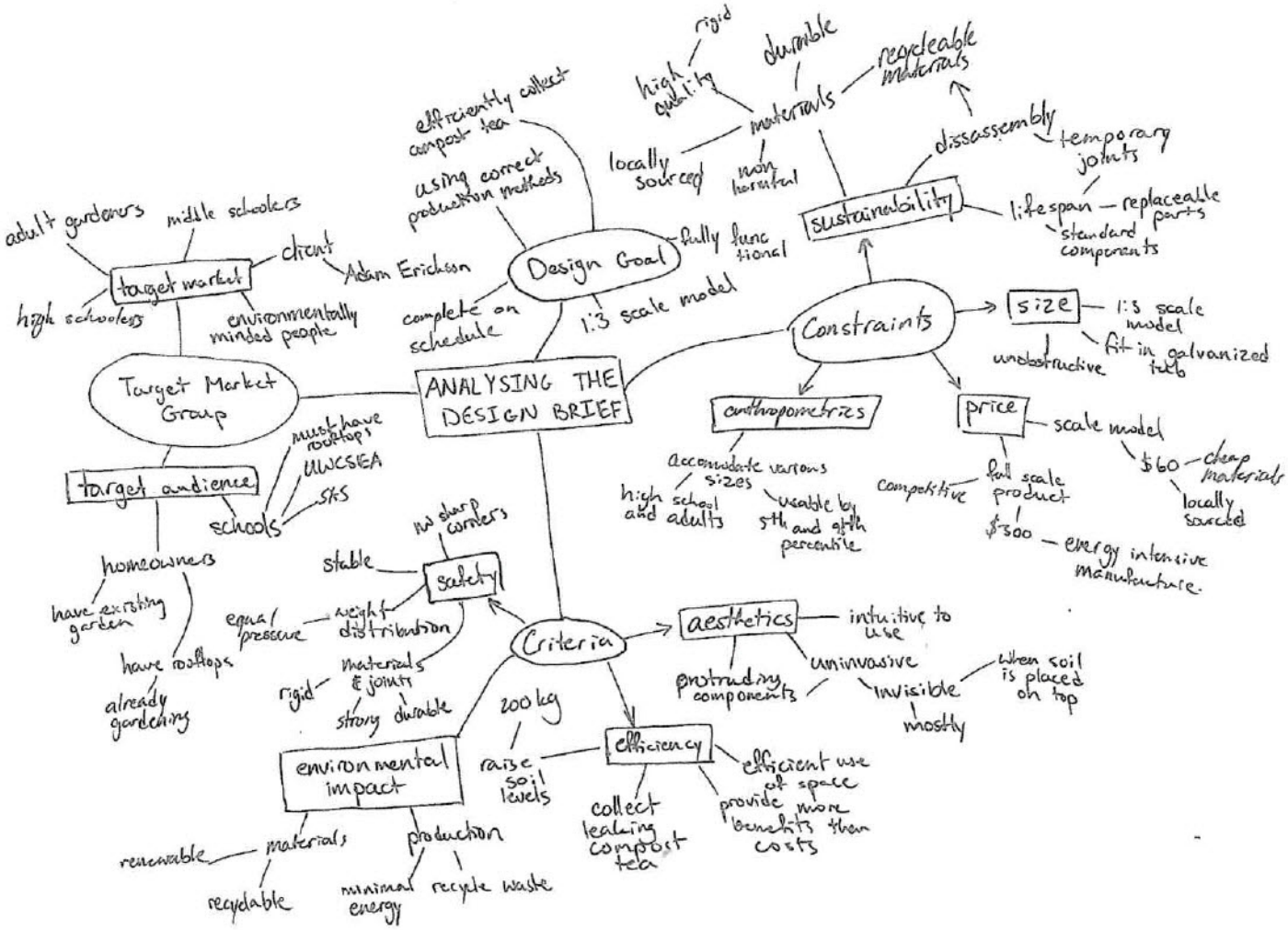
Target Market

In this case, as I would be making a scale model of the product, there would not be a target market for the scale model. However, I would have to assume that this scale model will also be made for the same people as the final product would have been. If we assume this, the target market would mostly consist of the people who participate in the rooftop garden after school activity. As this activity is only open for high schoolers to sign up for, the majority of people using this garden will be high schoolers. However, as middle schoolers also frequent the gardens, they are part of the target market. Other staff such as gardeners who help maintain the facilities must use the gardens. Finally, is other people may be having the same issue, if this product is batch produced, its target market could be anyone experiencing the wastage of compost tea.

Criteria

The product should:

-Be completed by the deadline
-Will consider anthropometric data of people using the final product as well as size constraints of galvanized tub
-Will be invisible after dirt is placed on top
-Designed to perfectly fit the contour of the galvanized tub



Research plan

Below is a table of the research plan I have been able to develop outlining the various things I need to research to more accurately understand exactly what the client wants from this product and what other limitations I must consider while designing the product. The order of this research plan was made depending on the priority and feasibility of the research task. It also outlines what sources I would use to collect this data as well as whether it is quantitative or qualitative data.

Research Priority	Justification	Qualitative/ Quantitative	Primary/ Secondary	Sources/ Method
1. Find any necessary anthropometric data on target market	This data is necessary to know what the optimal height to make the platform. Doing this research will minimize the amount of lifting issues people may have while using the gardens at the lower elevation.	Quantitative	Secondary	Search through books on anthropometric data.
2. Dimensions of current galvanized tubs and current amount of soil used in tubs	These dimensions will be exactly what I must conform and keep in mind while designing the product. Although I am making a 1:3 prototype, this data is needed for the prototype nonetheless. Knowing that amount of soil will also closely link with the anthropometrics of the platform.	Quantitative	Primary	Go to rooftop garden and take measurements myself.
3. Find out how client feels about product	This is because I need to know whether the client is satisfied with the functionality and purpose of the product. If the client is dissatisfied with the product outline, it must be redone.	Qualitative	Primary	Interview Adam Erickson.

4. Find out how any potential users feel about the product	The opinions of the potential users must also be considered for they will be the ones using the product. This opinions will also include how they feel about the issues this product will be solving and whether it is such an urgent one.	Qualitative	Primary	Send out survey to select people who I believe are affected by these issues.
5. Research other products such as similar products or ones that could be used in this design	The research of other products in necessary as it would give me a good idea of the pros and cons of components for components I could use in the product I am designing. It would also make the production much simpler as I would not have to produce all the components.	Quantitative and Qualitative	Secondary	Look at other products which I believe could be used in my compost collection system.

Research and Analysis

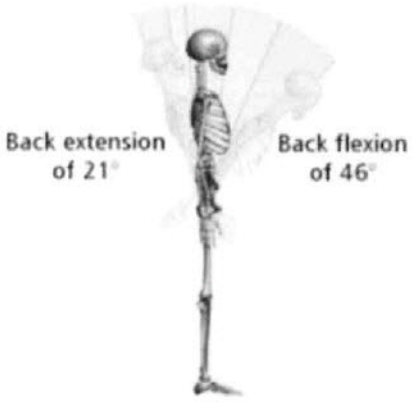
This section discusses in detail all the research I conducted based on the research plan above. The data collected was either from primary or secondary sources. The order in which the data will be presented is as listed by the research plan, from highest to lowest priority.

Priority 1: Find any necessary anthropometric data on target market

As previously discussed, the target market is anyone using the gardens and more specifically, the galvanized tubs for gardening. This includes anyone from the high schoolers who look over the garden every week after school for their service activity. However, adults such as gardeners who look over the on the other days of the week must also use the tubs. Every once in awhile, middle schoolers also visit the garden for further educational purposes. This means that the ages of the target market group range significantly from about 12 to 40 years old. However, as it is not efficient to look at anthropometric data for each age, I believe it is best to split it into three sections, middle schoolers, high schoolers, and grown adults.

The anthropometrics of this product are mainly dealing with the heights of the individuals and the product. Therefore, to the heights of all the potential users and ideal height of the platform must be considered. However, for this, a number of assumptions must be made such as the average age used to find the 95th percentile of the select groups. The 95th percentile will be used as because if the product is comfortable for the 95th percentile, then it would be comfortable for the 5th as well. As one of the functions of this product will be to elevate the soil in the tub for the purpose of farming the contents of the tub easier, naturally, doing so for shorter people (the 5th percentile) would be easier. This is a safe assumption to make as taller people would have to lean down lower to tend after the garden. For the sake of understanding the lower limits and 50th percentile as well, I will include the 5th, 50th and 95th percentiles of measurements of heights.I have consolidated this important information from Appendices 1.1, 1.2, and 1.3 into the table below.

Age	Gender	Mean (cm)	5th percentile (cm)	50th percentile (cm)	95th percentile (cm)
12 years old (middle school)	Male	154.6	143.1	153.4	168.2
	Female	156.1	142.9	156.7	166.3
16 years old (high school)	Male	175.1	163.3	175.4	186.3
	Female	162.2	151.9	161.4	171.6
30-39 years old (adults)	Male	176.4	163.3	176.5	188.5
	Female	163.4	151.4	163.4	174.9

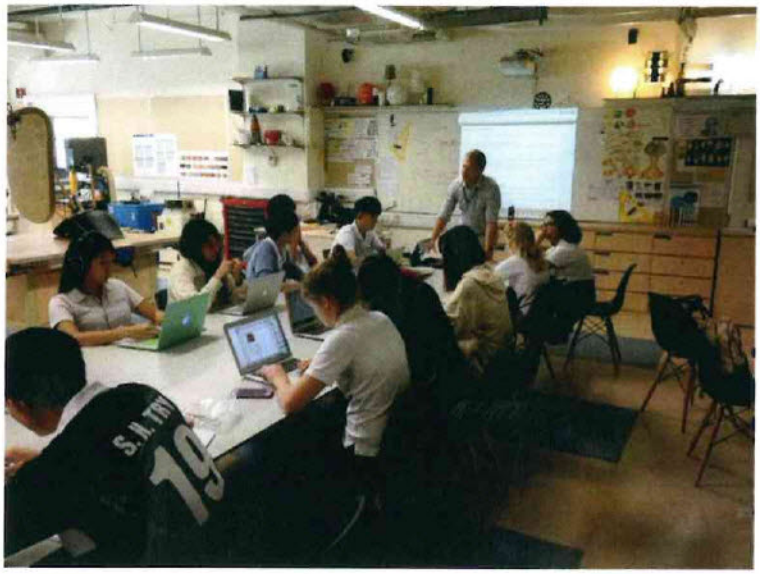


This information is very important to keep in mind because it is not recommended to lift objects after a certain angle bent down. This can be shown by the diagram below where it shows the comfortable and possible positions for lifting object. It is not recommended to lift object after bending further than 46 degrees as it could injure the person doing so. With this, it is possible to find out the ideal height the dirt should be placed at so that it is comfortable for even the tallest people to use. However, if this

height is higher than the top of the galvanized tub, the limit would have to be the edge of the tub. This closely links with measuring the dimensions of the tub and soil to find the ideal height.

Priority 2: Dimensions of current galvanized tubs and current amount of soil used in tubs

To understand the full limitations of the design, I had to find the maximum sizes of the galvanized tubs. When I went to measure the dimensions of one of the tubs, I found it to be 220x132x60cm. As I am making a 1:3 scale prototype, these dimensions will be halved. However, it was also necessary to find out the height of soil required to grow the plants. The thickness was simply measured by sticking a meter stick into the ground and measuring the amount covered. With this, I was also able to measure approximately the weight of soil inside the tubs. By taking a sample of soil inside the tub and weighting its mass as well as measuring the volume, I estimated that 1 cubic centimeter of soil equals roughly 0.3 grams. Multiplying this out by the total volume of soil inside the tubs, I was able to deduce that there is about 175 kg of soil in each tub. This would mean that whatever platform I am designing, it would have to hold 175 kg of soil to be safely operational.



Priority 3: Find out how client feels about product

When Adam Erickson came to our classroom to discuss the various products he is a client for, I had the opportunity to ask him some questions specifically about the compost tea collection system. As he was the one that showed that this problem was present at the garden, I knew he believed it was a common issue people dealt with. When I asked him how he felt about the product potentially serving a double purpose of raising the elevation of the soil as well as a compost tea collected system, he thought it was a great idea as it would be solving two issues simultaneously.

I asked how he preferred the compost tea to be caught as well, whether to be redirected to another storage area or be collected under the platform. He told me that he didn't necessarily have a preference, however, I would have to make sure that wherever it went, it would not turn into a breeding ground for mosquitos. This means that I would have to avoid having still, open compost tea for extended periods of time. This could be avoided by covering the storage container of the tea, or by having someone regularly emptying it.

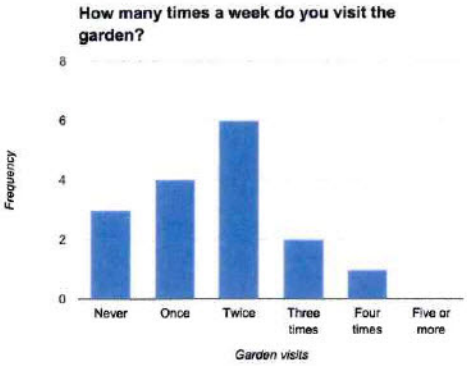
There were several more questions I had regarding the galvanized tubs themselves. When asked whether it was allowed to cut through the tubs, he said that it is possible, but it would not be ideal. This is because the raw steel on the edges of the tub would be exposed and prone to rusting. Adam said that if I were to apply a coat of paint or anything that would prevent it from rusting he would be more willing to cut an opening in the tub. Despite the fact that he has given permission, it would be difficult to perform nonetheless as cutting through steel requires specialized equipment.

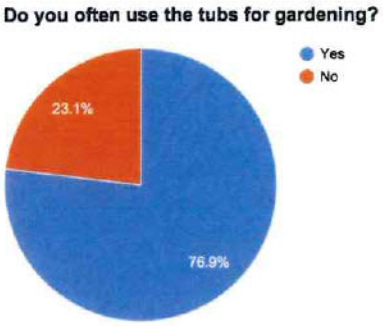
Lastly, I asked whether he thought the product should have any extra functions that it should serve to which he said no. As a matter of fact, he believed that the platform should be completely hidden from view under the soil. He said that due to the lack of space available in the garden, it would be best to maximise the amount of gardening space, however, if need be, a small amount of the platform could be visible if it is unavoidable or makes it easier to operate.

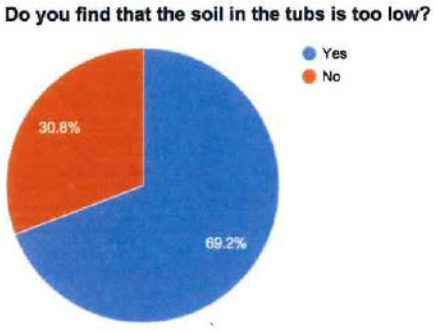
This information will be especially useful when making the specifications for the product. I will also need to keep this information in mind while designing the product, primarily the storage of the compost tea, as it is critical that mosquitoes do not breed. From the interview, I was also able to find out that he permits cutting through the galvanized tubs. Being able to do this opens up many more possibilities for the collection of the compost tea.

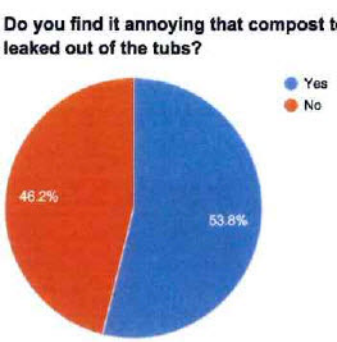
Priority 4: Find out how any potential users feel about the product

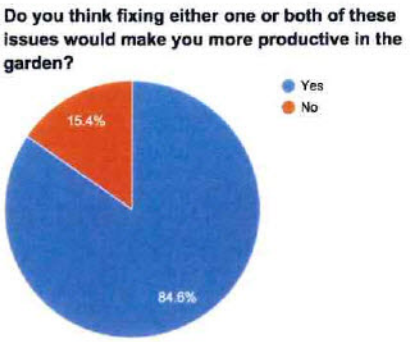
While Adam Erickson was available for interview, I asked him for the names of some students that attend the garden fairly regularly, either as an activity or during school. From him, I received a list of about 10 students, but I also sent the survey to several who I believed were also involved. The full form I sent can be seen in Appendix 4, but I will show the outline of the results. This survey was not meant to be open ended, which after some consideration I thought could have been a mistake, since getting more detailed opinions from the users' would have been even more helpful to the research.











Only 16 people responded to the survey which I sent out. Of these 16, 3 people said they did not visit the garden weekly, meaning they do not take part in any weekly activities related to the garden. After that, I had to ignore any results from them as they had either answered no to the other questions or did not answer, distorting the data of the actual users. However, from the survey, it is possible to see that the majority of the people who do use the garden feel that the height of the soil in the tubs is too low. On the other hand, nearly half of the users' do not find the leaking of compost tea important. However, this could also be because they have gotten used to the leakage and hardly pay attention to it now. Finally, nearly everybody believed that solving one or both of these issues would be beneficial to their productivity. Given the other results, I would believe that the height of the soil is a bigger problem to most than the leaking compost tea. This means that I would have to place a bigger emphasis on raising the elevation of the soil rather than catching the compost tea. Yet this does not mean that I should ignore the compost tea leaking entirely.

Priority 5: Research other products such as similar products or ones that could be used in this design

Here I will carefully evaluate all the competition for this product. Although I was not able to find direct competition, these are the closest products I came across.

<u>Garden365 Mobile Garden</u>

This container is the closest competition that exist to my future product. The mobile container is the image on the left while the mini elevated garden is on the right. The dimensions of the mobile garden are 99x69x36 cm. Although the mobile container is also intended for gardening, it does not solve the exact issue I am facing. For one, this will not fit the galvanized tubs at our school. Secondly, given the research done above, I believe that the height of this tub is too low as it may cause problems in users over the long run. Although I am no gardening expert, I do not believe that the area for gardening is enough to meet the quantity that the school wants to produce at. This mobile container features four caster wheels for mobility of the garden. Each of the caster wheels also has a lock on it to prevent it from moving from accidental bumps. The website also states that this garden could be used indoors as well as outdoors which is why having this mobility is important. As it is important for the plans to receive sunlight, the mobility would allow the user to push the container around whenever needed. The product also has two drain ports. The website claims that these can be used interchangeably as drains or watering options. If connected to an automatic irrigation device, these could ports could also water the plans. Furthemore, if being used indoors, these ports could get sealed with threaded plugs. However, this could only be done when the tub is empty and not in use. The mobile garden is currently being sold for a listed price of $249.99.

Garden 365 Mini Elevated Garden

The mini elevated garden exhibits similar properties to the mobile garden as they were both made by the same company. This garden tub has the dimensions of 69x69x76 cm. The mini elevated garden has four legs that elevate it. The elevation means that anyone using the garden would not develop long term back issues as they are not forced to bend lower than the 46 degrees as identified previously. Another advantage of these legs is that it provides air circulation underneath the tub. This means that the underneath of the tub will stay dry as any moisture would be able to circulate. This way, the bottom of the tub would also be very easy to clean from any mess or spillage of the soil. Although this garden does elevate the soil and solves one of the issues the mobile container had, it has flaws of its own. The volume of the tub is significantly lower than that of the mobile container, thus meaning that the total output of the garden would be even lower than the mobile garden which was already small. However, this garden does also feature the same draining/ watering ports which can also be opened and sealed depending on its location. Both of these tubs are made from polyethylene, which means that the overall maintenance of the product will remain low. I was also able to identify in my similar products section that polyethylene is UV resistant which means that even in direct sunlight this product would not wear out. The steel legs are also galvanized and powder-coated to increase the lifespan of the product. Garden365 offers a 10 year limited warranty. The mini elevated garden is being at $199.99 which is only a slightly cheaper option than the mobile garden.

Research Summary

I have collected the various research which I believe is important to know before designing and manufacturing the product. In this section I will summarise the main points of data I have come across in my research.

One of the main outcomes of the research was that I understood how the client felt about the development of this product. The first thing I was able to find out from Adam Erickson was that having still, open compost tea in my design is not an option to prevent the breeding of mosquitos. He then said that the design could, but would preferably not, involve the cutting of the galvanized tub as it could lead to rusting along the cut sides. This issue could be dealt with by applying a coat of any water repelling finish. Lastly, Adam informed me that the platform should not be visible from the surface, or at least kept to a minimum to maximise the amount of usable gardening space.

There was a significant amount of useful anthropometric data I was able to collect. This data included the heights of both males and females of nearly all heights. This data can be seen in Appendix 1, however, this was all secondary data, meaning that there is a possibility of slight error. For example, I am not sure whether this data could represent the population of the school. As our school is very diverse in terms of ethnicities, and as I am unsure which ethnicity of people this survey was centered around, it cannot fully represent our school. Nonetheless, with the data I collected as well as knowing the maximum recommended leaning angle for lifting object I would be able to understand the safest working height for the garden to be. Then, to understand the upper limit, I found the full dimensions of the galvanized tub which turned out to be 220x132x60cm. Along with this, I found the height of soil required to grow the crops to be 20 cm. Lastly, I was able to estimate the mass of soil used in one of the tubs, which was approximately 175 kg. This mass will be important while making the specifications, as it is important that the platform will be able to uphold this mass.

I was then able to understand how the potential users' felt about the product. As mentioned previously, I regretted not asking more open ended questions as I would have been able to receive much more detailed information on how the students felt about the issues. There was also the issue that only 16 people responded to my survey, which again means that the survey may not fully represent the target market/audience accurately. The survey was oriented towards existing users of the garden which is why the results came back so well. If this was oriented towards people that have never used the garden and are unaware of the issues experienced there, the results would be very different. After further thought, I should have also sent the survey to at least some of the gardeners as well, as they potentially are even more affected by it than the students. Putting this aside, I found out that most of the students believed that solving the issue of the soil being too low or compost tea leaking would make them more productive at the garden. The survey also showed that most of the students only visit the garden about once or twice a week and rarely more than that. However, it also revealed that the majority of students using the garden are affected by the problems I am trying to solve, which is a good sign as the product would be found useful.

I discovered that there are no existing competing products for the specific dimensions of my galvanized tub. However, the closest competition I found were the mobile and mini elevated gardens by Garden365. The issue with both of these gardens is that they were both produced by Garden365 which means that they would have very similar qualities and not differ exceptionally. This limits the scope to which I could analyse the full competition. Both of these products solve separate issues. For example, they both have drainage ports which can be connected to a hose for neat and efficient drainage of the compost tea. The largest advantage I found from the mobile garden were the caster wheels which gave it mobility and meant that the product could be used in any environment. However, the mini elevated garden was elevated to a height which would not cause any long run issues to the user. Both of the products were made of UV resistant polyethylene which meant that they could be used outdoors indefinitely. I believe that there is no direct competition because the problems I am trying to solve are very specific to the galvanized tub. I doubt that there are many people that own these galvanized gardening tubs and experience the same problems as Adam Erickson. Therefore, any product I develop has a high possibility of being used at UWC as no other products like it would exist.

Market analysis

This section will look at the market segmentation for this product. This will stem from a lot of the research conducted and will consist of various groups such as geographic or user needs. This section focuses on how this product will differ from other competition given the situations it will be facing and issues it will be solving.

Geographic Segmentation

This product will be used in Singapore at the United World College. It will be used on the high school rooftop garden. This area is open and has no waterproof roof, meaning it will be receiving a lot of rainfall and sunlight. The roof does have a semipermeable tarp which means that sunlight will only slightly get filtered. The climate in Singapore is very humid, but as the product will be under a layer of soil, it would be very damp under the soil. Temperatures in Singapore can rise to approximately 36 degrees Celsius during the months of April and May. This is due to the strong sunshine.

Psychographic Segmentation

One of the user specific requirements is that it must make gardening easier for the users. The UWC mission is *to make education a force to unite people, nations and cultures for peace and a sustainable future*. What must be pointed out is that the words 'sustainable future', which this product will help create. By educating people on the importance of collecting compost tea, this product will lead to a more sustainable future. However, it is also the message of reusing and collecting what some might consider waste, sending a green message to others.

Demographic Segmentation

As previously discussed, the ages of the potential users will vary depending on whether they are student or school employee. The age of students will range from around 12 to 18 years old, being both high school and middle school students. The gender of these students will include both male and female as the garden is open to anyone. On the other hand, the school employees who use the garden will be much older. They could be anywhere between their 30s or 40s. Their gardening skill would also be significantly better than high schoolers as this is part of their job rather than an activity. These adults also have access to the garden all throughout the day unlike students who only become available after 3.

Marketing specification

This section outlines in detail the various marketing specifications that I must consider before producing and designing the product. I will create the marketing specifications, justify what and why I have selected what I did, and then state how I plan to achieve it.

Point	Justification	How will it be achieved
Target market - should appeal to environmentally minded individuals - appeal to those interested in environmental sustainability	This means that that the product should target everyone interested in portable gardening such as this one. Also anyone interested in environmental sustainability and looking to increase the productivity of their own garden.	Meeting their needs will be done through interviews and google questionnaires.
Target audience - same requirements as target market	Although in this case, the target market are the users using the garden at UWC, the target audience could be anyone using the galvanized tubs for gardening. Although they would already need to own one, these people would most likely be environmentally minded and friendly people who are interested in reducing their carbon footprint by utilizing their rooftop space and turning it into a garden.	Because the target market and target audience would experience the same issues with the product, the data used could be the same as the data already collected from interviewing the target market.
Market analysis	The issue this product is very specific, due to this, the market for the product is probably not that large.	There is no way to prove how a product would perform on the

	When most people do gardening, they do not use portable tubs as they would have access to a full garden with land. However, due to the lack of other competing products on the market, I believe there would at least be some room for profit.	market with a prototype, therefore, this would simply be assumptions.
User need - should be evidently sustainable - should collect compost tea effectively - should raise elevation of soil	Users are looking for a product that would satisfy them by collecting leaking compost tea as well a raising the elevation of the soil, making it easier for them to operate in the garden.	Testing of scaled prototype will conclude whether the product is strong enough to sustain weight of soil. Testing will also determine whether product collects compost tea effectively.
Competition - should compete with similar sustainable products on price - will compete with similar products on functionality	Competitive products consist of other portable gardening products such as the garden boxes and Garden365 Mobile Garden. Although the garden boxes were made by hand, the Mobile Garden sold for $249.99, with the Mini Elevated Garden selling for slightly less, which is still quite a large price tag. The issue is that neither of these products solve both issues my product will be, only one or the other. This is why the compost tea collector will not have much competition as there are no similar competing products.	Most of the research on similar products has already been completed in the research section. However, the success of a scaled prototype is difficult to measure as it would never really be on the market. This would mean that I would have to conduct surveys with other potential users to see whether they would purchase my product over other similar ones.

Product design specification

The product design specifications is a very detailed list outlining what criteria the product needs to meet to be used successfully. These criteria look at various issues such as the properties of materials which must be used as well as how to make the product sustainable in the long run and other performance requirements.

Specification	Requirement	Justification
Aesthetic requirements	Must not be invisible to the user unless fulfilling another purpose	This is because when I interviewed Adam Erickson he told me he preferred the product not to be visible from the surface of the garden unless it is fulfilling another purpose or is absolutely required.
Cost constraints	Must cost half of the competing products, so $130 or less to produce. The scaled prototype should not cost more than $60 to produce.	This is to be able to have a decent enough profit margin and remain competitive in the market for other similar products.
Customer requirements	It must elevate soil above current level. It must collect leaking compost tea effectively. Product must be easy/ intuitive to use. Must have easy access to collection area.	This is because one of the requirements the client gave was that the product should elevate the soil. It is because the user feedback also suggested that most of the people thought the current soil levels were too low and it would make them more productive if they were raised. Again, this is very similar to what is written above. The survey sent to the potential users showed that nearly half the them were annoyed that compost tea was leaking from the tubs, thus the need to catch it effectively. This is so that anyone approaching the product would be able to use it without a second thought. Also so that there are not an excessive amount of steps the users must do to use the product. This is for the user's safety so they do not injure themselves while using the product.
Environmental requirements	Must use temporary joints.	Temporary joints will allow the product to be more environmentally friendly as specific broken parts can be replaced rather than having

	Components used should be able to be disassembled so they can be recycled. If possible consider materials which must come from close region to save impact on carbon footprint.	to throw away the entire product. Using temporary joints, these materials would be able to be disassembled and recycled to extend the lifespan of the product instead of scrapping the entire product. I understand that Singapore is not a large manufacturer of materials such as acrylic or steel, so these are ordered and shipped in from outside. However, what could be done is minimizing this transport distance and sourcing materials from other regions of South East Asia.
Size constraints	Must fit within the galvanized tubs which have dimensions of 220x132x60cm.	By measuring the dimensions of the tub, the maximum dimensions of the tub are as stated and if the product was larger it would not fit, yet, if it is smaller, the soil would fall through.
Safety considerations	Must be safe to use. - During installation and use the target market group will not hurt themselves as all. However, the edges, corners, fixings and fasteners will be safe to handle and use and the end product will not have any sharp edges or corners	The point of this product is that it is attempting to make gardening safer for the users as it would mean not having to bend below the advised level as discussed in the research.
Performance requirements and constraints	Must be able to hold 200 kg of soil.	This is because I estimated the mass of the soil currently in the tubs to be 175 kg and just to be safe, the product should hold 200 kg of soil.
Manufacturing and material requirements	Must use durable materials. -the material must not be brittle and must have high tensile strength -material must be chemical resistant Must be and chemical water resistant.	This will assist in achieving the previous specification. By using durable materials with high tensile strength, the collection system will be able to uphold the soil for extended periods of time. Must also have good chemical resistivity as the pH of the compost tea is unknown. Due to the geographic location of this product and the fact that it will constantly be exposed to moisture, the product must be water resistant. This should be achieved either through non organic materials or water resistant finishes.

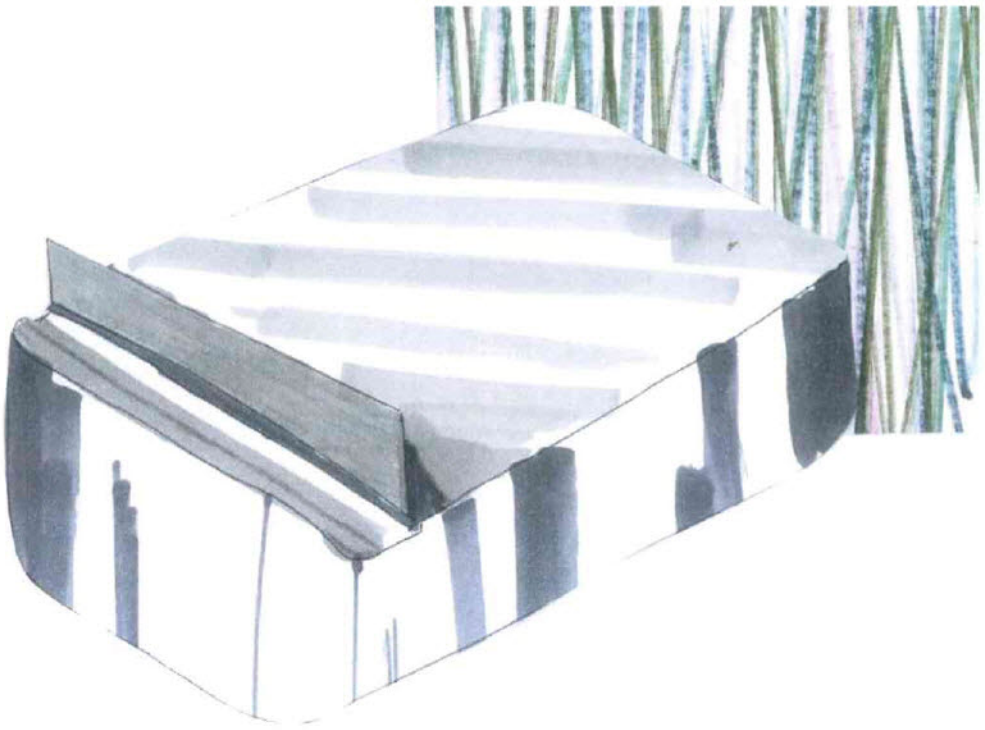
Criterion B: Conceptual design

Initial Designs

IDEA 1

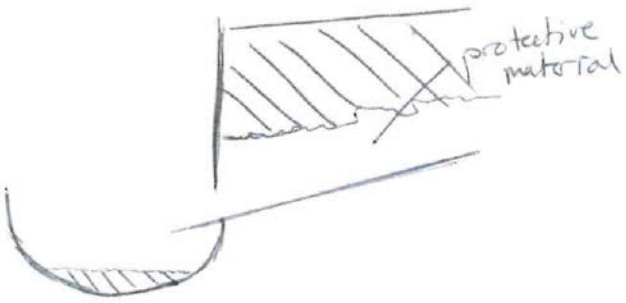
This design has been designed around the use of gravity to collect the compost tea effectively. Although it is not perfectly visible on the drawing, the base of the platform will be on a slight decline to have the compost tea leak down into the collection area at the bottom. The platform will be make from a large sheet of aluminium, which is both lightweight and will not rust when exposed to water and the elements. The downside of using aluminium is that it is very malleable and could bend under a lot of weight, which I calculated to be roughly 175 kg of soil in each tub when wet. Although I considered steel for the material, I believe steel would be too expensive and would not meet the criteria of being cheap as well as using easily recyclable materials. To support the aluminium base, I would consider reinforcing it with either a T beam or an I beam, both cross sections are shown here. Despite the I beam being slightly stronger, I believe it would be a waste of materials as it uses about 50% more material than the T beam.

Next, the entire body of this product would also be made out of aluminium as well. Supporting and enclosing it will be long sheets of aluminium. Making it out of one sheet would be nearly impossible as finding a sheet that long would be both expensive and hard to transport. For this, the aluminium sheets would have to be pop riveted together. Otherwise, to make any repairs to the inside, the aluminium could be held together with a nut and bolt for a more temporary joint.



An advantage of the declining base is that there will be multiple thicknesses of soil along the design. This is an added bonus as some plants may require more depth to grow if their roots grow deeper while some may need less. This way, space and soil could be more efficiently used.

I understand that I did not draw the collection system perfectly. For this, I have added an image of the cross section of the collection area. This is meant to show how the compost tea will leak down into the collection zone with the assistance of gravity where it will be later collected. To prevent the soil entering the collection area through the drainage hole, there will be a protective material resembling the material of cloth, where a liquid could pass through but a solid would stay on the other side. The idea is that this compost tea would stay there for as long as needed until collected. The collection could either happen by scooping the compost tea out or by placing sawdust into the collection area. The sawdust could be collected with a small shovel and then reused as further compost in the garden. There will also be a guard in place to prevent the upper soil from spilling into the collection area.



IDEA 2

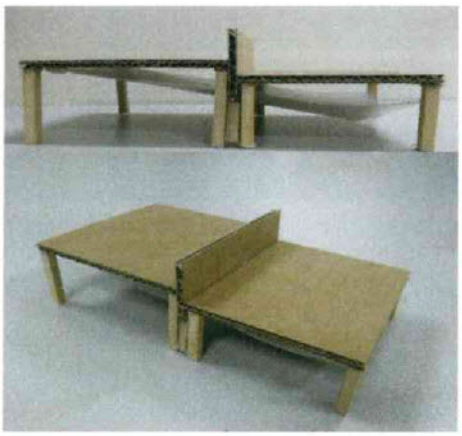
Similar to the previous idea, the majority, if not all of this product will also be made from aluminium. The reasons for the choice of material stay the same as aluminium would not rust or corrode from prolonged exposure to water, the elements, and compost tea. This design is more efficient than the previous one as it maximises the total available space for gardening. This image does not display a collection basin - these will be discussed on a later page in more detail.

In this drawing, the legs are standing alone, however, with the total mass of the soil on them, I would expect this design would not hold for long. Because of this, I believe they would need to be reinforced in the shape on an 'X' with T or I beams to strengthen them and make sure the design doesn't buckle.

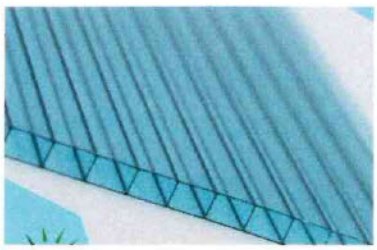
I chose to perforate the aluminium bases to let the compost tea to leak through. As the aluminium bases are so large, this would have to be done by a CNC drilling machine. Drilling holes into the aluminium would also decrease the weight of the base and overall model. Again, to ensure that no soil gets through the holes, there will be a protective material preventing it from getting through. The holes will also be approximately 5 mm in diameter and spaced approximately 20 mm away from each other to make sure that all the compost tea is collected.

As can be seen, this is a tiered design, where there are two levels the soil could go on. This would mean that the plants with larger root systems could be on the deeper side while the smaller ones could be on the other. To join the bases to the centre piece, I would use an angle bracket, which would keep everything together. A nut and bolt would again be used to allow the collection system to be disassembled.

I have also created a scale model showing the underside of the collection system detailing how the compost tea would actually get collected. As can be seen, the system would actually be quite efficient in collection the compost tea. It would all drain down to the right side where it would get picked up by some container. This piece that actually collects the tea could potentially be made from a sheet of PVC or UV stabilized polyethylene, as what is used in other similar products storing compost tea. This would reduce the amount of work done by the gardeners and students for they would not have to collect the tea themselves, instead it would drain into one locations where they could simply collect it from there.



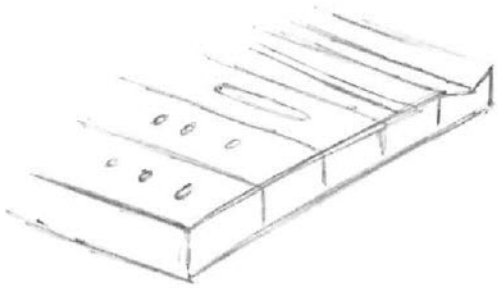
Another advantage of this design is that because of the center piece dividing the two tiers, there would have to be supports at the middle of the model. This would naturally mean that the product could hold up much more soil than the others. I would also have to chamfer the edges of the dividing piece to make sure that nobody cuts themselves on the sharp edges while using the garden. The corners would also have to be rounded for the same reason.



However, utilising the entire area of the tubs would come at a cost. This would mean that to retrieve the container collecting the compost tea, a reasonably sized hole would have to be cut through the bottom galvanised tub. This would mean that to prevent rusting of the tub I would have to coat the tub with a waterproof material such as paint or another finish.

IDEA 3

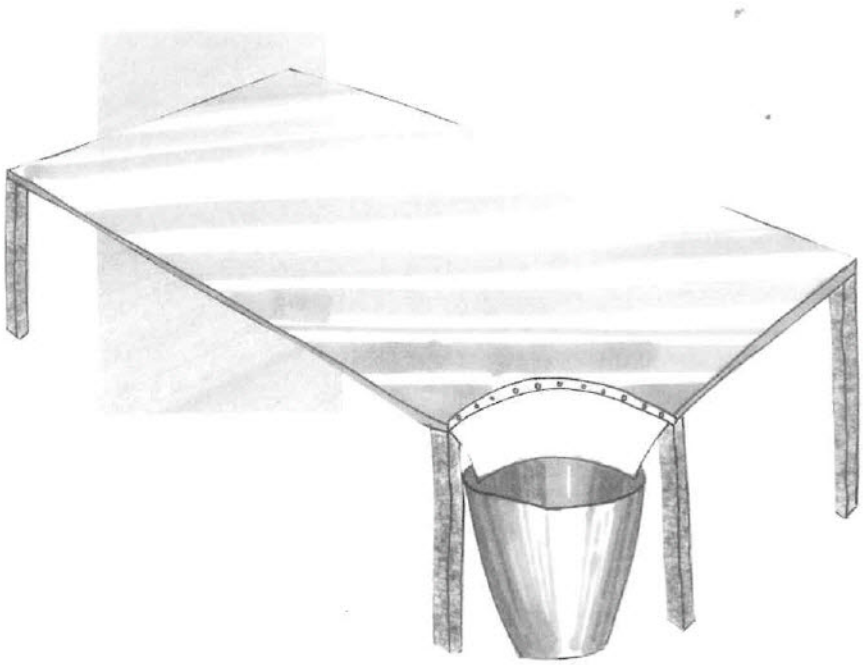
Initially this idea looks very similar to the previous ones. Although the base of the model looks to be aluminium again, it would have to be a thick polycarbonate hollow sheet of plastic that resembles the image provided. These can be bought from Alibaba for roughly $3.5 per kilogram, making them very affordable. The idea is that these hollow tubes would all point towards the corner of the tea collection system where it would then get collected. This would be a small layered system as the compost tea would leak through the first layer and then run down through the tubes to the collection area. I have also included a sketch showing various areas for holes I could use that the compost tea could leak down through. The first two are the same, with similar perforations as idea 2. However, the second method is to use longer and more drawn out holes which could potentially collect more compost tea. The next idea is to simply cut along the entire length of the tube. However, the last one would collect all the compost tea as it is on a slight decline, meaning all the tea would leak into the tubes. Also, to make sure that the tea drains into the desired place, the upper end of the design would have to be elevated higher than the bottom end with the bucket.



As these tubes are also quite small, they would have a high chance of getting clogged with small particles of soil. There may be some measures put in place to prevent this such as the protective material. To clean the tubes, the side of the galvanized tub where the arrow is pointing could be cut out. With this, water could be poured with a hose directly into the tubes giving them an instant clean.

As plastic is significantly thinner and weaker than any metal I would use, this model would have to be significantly supported. However, the beams used would have to run perpendicular to the tubes, as the plastic would already be strong in the direction the tubes are pointing. The joints between the plastic and wood would not even have to exist necessarily, instead, the plastic could get glued onto the beams supporting it as well as the wood. This is because any other way would mean having to make holes through the tubes resulting in potential leakages.

Just like the previous design, this one would not be able to hold itself up with the flimsy legs I have drawn on it. These would have to be supported by other planks. I have also chosen to use a wood as the legs as there should not be any liquid reaching the underside of the product, therefore they should not rot for a long time. The wood used would be pine as it is lightweight, cheap, and durable. To take precautionary measures, to prevent water from getting inside the wood, I could finish it with a waterproof paint that would significantly increase its lifespan.

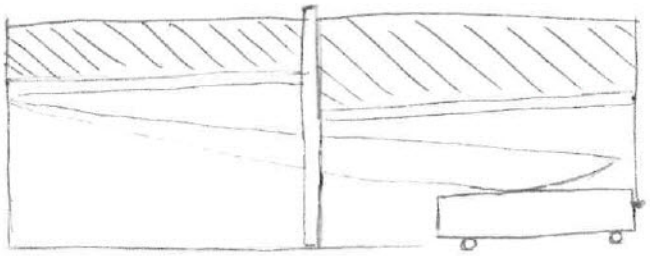


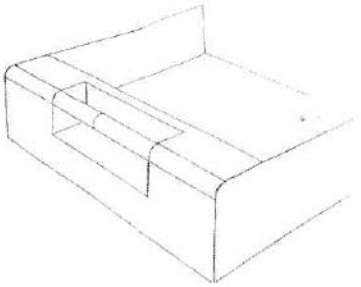
As the water drains out of the tubes, there will be a waterproof tarp of sorts making sure that there is no spillage as the compost tea leaks out. This tarp would have to be placed inside the bucket so that no compost tea is spilled. Also, the bucket would be a premade bucket that could be bought at any store. In this image, the bucket appears to be much larger than it would be. The bucket would also have a handle to make lifting the compost tea in and out of the collection area easier for the users, rather than having to hold onto the edges of the bucket.

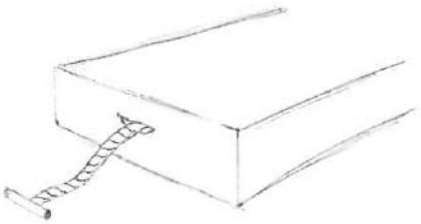
While drawing this, I did not consider that there would have to be a wall preventing the soil from spilling into the collection area. This wall would be made from aluminium as it is a very easy material to bend into a circular shape due to its malleability.

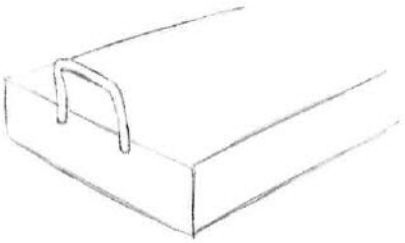
BUCKET IDEAS AND EVALUATION

For idea 2, I discussed a bucket that I would have to make to for the compost tea to drain into and get collected in. From the side, this is what the design with the bucket would look like. As the compost tea drains through the perforated aluminium base into the collection area. As it drains down the polyethylene catcher, it will eventually reach a collection bin. In this section, I have drawn a few designs for the handles for the collection boxes which I will also evaluate.









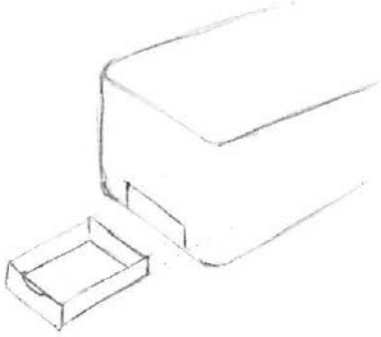
This idea could easily be made out of acrylic. Once all the dimensions of the box are sorted out, each individual piece could get laser cut and glued together. The handle is also rounded to make gripping it easy. The design also has a splash guard, so when the compost tea leaks down and potentially splashes, there will not be any residue on the handle when people grip it. An advantage with this design is that it would also be flush with the galvanized tub and not have any parts sticking out from the tub, unlike the other designs.

This concept has a rope instead of a handle. At the end of the rope there would be a wooden handle where the user could grab and drag the collection box. The largest advantage of this design is that this box could serve a double purpose where it could be used to transport other materials around the gardens such as equipment. The length of the rope is not proportional in this image, but based on the anthropometric data, the it would have to be roughly 1 meter in length. However, if not stored properly, people could trip over this rope and potentially injure themselves.

This handle would be similar to the first one, however, this one would stick out and up, meaning that the user would not have to bend over as much to pull this collection box out. As this extra stress on the back is exactly what I am trying to avoid, this design would be ideal. The disadvantage however is that depending on how much the handle sticks out, it could also hurt someone. This handle also has the highest chance of breaking off as the forces would be most concentrated on the two particular small areas where the handle and box make contact.

All three of these designs would of course be equipped with wheels such as the one shown that would be able to swivel 360 degrees. This would allow the box to be dragged around to the desired locations where the compost tea is needed. Although the wheels in the photo are not exactly what I would use, the tires would need to be rubber to be able to absorb some amount of shock, as I would not expect the box to be treated lightly.

For the way that the box fits into the tub, to try and conserve the look of the tub, it would be best to cut off as least of it as possible. For this, the size of the hole would preferably only be just larger than the collection box. This way, the box would stay in place as well as preserving the look of the tub.



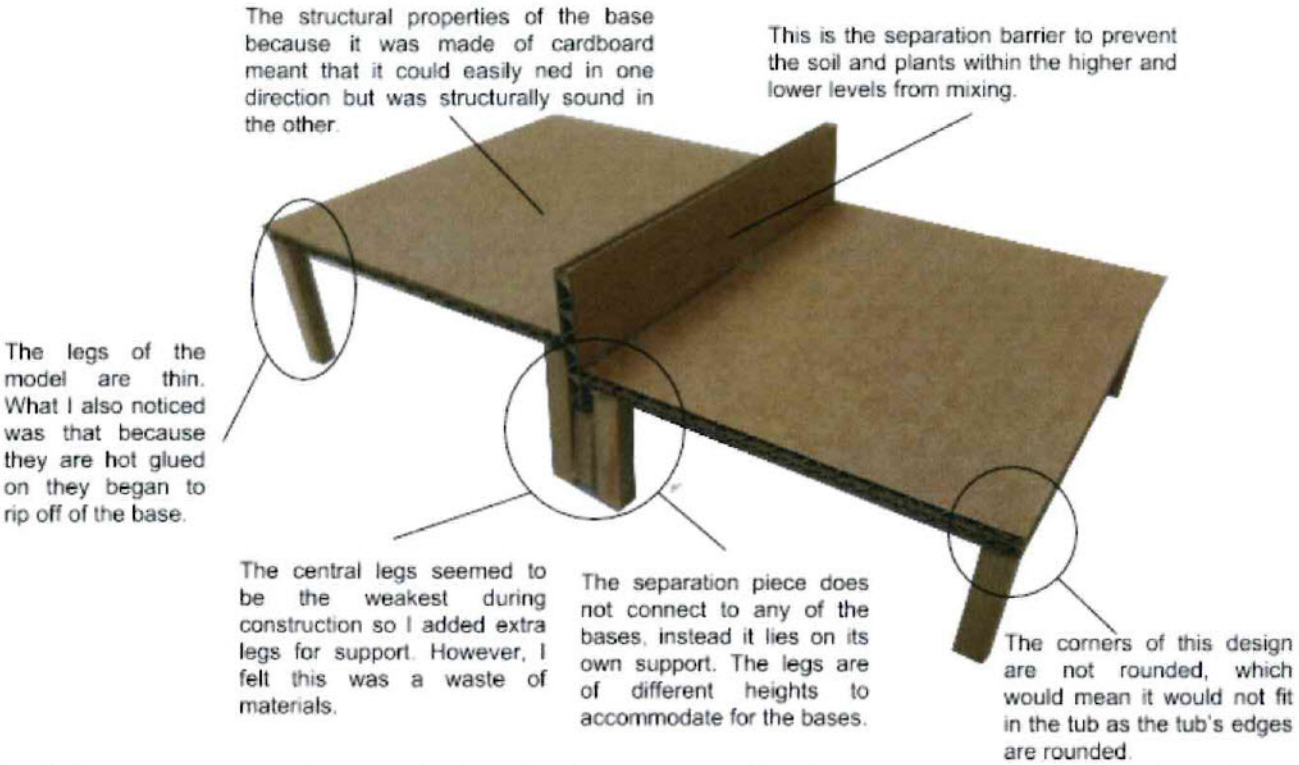
Specification	Idea 1	 Justification	Idea 2	 Justification	Idea 3	 Justification
Must not be visible to the user unless fulfilling another purpose	2	Despite an entire side of this design being visible, it is indeed carrying out another purpose of collecting the compost tea, therefore is fully fulfils this criteria.	2	This product is absolutely hidden. Other than the separation wall in the centre. However, this is so minor that it would not influence the way that this product will be used.	2	Despite an entire corner of this design being visible, it is indeed carrying out another purpose of collecting the compost tea, therefore is fully fulfils this criteria.
It must collect leaking compost tea effectively	1	The efficiency of this product would greatly depend on the angle of the decline. One of the problems it might encounter is that the protective material would simply soak up all the compost tea hindering it from being collected.	2	The collection system below this product would most definitely collect the compost tea most effectively. However, the base could use some further improvement, but it still collects the tea effectively.	1	This product could be susceptible to being clogged which would prevent the compost tea from being collected well.
Must be produced using sustainable materials	0	Due to the large aluminium sheet lining the outside of the product, this would not be a sustainable solution whatsoever.	1	This product also uses a significant amount of aluminium which would not be sustainable. However, it uses much less than idea 1.	1	Although this does not use aluminium, it does use a plastic, meaning it would be bad for the environment if not recycled after use. It would also require a lot of wooden planks to reinforce the legs.
Must be able to hold 200 kg of soil	1	Depending on the amount of reinforcement behind the aluminium sheets, it could hold up this much. However, aluminium is a very soft material and would buckle easily under this kind of weight.	1	As the legs would be made from square tubes, solid or hollow, they would be stronger, however, I still doubt how much they would be able to support in the long run.	2	I believe that wood would be the best option to use as legs as wood would be the strongest of the previous options. However, the issue might be how much the plastic itself would be able to hold, even with the T beam supports in place.
Must be safe to use	2	There are not a lot any moving components in this model which would make it significantly safer to use as it a product.	2	Due to the simplicity of the design, there is not much danger to it as there are no sharp edges and no moving parts.	1	The corner on this design could be potentially dangerous. This is because while pulling the bucket out of the collection area, the user may cut their hand on the way out. Although this is somewhat unlikely, the risk is still there.
Must use materials that are durable and will not degrade over time	2	As this product would be made entirely from aluminium, it would not rust or lose its functionality over time.	2	Also entirely made out of aluminium, thus, it would would not degrade over time. Also, if the bases are supported properly, there should not be any bending of the design.	1	This product would include three materials: wood, aluminium, and plastic. Although the plastic would most likely last thousands of years, the wooden legs of the product would have a much shorter life span. These would most likely rot after several years or so, yet can be easily replaced afterwards as the joining technique would be temporary.
Components used should be	0	None of the components of this design can be taken apart	2	The simplicity of the design allows the components to	2	This is similar to idea 2 where the components are

able to be disassembled so they can be recycled		easily.		be disassembled. Many of them are easily replaceable as they are standard components such as the wooden legs.		very easy to take apart. However, the detail of the fluted cores may mean that the base would be readily available.
Totals:	**8/14**		**12/14**		**10/14**	

Development

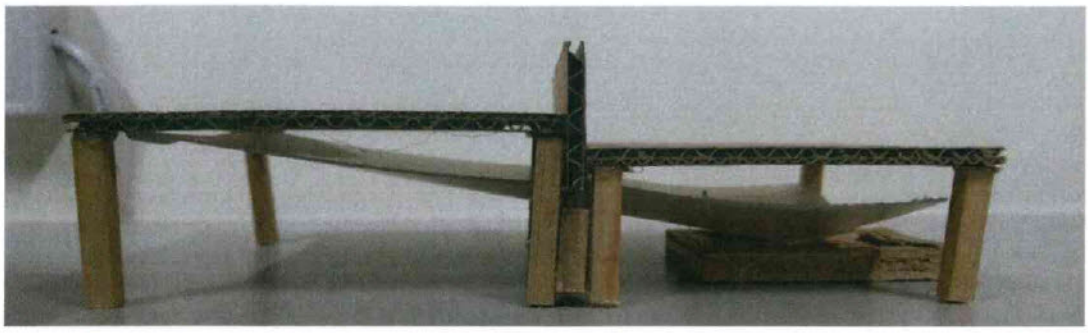
For the further development of my ideas I have chosen ideas 2 and 3. I have decided that idea 3 is more practical to make as it requires much less components than 1 and was slightly ahead of it in terms of overall score. As idea 1 has more components it would have more room for failure or getting jammed at some point. Because of this, I believe that making 3 is more feasible.

IDEA 2



From this initial prototype I was able to develop the following concerns which which I would have to consider if I were to choose this idea to develop further:

1. The directional strengths of the materials which I would select. I will need to consider if it has a higher likelihood of breaking in one direction or the other and reinforcing it if need be. If I were to use a corrugated material it could break easier in one direction versus another so supports may be needed.
2. The curvature of the edges is important to consider as there should be minimal gaps between the walls of the tub and the collector. This is so that the soil on top of the collector does not spill out the sides.
3. The thickness of the legs is important. As the specifications say that the tub must hold at least 200 kg of soil, the legs should not buckle. If they are too thin, they could snap or buckle and the entire collector collapse.
4. The placement of the legs and joints at the centre of the design. During the making of this prototype I did not fully consider the placement of the legs and where they may be weak so I ended up adding three legs to the centre.



The image above shows the side view of the collection system with the pull-out bucket. The compost tea is collected by perforations in the base which let the compost tea drip down onto the plastic collector. This tea would then all collect near the bottom where it would go into the collection box.

4) 4" Caster Wheels Heavy Duty Set 2 Swivel 2 Side Brake No Mark Non Skid

$23.00
Buy It Now

Roll it right with these heavy duty premium industrial caster wheels. We produce the highest quality industrial grade caster wheels, with our tough and smooth double ball bearing design and double zin...

I mentioned previously that I would need to use swivel casters in my design for the collection box. On eBay, 4 swivel wheels could be bought for $23.00 which is well within the price range. These wheels also have breaks, meaning that they would be able to be parked when they are under the collection area. The wheels with breaks will be placed at the front end of the collection box. This is so that the wheels are facing outward and can still be locked from the outside. The other wheels are stationary wheels, meaning they would not have the ability to rotate, which would allow the box to be parked in place effectively. As these are industrial grade wheels, they would not skid on the surface due to the higher friction of the wheels.

I believe that the rope handle would also be most effective for the box as it would allow the users to carry drag the cart along with them. With this, I will be evaluating the various handles and grips that could be used for the collection box. I believe that the optimal material to use for the handles would be oak as it would not dent easily when dropped or hit against something. This would improve the overall lifespan of the handle. The wood could be sealed with epoxy or varnish to make sure that it does not absorb any water when being used. This would also improve the aesthetic look of the handle.

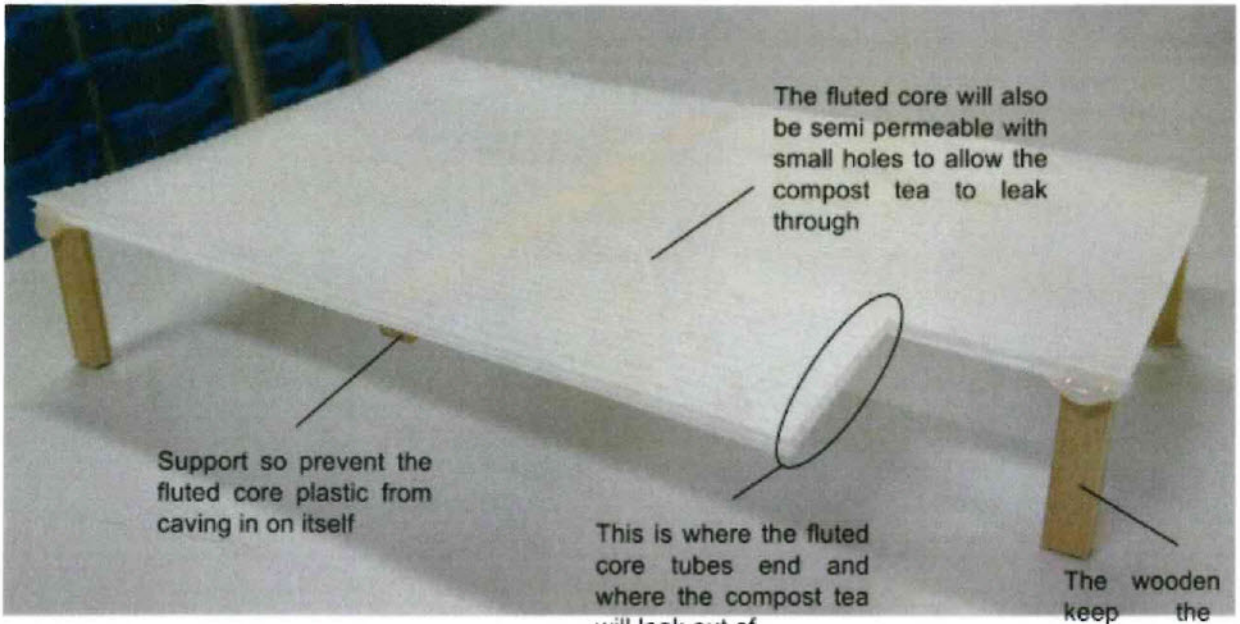
These handles resemble those that might be on skipping ropes. These handles would last for a while and would be easy to connect to the rope. The disadvantage would be that holding them would be uncomfortable as the user would have to bend their wrist at a very awkward angle. They would also have to apply more pressure to hold the handle as it would be constantly slipping through the palms of their hands.

To simplify things, I could purchase this premade handle or I could make it myself. This would be done by drilling a hole through the centre of the wooden cylinder that would allow the rope to pass through. This model would last longer than the one on the left as the pressure would be distributed among both sides of the rope. However, the problem with this is that it might slip as the handle would be free to move in the user's grip. To compensate for this, the user may have to add pressure in their wrist to keep the handle from slipping.

This method would be the hardest to produce because making the connection between the rope and the wooden handle would be difficult. One way to do this could be to tie a loop around it or also glue it. However, glueing it would weaken the handle significantly as it would not have that much surface area to hold on to. On the other hand, this handle would be one of the best as it would not apply any additional stress to the hand of the user.

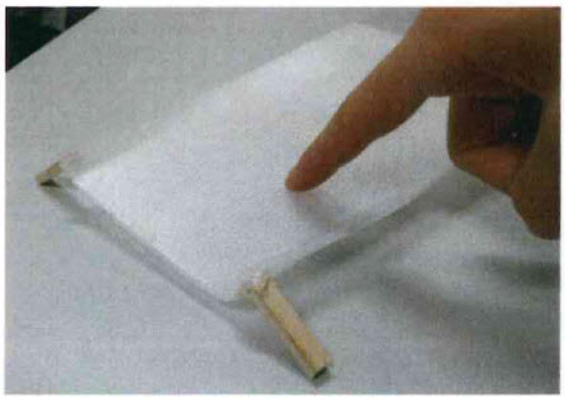
There are some major issues present if I were to use the collection box to collect the compost tea. Firstly, the box could easily overflow during times of heavy rain or excessive watering. Although this would be collecting some of the compost tea, I would like to minimize the amount of compost tea spilled onto the floor. This is both for aesthetic reasons of the garden as well as for the safety of the students using the garden.

IDEA 3



Just initially looking at this prototype, multiple problems can already be seen. Here are some of the issues I would have to consider:

1. The fluted core tubes are unable to bend and need a way to direct all of the tubes towards the corner of the model. This could only be fixed by ordering a custom fluted core sheet.
2. Based on my design specifications, the fluted core plastic would not be able to hold 200 kg of soil, and therefore would need to create a similar effect but out of a different and more durable material.
3. The wooden legs do not support each other and simply give way under even the slightest pressure. This is because of the legs and the quality of the fluted core plastic that it bends easily. This issue can be seen on the image below.
4. The support is nearly ineffective of keeping the fluted core plastic together.



In this current state, the product is nowhere near usable. The main issue at hand is that it is unable to hold 200 kg of soil. One solution to this would be to join the legs together so that they do not slide under each other. The legs are also only made of wood, which over time with moisture will rot, which is why materials and moisture of the product will have to be considered in the later stages of design.

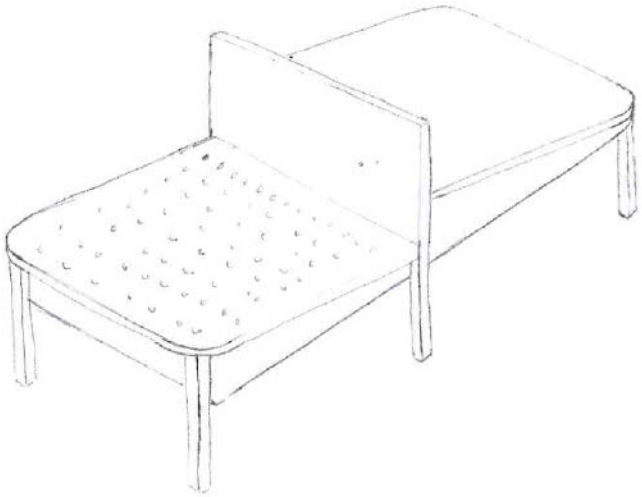
I noticed that the fluted core plastic has great strength against the direction of the flutes themselves. If the legs are joint together, the model would immediately be able to hold more soil. However, the flutes and material itself are very thin, which is why the core bends so much. Another solution is to use a thicker and more industrial fluted core such as the one shown below. With a thicker base, cutting holes into it would be easier and they would be able to hold the mass of the soil without collapsing into itself. However, this would increase the price of the product as the prices of the components would also increase. Then, another addition could be to add more supports underneath the base to further prevent it from collapsing. The final product would need to use a heavy duty metal for these supports as a metal such as aluminium would bend too much. If I were to use steel supports, the product would again become more expensive, yet at the cost of structural stability.

Criterion C: Development of a Detailed Design

Development of solutions

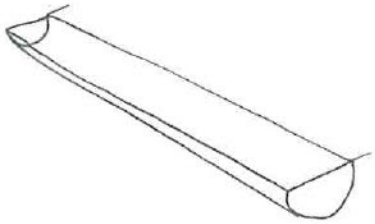
In this section, I will be elaborating and further developing Idea 2 which I believe to have been the strongest out of the two. This section will include trying to take as many of the pros from each concept and minimizing the cons. This section would then lead me to the final working prototype which I will eventually produce to scale.

Although I did not select it for development, one of the greatest things I liked about idea 1 was the collection area of the compost tea. In this model, the compost tea could get collected at any time, unlike the idea 2 where the compost tea would leak without the collection box. Another advantage of this design is that the user would not have to bend as lot to collect the compost tea. However, idea 2 utilizes the gardening space much better. Because of this, I believe I could combine the two ideas. I also considered incorporating parts of idea 3 into this - specifically the base and how it should look. However, I chose to stick to the original idea of circular perforation as it would make the process of making it much simpler and less time consuming. Acquiring the perforated base is simple, I could either purchase a premade one or use a CNC drilling machine to perforate it for me resulting in much higher accuracy than doing it by hand.

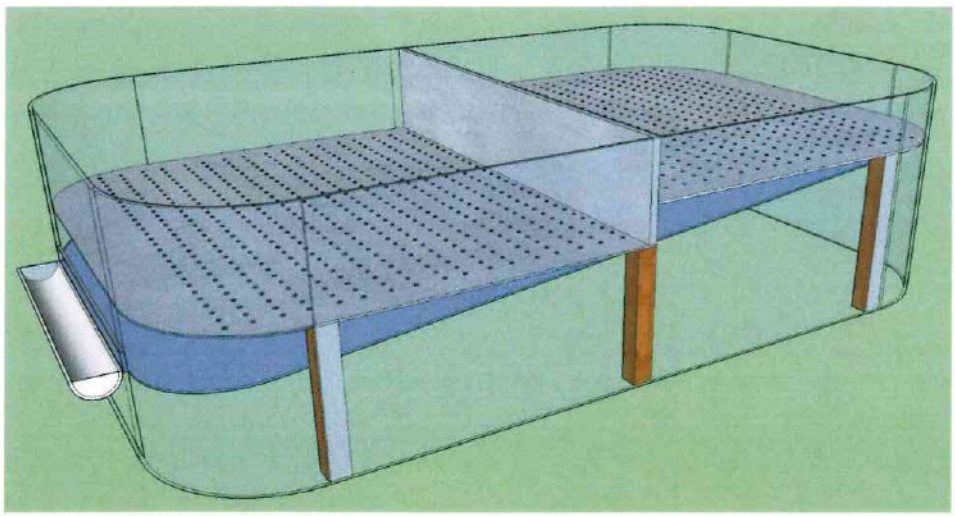


Although only slightly modified, this idea looks primarily like idea 2, however, the difference is that now there will not be a collection box underneath the tub. In this case, the compost tea will drip all the way to the bottom of the collection system.

Nonetheless, this idea too has several issues with it. For one, the compost tea actually does not have anywhere to go. I believe the best solution to this is very similar to idea 1 where the compost tea would go to collect in a half pipe such as the one shown. I believe the best way to do this would be by either using an already existing gutter. The advantage of using a gutter is that I could further redirect the compost tea to a larger bucket or area that could hold more tea. Or I could simply use a cross section of a PVC pipe and seal the ends with PVC sheets cut to shape. I would have to use PVC for its chemical resistivity. It would also last for a very long time when exposed to the sun and other elements.



However, one other issue that must be dealt with is the fact that the legs at the base of the design would get in the way of the compost tea catcher, preventing it from reaching out. For this, I believe I would have to round the catcher at the end so that it does not get in the way of the legs. Next, I would also have to move the holes on the base a little further from the edges of the design. This is because I believe they would drip off the edge and onto the floor. The reason I have this concern is that the legs actually mean that there is a space between the galvanized tub and the catcher that the compost tea could go through. As the compost tea can only drip through the holes, moving them further from the edge would mean that the compost tea does not leak onto the floor.



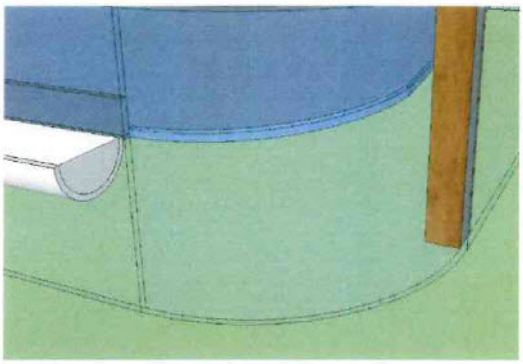
I have provided a better and more developed visual which I have designed in SketchUp.

The transparent edge is an accurate depiction of the galvanized tub which is my limitation for this design.

What can be seen was that I decided to add the collection system to the outside of

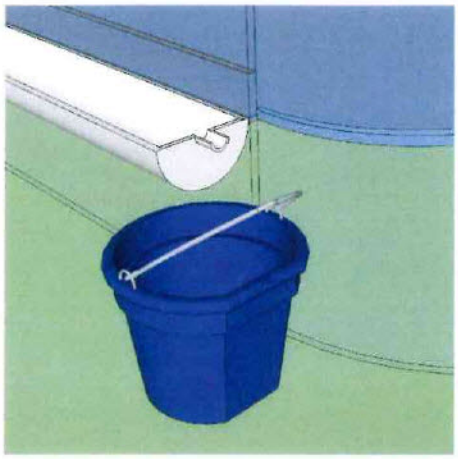
the design. This would mean that anyone collecting the compost tea would not have to reach inside of the galvanized tub. One of the issues with this is that I would have to cut a hole within the tub to let the compost tea leak outside. However, as previously discussed, this should not be too much of an issue as it would be easy to prevent the edges of the tub from rusting.

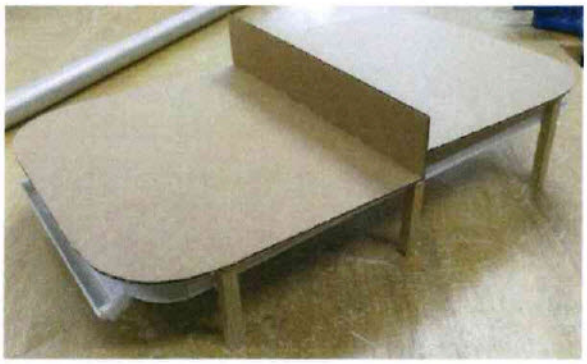
Yet after looking at this design, I realized that there were further issues with it. As liquids do not often flow linearly, they could stray off their path to the bottom. They could go off the edge of the catcher if it has no lip on it. They could also go off the very end where the catcher curves towards the collection system. If there is no lip, the system could expect to lose roughly 25% of all the compost tea it is collecting. For this, I would have to add a simple lip to the catcher.



Although this image does not show it, the lip has been added all along the catcher so as to minimize the amount of compost tea lost. This way, nearly all of the compost tea should reach the collector.

With this idea, I believe there is more potential to develop a solution to overflowing compost tea. It also has a lot more flexibility in terms of how deep and how much compost tea the collection area could hold. In case of an overflow, a simple nozzle at one of the ends of the collector could be added. An image on an example can be seen on the right hand side. The nozzle could be made out of a much smaller cross section of another PVC tube. This could then be used with a bucket if there are exceptionally large rains. However, the limitations after this point would only be the size of the bucket. For unless there are people present making sure to replace the bucket whenever necessary. I would not be able to provide the bucket, but the gardens do have their own buckets which they could use to collect the excess tea. Another thing that could be done is actually add another nozzle on the other side, doubling the amount of compost tea overflow the system could collect.



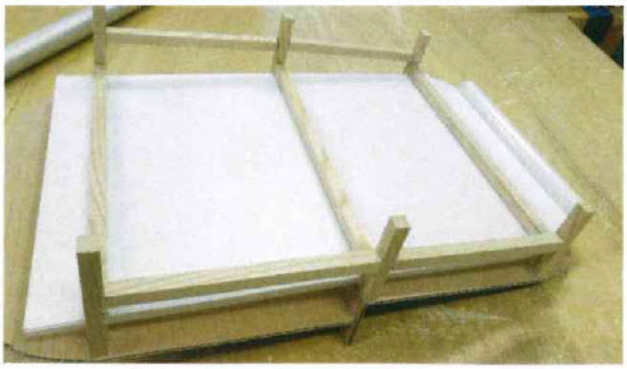


Keeping in mind as many things from my development in Section 2 as well as taking as many elements from my SketchUp development as possible. The result was this physical model made from cardboard and fluted core plastic. I have chosen not to create the holes yet as it would be very time consuming if I were to do it by hand or if I laser cut it, the cardboard could fume up and burn. I did not choose to spend much time on the joining methods between the materials so everything is hot glued together, this is something I will have to consider more when making my final design. One of the joints that I may need to think about the most is how I am going to attach the two bases with the vertical separator without any cracks or holes.

From this initial model, I was able to see that the legs on their own would not be able to hold the bases as they are highly unstable if any pressure is added to them directly from above as would be done by the soil. Of course, as I only chose to hot glue the legs to the cardboard instead of using a more permanent joint it only added to the instability. Therefore after the initial version was complete I added beams between the legs that would attach them to each other and minimise further movement.

This edition saw great improvements to the stability of the design. However there were further issued I had discovered that came about with this. Although I had fixed the issue of stability across one direction of the model, it would still wobble, although very slightly, in the other direction. To fix this, I added more beams that go across the width of the model as demonstrated by the image below.

An unintended advantage of this was that it also provided support for the compost tea catcher. I had not considered that the large size of the catcher would mean that it may bend under its own weight and would thus need support to prevent from breaking over time. Another issue is that I would not be able to glue the catcher to the side of the model in my final model, so I would have to consider other ways to make it stay in place. This is why these added supports are a great advantage as they would prevent it from sliding downward.



The final issue I noticed from this model was that the collection tray was hanging quite low and at an angle as if it was about to break. Again, this is because using hot glue as a joining method may not have been the best idea, but at the time of making this model I did not know how to fix this issue. As I further design my model for the final design, I will have to consider this issue for how to attach the collection tray better and more permanently to the catcher.

Materials & Manufacture

In this section I will discuss the advantages and disadvantages of materials I will be using to construct my final model as well as giving other options I could have used. I will discuss the various manufacturing techniques I could utilize. What is important to remember is that for my final project I will be constructing a scale model of the compost collector and thus some of the materials may not be available in the scale sizes. This means that the materials or manufacturing techniques I will discuss here may not be the ones used to construct the final working product.

PROPERTIES AND USES OF THERMOPLASTICS AND THERMOSETTING PLASTICS

Plastic	Type	Properties/characteristics	Uses
Acrylic	Thermoplastic	• Stiff, hard and durable • Easily scratched • Good electrical insulator • Available in a wide range of colours • Polishes and finishes well	• Baths and bathroom furniture • Car indicator covers/reflectors
Polythene (low density) – LDPE	Thermoplastic	• Tough • Resistant to chemicals • Soft and flexible • Good electrical insulator • Available in a wide range of colours	• Squeezy bottles for shampoo and washing-up liquid • Toys • Carrier bags
Polythene (high density) – HDPE	Thermoplastic	• Stiffer and harder than LDPE • Surface has a waxy feel to it • Can be sterilized • Good resistance to corrosion	• Buckets • Bowls • Milk crates • Bleach bottles
ABS	Thermoplastic	• High impact strength • Lightweight and durable • Resistant to chemicals • High quality of surface finish	• Telephones • Kitchenware • Toys
Polyester	Thermoplastic	• Stiff, hard and brittle • Very resilient when laminated with GRP (glass reinforced plastic) • Good heat and chemical resistance	• Product cases such as hair dryers • Paperweight castings • Boat hulls with GRP
Epoxy resin	Thermosetting plastic	• Good resistance to wear and chemicals • High strength when used as a bonding agent on **fibrous** materials	• Adhesives • PCB (printed circuit board) material • Lamination of woven sheets such as fibre glass

Bases:

These plastics separate into two separate categories - thermosetting and thermoplastics. The advantage of a thermosetting plastic is that if anything is messed up during the process, it could reheated and remoulded. I believe that if this design were made on a large scale, the plastic needed for the base would need to have good chemical resistance and to be very stiff. With these properties, I believe HDPE would be the correct choice, however, as I am only making a scale prototype and HDPE is not readily available for use. Typically, HDPE is used for piping and insulation which is not the purpose I need it to suit in this case. However, I am only creating a scale prototype so it will not be used the exact same way that the final product will be used in.

To create the holes in the base there are two manufacturing options. The first is to use a hand drill with careful marking out. However, there are many problems with this such as small errors as well as acrylic being very brittle, so there is a chance it cracks when drilling. The much better and safer option would be to laser cut the acrylic as it will guarantee a quality cut of each of the drainage holes. To create the bend in the bases, a hot wire heater could be used along with a jig at 90 degrees to make sure that each piece is parallel to the other. However, another material I could use is sheet aluminium. At our DT lab sheet aluminium is readily available and requires no further production. As I have to bend the material, sheet aluminium is a good option as we have a sheet metal folder from which quality can also be guaranteed as the bending angle is very clearly marked out. Another advantage of aluminium is that it will not rust as it contains no iron, which will prolong the lifespan of the product.

I have outlines multiple materials and manufacturing methods I could use to create the bases of the product, however, I believe that for this model, using acrylic would be the best option as the laser cutter would mean that quality is guaranteed when creating the drainage holes. Furthermore, acrylic is a thermoplastic meaning that when I bend it to be 90 degrees, if there is some misalignment, it can be placed into a heating over to be reshaped.

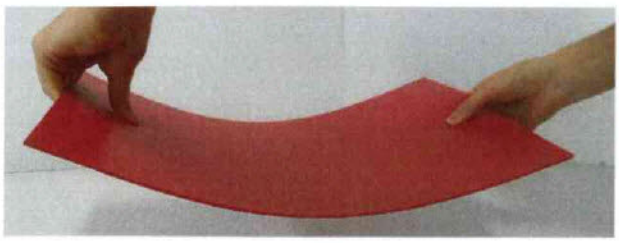
Supports:

The DT department offers a variety of methods to create the supports of the model, however, I believe there are two main options which I will discuss. Firstly, there is a variety of hollow steel bars that would suit the scale model I am making. These bars come in various shapes, sizes, and thicknesses. However, there is no convenient method to join all of these, as welding is nearly the only option. The issue and advantage with welding is that it is a permanent joint and would never come undone. This is an advantage unless there is a mistake made while welding, or an issue with one of the legs, at which point the entire support would have to be scrapped and another one created. Welding is also a very energy and time intensive process, which would not be sustainable if this product were to be made on a larger scale.

A better solution, which I will be using to construct this scale model is to use the T-slotted aluminium bars along with the L-brackets. These bars are extruded aluminium bars that are very easy to connect with the help of an L-bracket. The L-bracket is an ideal joining method as it meets the criteria of being a temporary joint yet provides the strength necessary to keep the bars from falling apart. If a part on the support needs replacement, it can easily be done as the L-bracket can simply be loosened and the bars taken out. Of course, there is also the option to weld the aluminium bars to each other, but as discussed a temporary joint would be better for the sake of replacing any faulty parts if they occur. I previously discussed the properties of aluminium and understand that it is a very soft material. However, these bars are not made of pure aluminium and are rather an aluminium alloy. Furthermore, the shape of the bars adds significant strength to the bars for them to be able to hold much more weight. These bars would be perfect to use for the scaled prototype as I also have a price constraint and these bars are significantly cheaper than the steel tubes. For these reasons, I believe that using the T-slotted aluminium bars along with the L-brackets would be more efficient and less energy dependent than welding the steel bars together.

Catcher:

I am very limited for choices to make the catcher out of. This is because given the design, there are not too many choices I have that would last a long time. In my initial model prototype I used flute core plastic and simply added a border to it to prevent the compost tea from leaking out. However, adding the border and smaller details to the catcher was very time consuming which is why in my final model I have developed a different way to catch the compost tea without having to add the borders. To allow the curvature of the plastic, I would need a malleable material that is easy to bend. The first idea that came to mind was again to use aluminium as it is can be bent very easily and with the help of a jig, a very consistent bend could be achieved. This could then be attached to the aluminium bars by welding it. However, this would go against the entire purpose of using L-brackets in the first place and nothing would be replaceable at that point. This led me to think that I would need to use some sort of plastic as it would need to bend easily. If I were to use a waterproof tarp and string it around the aluminium bars, I would be able to direct the compost tea towards the collection tray. As tarp already has holes for string attached at the corners, all I would have to do to get it to stick is to add some L-brackets at each aluminium bar and simply tie the string around the L-bracket. Of course, this is not the best solution as the



strings may come undone. Another possibility if the dimensions are correct is that the holes in the tarp could be put around the exposed L-brackets and fastened that way. However, the final solution to this, which was inspired from the initial model could be to use the fluted core plastic. As the 'flutes' only go in one direction, there is quite a lot of resistance going across them perpendicularly. Therefore, if the pressure is applied to them as such, they would have a natural tendency to be flat. This is a very similar quality to cardboard where it can easily break in one direction while having great rigidity in the other. In the prototype, the plastic was straight, but with this, the force with which the fluted core plastic catcher will want to push out will keep it from sliding. It is also water and chemical resistant making it a perfect material to use.

Collection Tray:

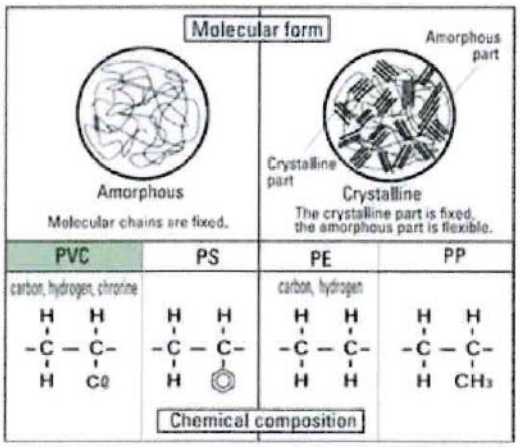
The collection tray is the final component of the design. This is the area where the compost tea will aggregate and be stored until it is collected. I believe that the collection tray must be made from a plastic as this is the component with which users will be interacting most with. For this reason, it must be finished well and have good aesthetic value. I do not believe that any metals such as aluminium would be able to fulfil this as it could be very sharp and lead people to injure themselves. One readily available option to use is acrylic as discussed before. These are some of the characteristics of ACRYLITE FF (acrylic). As this area will be exposed to sunlight, using acrylic would be a good idea as it is weather-resistant. Furthermore, during manufacturing, acrylic would be a good choice as it can easily be heat formed into the desired shape, in this case a half tube. The acrylic can also be cemented which means that the end caps can be applied very easily. These endcaps can be laser cut for precision and then applied using acrylic glue.

Characteristics

The clarity and light stability of acrylic resin make it possible to manufacture crystal clear ACRYLITE FF sheet.

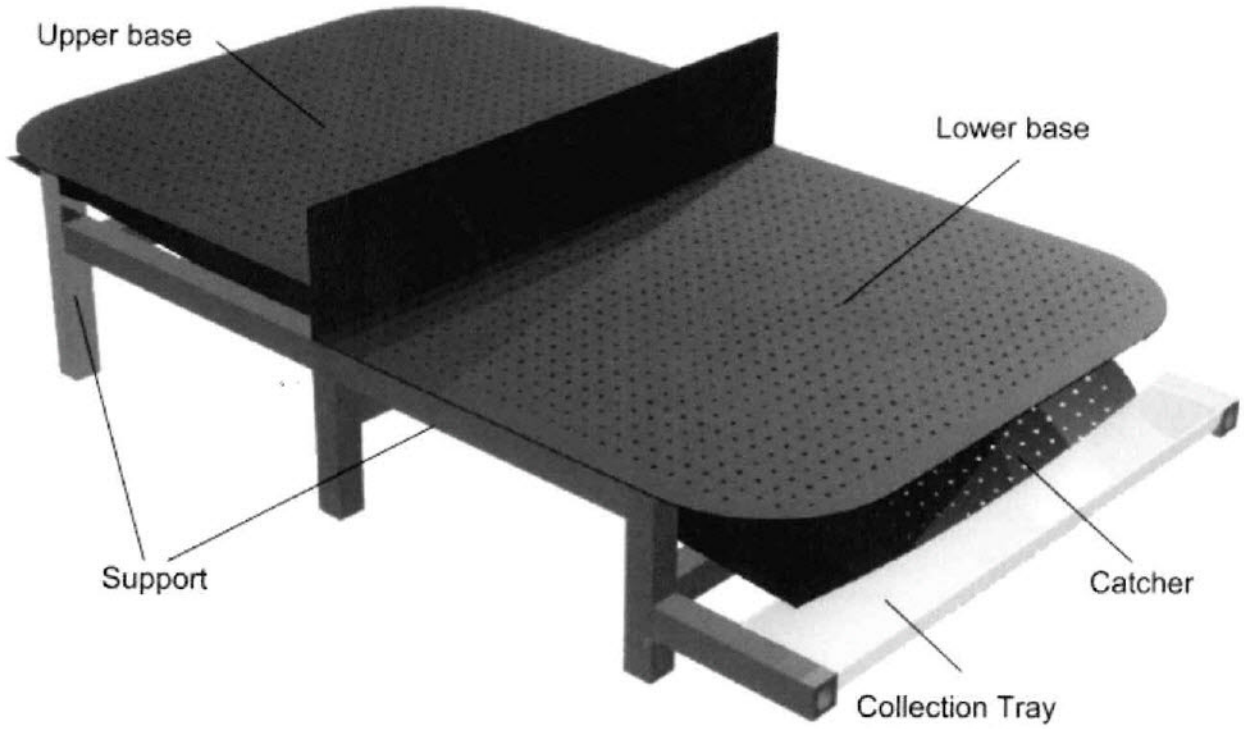
ACRYLITE FF sheet is a lightweight, rigid and weather-resistant thermoplastic. ACRYLITE FF sheet is dimensionally stable and resistant to breakage, and can be easily sawed, machined, heat-formed and cemented.

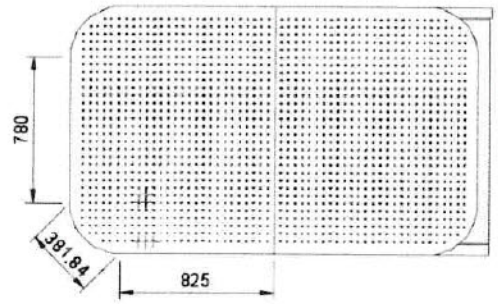
Because of its virtually distortion-free clarity, it is well suited for use in a variety of applications.

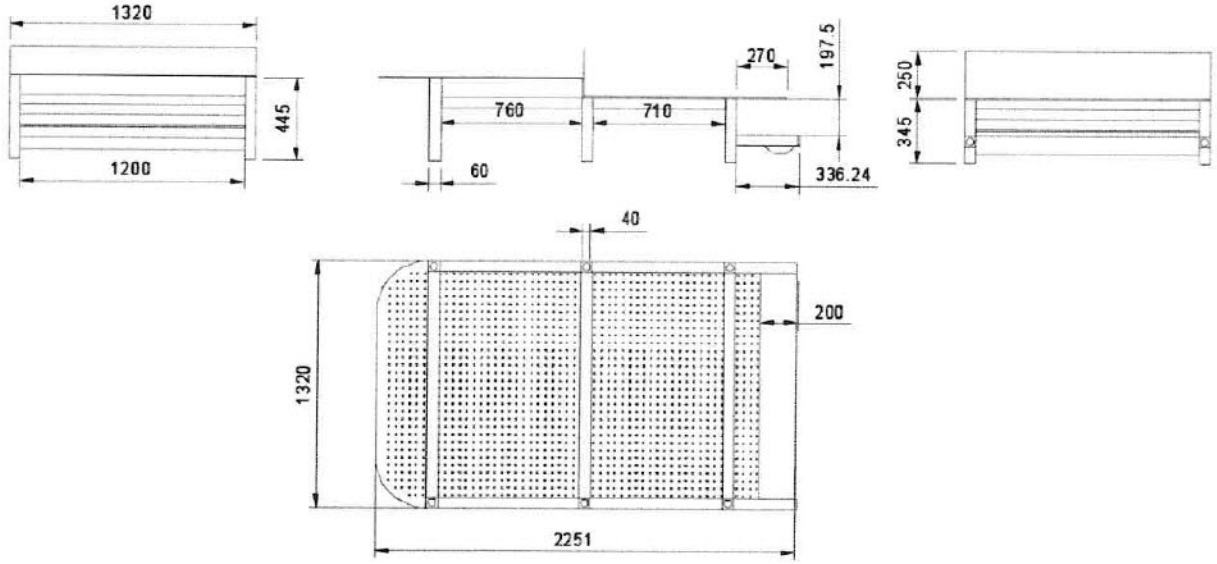


However, besides acrylic, another option for the tubing is PVC (polyvinyl chloride). I read that the presence of chlorine in PVC as well as its amorphous state, this makes the acrylic very chemical resistant. Although this is not the only property it is one of its best. For this reason, PVC is widely used for piping and insulation. To add to this, pvc.org states that "the factor most strongly influencing the durability of a material is resistance to oxidation by atmospheric oxygen". Given the chemical composition of PVC, it means that PVC will not react with any oxygen, and therefore has very high structural durability. Depending on how one would look at it, an advantage/ disadvantage of PVC is that it is a thermosetting plastic meaning that it can only be moulded once. Although this means that it has high heat resistance after, there is little room for error after shaping it. Luckily, PVC is most commonly found as a pipe. As the shape I need to create for the collection tray is a half pipe, the easiest process by which to create the half pipe would be to cut the PVC pipe in half using a bandsaw and the guides provided. However, using a bandsaw has high safety concerns, which is why I would need to use guiding blocks of wood to push the PVC pipe through without putting my fingers in danger.

In this section I will show the final design that I believe has met as many specifications as possible while being fully functioning and practical. The final design has been made using Autodesk Fusion 360. Also provided is a full orthographic projection of the design for specific dimensions.Keeping everything I had learnt from prototyping and my specifications in mind I was able to compose a final design that I believed solved some very key initial flaws from the original ideas. This product is also much safer to use and more stable as all of the components are joined together with temporary joins so as to replace any faulty parts if they arise.



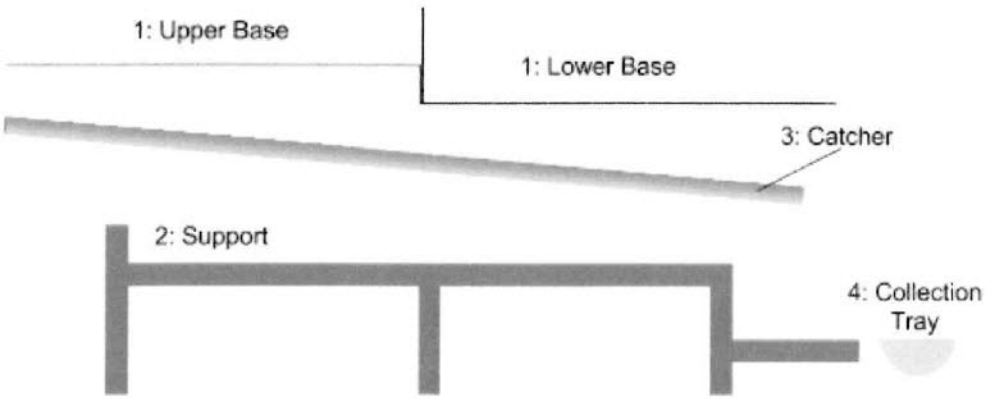




Below is the Bill of Materials required for the product. It also discusses the tolerances of the materials and manufacturing techniques needed to be considered when manufacturing the product.

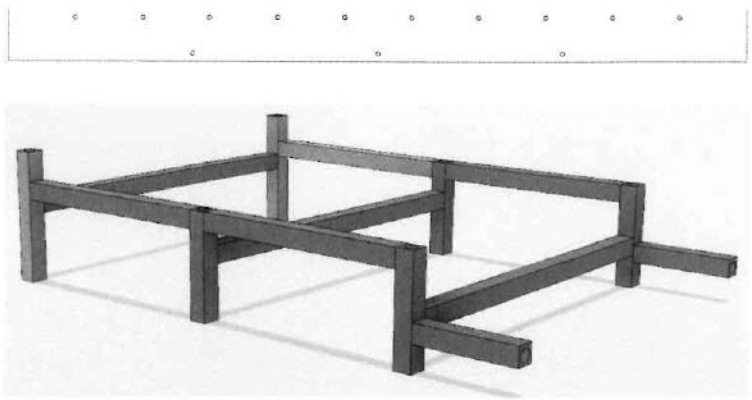
Bill of Materials

ID	Part Name	Quantity	Unit of Measure	Dimensions	Material
1	Lower Base	1	millimeter	446x527x3	Grey Acrylic
1	Upper Base	1	millimeter	413x527x3	Grey Acrylic
1	Hex Screws & Nuts	13	millimeter	3 (diameter)	Steel
1	Domed Screws	4	millimeter	4 (diameter)	Steel
2	T-slotted bar	2	millimeter	25x25x148.3	Aluminium
2	T-slotted bar	4	millimeter	25x25x115	Aluminium
2	T-slotted bar	3	millimeter	25x25x400	Aluminium
2	T-slotted bar	2	millimeter	25x25x112	Aluminium
2	L-bracket	16			Aluminium alloy
3	Catcher	1	centimeter	50x88x0.3	Polypropylene
4	Collection Tray	1	millimeter	490 (length) 40 (outer diameter)	PVC tubing
4	Collection Tray	2	millimeter	50x50x3	Acrylic sheet



This is an exploded orthographic view of the compost tea collector. Although it consists of many more parts than shown, such as the lower and upper bases, I chose to represent it as the four primary parts: base,support , catcher, and collection tray.

Base: The upper and lower bases will be joint together using hex nuts and screws in the form shown below. There will be 10 screws on the top keeping the lower and upper bases together, but there will also be another three screws at the bottom to ensure that the bases to not come undone as well as adding extra stability. This process will require a very high tolerance so as to avoid misalignment. This would require a tolerance down to 0.3 mm. Making the holes too large could mean that the base wobbles too much and the screws could loosen over time.

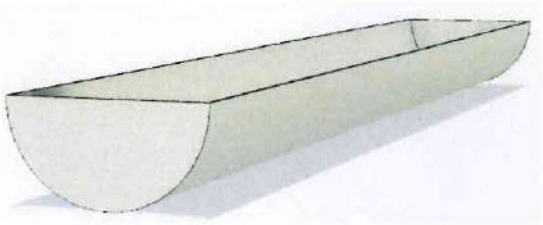


Support: The full image for the support is visible below showing each component and how it appears aesthetically when joined together. It was only for the sake of the model

that I make hollowed out aluminium bars, however, in reality, the supports would still be made of the T-slotted aluminium bars or varying length but consistent thickness. Noticeably, the largest change I made to the supports was making it support the collection tray as well. The tolerance for the support is also very high as given its size, any small changes in one area could impact others. This is why the joining areas must be very carefully planned as it could create imbalance in the the design and lead to a difference in elevation and thus more wobbling. The area of this support with the lowest tolerance can be the collection tray support as the height of that can be adjusted at any time to accommodate the rest of the design.

Catcher: While creating the catcher in Fusion 360 my expertise and knowledge of Fusion was a large setback as I was unable to create a thickness to it, moreover adding tubes to it. However, as this is only a model, this representation will do. The curvature and the material trying to push back against the support will do enough to keep it in place as the compost tea will not move it. The tolerance of the compost catcher does not have to be high as the degree of the curve can be adjusted.

Collection Tray: The final component of the design is the collection tray where the compost tea will drain into. This will be a large tube with two end caps at the ends to contain the compost tea. The tolerance for when the tube is halved does not have to be high, however, the tolerance for the end caps must be high so as not to have any leaks. As small gaps cannot be avoided, the end caps will be applied with hot glue to fill any smaller cracks and imperfections.



Manufacturing Plan

The manufacture plan table shows how I plan to complete this product and an estimate of how long each process will take to make sure that the product is completed on time. Furthermore, it outlines the quality control measures and risk assessment I will take to make sure the product is of the highest quality while staying safe.

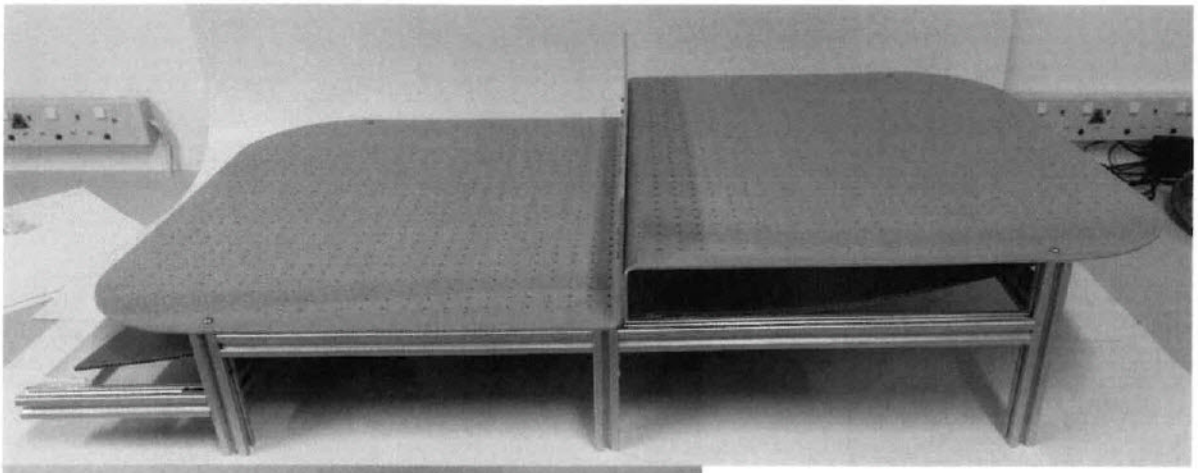
Stage	Component number and part name	Description of process	Equipment needed	Estimated time (mins)	Quality control measures	Risk assessment
1	1) Upper and lower base	Laser cutting - laser cut the holes and outline of the upper and lower bases	Laser cutter, Adobe Illustrator	30 (excluding Illustrator design)	The laser cutter is a very high precision machine so not necessary.	Acrylic does not let off poisonous fumes.
2	1) Upper and lower base	Bend the two pieces of acrylic to prepare them for joining	Strip heater	10	Using the rulers on the strip heater to make sure that they are parallel.	Keeping hands and fingers away from the hot wires and making sure not to touch heater areas.
3	1) Upper and lower base	Joining the two bases using hex nuts and screws	Junior hacksaw (to saw off ends of screws)	10	N/A	N/A
4	2) Support	Cut the T-slotted aluminium bars with a tabletop saw	Tabletop saw	20	When replicating piece, use the previous piece as a guide for consistency.	Keeping hands out of the way, get someone more experienced to operate the machinery
5	2) Support	Join the supports together using the L-bracket	Alan key	15	Constantly check that the surface is level with the ground and that joints are perpendicular.	N/A

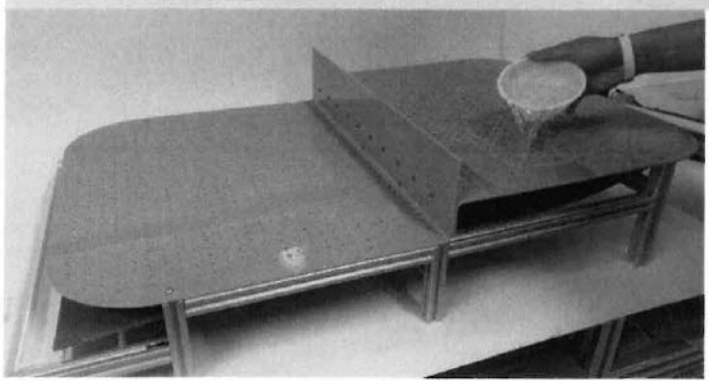
6	3) Catcher	Cut out the shape of the compost tea catcher	Craft knife	5	Do a second measure of the width after the supports have been assembled and cut it just wider than the measurement.	Keep fingers clear of craft knife
7	4) Collection tray	Cut PVC pipe into half using band saw	Band saw	2	Add a wall on one side of the saw to ensure a consistent cut throughout. Try to place the wall so it cuts directly through half the tube.	Do not let hands near the band saw. Insead, use long planks of wood to push the tube through. Cut slowly and know where the emergency stop button is.
8	4) Collection tray	Sand the edges of the tube to prevent any cuts	Sandpaper, sanding block	5	Constantly check whether the edges are smooth enough and that the two ends are still parallel.	N/A
9	4) Collection tray	Design and measure the lengths for the end caps and then laser cut them	Steel rule, Adobe Illustrator, Laser cutter	10	Make sure to leave a small gap from all parts of the half tube where the hot glue would be able to go.	PVC releases toxic fumes while being laser cut, so the end caps will be made from acrylic.
10	4) Collection tray	Hot glue the end caps to the tube to complete the collection tray	Hot glue gun, hot glue sticks	5	Make sure to get a good layer of hot glue while applying it.	Do not burn yourself while using hot glue gun.
11	Assembly	Insert the collection tray into the support and hot glue any corners for extra stability	Hot glue gun, hot glue sticks, spirit level	2	Use the spirit level to make sure that the collector tray is level with the ground for maximal compost tea collection.	Do not burn yourself while using hot glue gun.
12	Assembly	Bend the catcher against the direction of the tubes for most resistance and insert it into the support at an angle	Catcher, support	1	The bottom curved area of the catcher should be resting on top the the horizontal T-slotted bars.	N/A
12	Assembly	Attach the base to the support by screwing it in at the 4 corners of the support	Hand drill, domed screws	3	The holes in the acrylic were already laser cut so just align them with the aluminium bars.	N/A

Criterion D: Testing and evaluation

Summary of Feedback

In this section I will demonstrate how my product was able to meet my design brief as well as having interviews with both the client and target market regarding the product. I was able to interview Adam Erickson about the product as well as two high school students who are in the rooftop gardening activity.

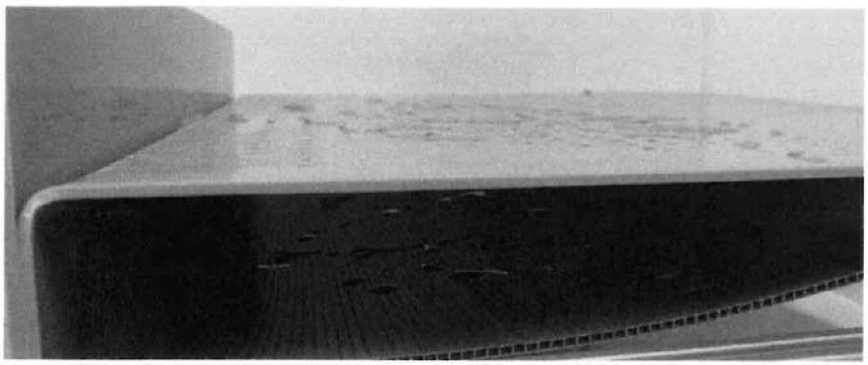




This is my scale model which I was able to use to gather user and target market feedback. The largest downfall to this was that it is still a 1:3 scale model and not all factors can be considered. For both of the interviews I was also able to carry out trials to demonstrate the effectiveness of collecting the compost tea. A photo of such is also provided. The slight possible flaw with this test was that I used water rather than compost tea so the viscosity of the two substances may be different, but overall, all other factors would remain nearly the same.

Adam Erickson Interview Summary

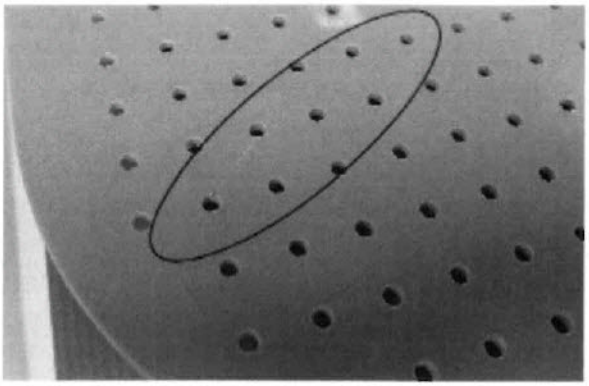
At first I asked him how he felt about the design without having shown how it works. This was to see whether it was a user friendly design and it worked very intuitively. As Adam was the client and very familiar with the issue at hand, he quickly understood how the device worked. Furthermore, he was very pleased with the idea that there are two tiers to the product for various plants to grow on. One of the issues he was pointing out was that there soil would fall through and clog the holes in the acrylic bases, however, after some explaining that there would be a cloth-like material that separates the soil and base he understood the concept. Perhaps this was another downfall of the experiment that I did not demonstrate it with the soil and separator. I also had to explain to him that this design would require cutting through the galvanized tub to make space for the collection tray. Although he did not initially like this idea, I explained to him that the advantages of this is that the compost tea would be much easier to collect and reuse. One issue he picked up on that I had not considered prior is that there are no supports going across the top base which means it is much weaker than the bottom base. Although the top base will have less soil on top of it than the bottom base, it would still be a substantial amount to potentially snap it. Apart from this, he told me he could not find issues with the compost collector. I then demonstrated how the would work and he was pleased with the efficiency of the collection. Although there was some water that was left on the catcher and bases as shown, most of the water was able to make it down to the collection tray. After demonstrating this he also pointed out that there did not appear to be enough room between the collection tray and catcher to remove the compost tea, however, I believe that if this model were constructed full scale this would not be an issue. It appeared that Adam Erickson was quite pleased with the product, however, the final concern of his that he pointed out to me was the cleaning of the product in the long run. After he saw that not all the water drained out of the catcher he was concerned that some of the compost tea may evaporate and



leave the residue on the catcher which may cause it to overflow sometime in the long run. This is something I will have to consider in the suggested improvements section.

Target Market Interview Summary

To investigate how the target market would react to this product I was able to interview two students who participate in the rooftop garden activity. I used a similar approach with them to see whether the design was intuitive as to how it works. This may not necessarily be important as this is not an active product with which the user interacts, rather it is quite passive. Although at first they did not understand the purpose behind the product I had to explain that it was to collect the leaking compost tea, after which they understood instantly how it would work. In terms of feedback, they had a very similar reaction to Adam Erickson, as to be expected. They commented on how it appeared that the collection tray did not hold much compost tea at a time without overflowing, however, as this is a 1:3 model, volume wise it would be able to hold 9x the amount of compost tea. Another detail that the two students were able to pick up which Adam Erickson did not notice was that were was a crack that was in one of the corners of the bases. I will discuss this further in the further improvements section.



Overall, the impression I got from these two students was that this was a product that did meet the goals of the design brief, apart from having all of the material thicknesses be to scale as well. The students were pleased that the collector could passively collect the compost tea and store it until their next arrival for collection. Although I explained that it should be able to hold 9x more compost tea than it appeared in the model, they still believed that more compost tea is produced weekly than the collector tray could hold. Given their expertise this this, the volume is something I will have to consider further in my further improvements.

Success of the solution against the marketing specification

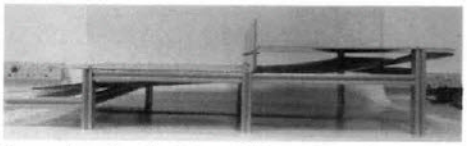
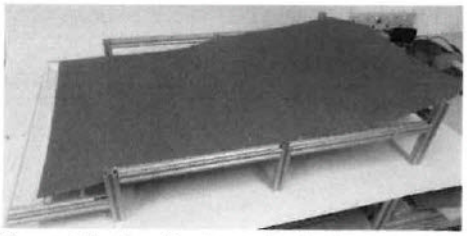
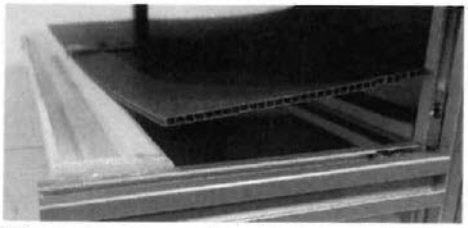
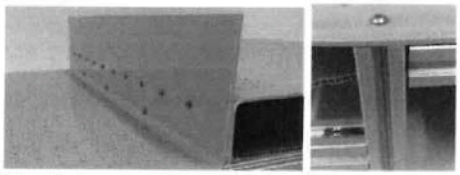
In this section I will be critiquing the final model against the marketing specifications I came up with in Criterion A.

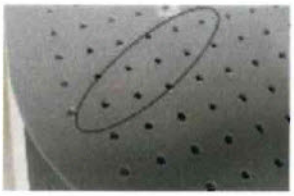
Section	Aims and Objectives	Purpose	Evaluation and Improvements
Target Market	My target market are the high school and any middle school that may be going into high school or are staying in middle school. The target market will also be any environmentally minded people interested in enhancing the efficiency of their rooftop gardens. The only relevant data is the anthropometric data as information such as race, gender, and incomes will be irrelevant when it comes to students.	The target audience refers to those who will directly be using the product. It talks about the location and how the product can be improved to better suit the target market.	This product is clearly targeted at a specific issue and at a very specific target audience. However, it it would be in everyone's best interest to increase the target market. Currently, this product would only work for those that have a galvanized tub of these exact dimensions, however, the target market could also be increased to anyone hoping to start their own rooftop garden without having a galvanised tub. As more people are realizing the potential of gardening, the target market for this could be growing over the coming years. This could be done with some refurbishing which will be done in the further improvements section.
Target Audience	My target audience are the schools or apartment complexes or home owners with roofs interested in collecting their leaking compost tea.	This point details who may be interested in purchasing the product rather than who will be the end user. Although the an apartment complex may be the target audience, the staff may not be the target market.	The largest limit to this product is the size of the rooftop, however, given that most roofs are in fact larger than the dimensions of the compost tea collector I believe it is safe to say that the target audience is not constricted to such a degree that very few people will be purchasing the product.
Market Analysis	I believe that if this product were to go on the market it would be able to succeed. However, this product is currently only made for a very niche market - people with an interest in improving the efficiency of their rooftop gardens as well as having the exact galvanized tub for which	This point reflects on how the product would perform in the market regardless of the competition. It would look at how much potential and profit there is to be made in this area if this product were to eventually go onto the market.	I believe that if this product were to be produced full scale and with the materials it was intended to be created with, this product would succeed in the market. This is because apart from emptying the collection tray, there is really no work necessary to operate the design while it does bring other advantages such as providing different soil

	this product is made. Given the size and effort required to produce this design, I believe that a price of approximately $200-300 would be appropriate. Chances are, as the demand for this product would initially be quite low in its growth stages, it would be produced individually, but as the demand grows, it could be put into batch production. Although the price range is very similar to the competition, I believe that this product solves a slightly different issue for a different target market, so the price should be justified.		thicknesses that to allow for growth of different varieties of plants. However, the market could further be increased if the quality of the product were to increase. This could be done by standardising more of the manufacturing process. Although there is already high accuracy when laser cutting, but there are other processes such as folding the bases which may have larger errors and being able to make jigs to ensure the quality of these steps would surely increase the reputation and market share of this product. Other improvements could be made such as those I will discuss further in my further improvements section. However, one of the largest disadvantages is the sheer size of the product. This leads to two issues which constrict the market: 1) transportation issues and 2) being able to ship it to other countries. A solution to this could be to produce it in other countries as well and package it as flatly as possible to make it easy for transport.
User Need	The main purpose of this product is to provide the users with an easier way to collect the compost tea without putting too much stress on their backs. It also attempts to make harvesting the vegetables easier by elevating the soil specifically for the dimensions of the galvanized tubs of the school.	This points out that this product meets the requirements of users that other products may not meet as there are no similar products that solve these problems.	Again, as this product is made for a very niche market it of which only a fraction of people will feel it is worth purchasing this product, it is somewhat disadvantaged. However, the issues it solves are not solved by any other product on the market. As previously discussed the nearest competitor to this product is the Garden365 Mobile Garden and the largest advantage of this is its compact nature and how maneuverable it is. I could learn from this and make different variations of the product to also make it more compact and maneuverable.
Competition	In my research on page 10 I discussed 2 of the closest competing products I believed were on the market. These were the Mobile and Mini Elevated Gardens by Garden365. Although these are what I believed to be the closest competition, they are not directly solving the issues at hand in this case. The majority of users do not consider brand loyalty when purchasing a product such as this because they are static products and are not meant to get changed often.	I compared the advantages and disadvantages of two products. The purpose of this was to get the best idea of whether the product would be competitive on the market and whether people would purchase it. It also looked at various features of the products and how it could be utilized in my own.	The main feature of the Mini Elevated Garden was simply that it raised the soil to a level that would be comfortable to be used by the users. On the other hand, the user would be able to move the Mobile Garden depending on where they wanted it to be placed. Both of these products had drainage ports that could get connected to a hose to drain the water. My product only utilizes similar features to these competing products and has no revolutionary features of its own. Because of this, the products would compete in the same market rather than solving a completely different issue which cannot be done any anything provided by Garden365.

Success of the solution against the design specification

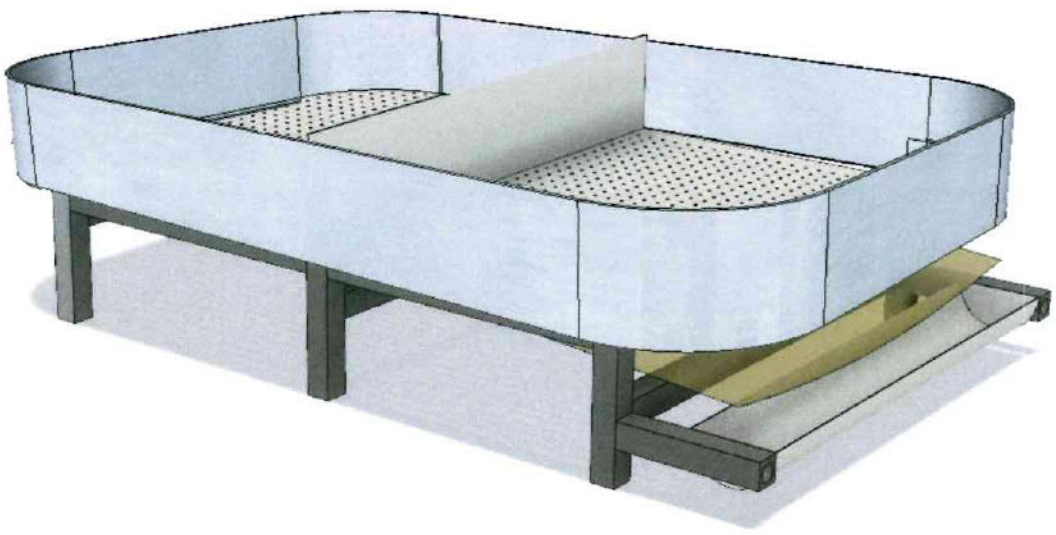
Requirement	Rating 0- does not meet 1- meets 2- exceeds	Strengths	Weaknesses
Must not be invisible to the user unless fulfilling another purpose	2	The photographic evidence has already been shown when the feedback from Adam Erickson was given. When the design is covered with soil the only parts that will be seen are the base separator and the collection tray which	The weakness is that the galvanized tub will have to be cut to make room for the collection tray. Although I am unsure how this would turn out, this could create some structural instability of the tub. The cut edges of the tub could also cut anyone if they were to use it

		both serve their purpose.	carelessly.
Must cost half of the competing products, so $130 or less to produce. The scaled prototype should not cost more than $60 to produce.	1	The prototype did cost less than $60 to create given the materials I used. Although I did not keep careful account of how much each component would cost, I would estimate that the prototype did not cost more than $50.	I do not believe that it would be possible to make the full scale model at less than $130. This is because a lot of the materials such as the legs that I used were to scale and they would get significantly more expensive the larger they because given their volumes.
It must elevate soil above current level.	2	 Even elevates it at two different levels, therefore it exceeds the criteria.	The top base does not have supports and may potentially collapse under weight of soil.
It must collect leaking compost tea effectively.	1	 The catcher is able to catch all of the leaking compost tea without spilling any of it.	The disadvantage of having a catcher that is not directly connected to anything is that if someone is carelessly emptying the collection tray they may accidentally hit the catcher and dislodge it. Given how the catcher is set up, this would be a very difficult job to fix that may even require emptying the soil out.
Product must be easy/ intuitive to use.	2	When I got feedback from both Adam Erickson and the two students, I learned that the product is indeed intuitive to use once the purpose is revealed. It is also very simple to use because it is very easy to collect the compost tea out of the collection tray.	There were no disadvantages in terms of ease of use and how intuitive the product was to use.
Must have easy access to collection area.	2	 This design was made so that access to the collection tray was especially easy.	As the collection tray is sticking out of the galvanized tub, someone carelessly walking past it may hit it and injure themselves or break the product. There are also edges that are unintentionally sharp oh which people may cut themselves.
Must use temporary joints.	2	 The design uses temporary when joining the bases as well as the supports.	The potential flaw with using temporary joints is that they could get loose over time, especially the L-brackets that are connecting the supports. Although having temporary joints does mean that the design is repairable, is could cause more problems than in fixes.
Components used should be able to be disassembled so they can be recycled.	1	I did use temporary joints for the product to be disassembled, and there is not part that cannot be replaced.	There is no way to make repairs while the product is in active use. There are also many screws that would have to be undone just to take a specific component off therefore earning a 1 as it is not fully exceed the requirement.
If possible consider materials which must come from close region to save impact on carbon footprint.	1	It is difficult to track the supply chain of the materials used within the product, however, I know that the acrylic sheets were shipped from China in bulk. Although it was from China, the marginal carbon footprint would have been reduced the more acrylic shipped.	The aluminium bars were shipped from the United States, which means that they were significantly less environmentally friendly than the acrylic. Although these were also shipped in bulk, the distance travelled by the aluminium was large.

Must fit within the galvanized tubs which have dimensions of 220x132x60cm.	1	The design would fit within the intended criteria, apart from the collection tray which would be protruding from outside of the tub.	There will be a gap between the compost collector and edge of the galvanized tub because given the shape of the tub it is impossible for there to be a perfect fit. Because of this, some compost tea may leak.
Must be safe to use.	2	The design is very safe to use as all of it (apart from the collection tray) is concealed by the galvanized tub or soil on top of the bases. The safety of the device is also reliant on how intuitive it is to use, so if it is very intuitive, people would understand how to use it.	The only disadvantage that the design has is that the edges of the aluminum that stick out at the collection tray could injure someone walking past as it is protruding from the galvanized tub.
Must be able to hold 200 kg of soil.	?	Looking at the model alone, I would not be able to tell whether the full scale product would be able to hold 200 kg of soil as I was unable to test how much soil even the model could hold.	However, when applying pressure to the model I could see that the acrylic bases bent quite a lot down the centre. If I were to make a full scale model, this bending would be even more exaggerated, and do not think the final model would be able to hold 200 kg of soil and other things.
Must use durable materials.	1	The choice of materials was very suitable. I know that the aluminium bars would never rust. The form of the bars also means that they will not bend under serious weight. Apart from the weakness of the acrylic bases, these bases are chemical resistant and would last a long time. The fluted core plastic is also a good choice as it will not break over an extended period of time.	 Although the acrylic cracked during production, this could have been more due to the manufacturing process rather than the materials themselves. This was because the intensity of the laser cutter was set too low and I had to tap some of the drainage holes out, and cracked the acrylic in the process.
Must be water and chemical resistant.	2	Similar point to what was written above. The main area that needs to have chemical resistance is the collection tray, and PVC has very high chemical resistance. Similarly, the aluminium alloy would not rust as iron is not part of that alloy.	I do not believe there are any issues with this. Perhaps the only material that will rust is the hex nuts and bolts as they are made of steel. However, this may not even be an issue as it is unknown whether they are stainless steel or not.

Improvements to the solution

In this section I will elaborate on how my existing model could be further improved from the discussions marketing and design specification. After revising the design against my specifications, I learned what aspects needed further work and what worked well. I will also use the feedback I received from both Adam Erickson and the two students to further improve my design. I will use CAD along with annotated drawings to illustrate any further improvements.



While revising my market specifications, I discussed attempting to increase my target audience and market to gain a larger share of the market. I believe that adding a rim to the outside of the product would make the product more competitive. One of the largest setbacks I believed that may hold the product down was the fact that it was specifically for those that already had the galvanized tub of these exact dimensions. However, by adding this rim, the product would be able to be used on its

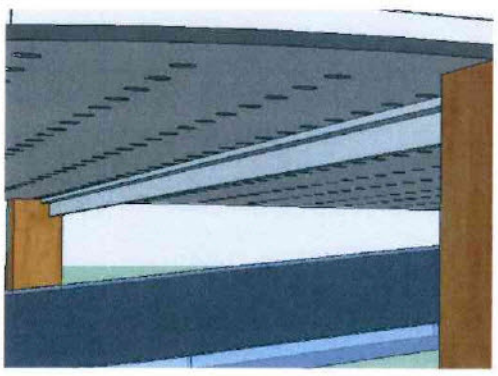
own without the need for the galvanized tub. This addition would increase the target audience and market as it goes beyond the people that don't on the galvanized tub. To see whether this is feasible, I would first cut the galvanized tub into the correct shape to test whether it works. However, afterwards, aluminium would be a suitable material for the rim. This is because aluminium would not rust and is a very cheap material meaning that it would not significantly increase my costs of production. With the addition of the rim I would be able to charge more for the product as more environmentally minded people would purchase the compost tea collector without the need for the galvanized tub.

Another advantage of adding the rim to the design is that there is extra space that is freed up below the compost collector for other things such as storage of gardening tools. This would further incentivise consumers to purchase the product as they would require less space for storage. The rim also solves the issue of repairability of the design. For example, now if the catcher were to get dislodged, it is much simpler to realign it underneath the collector as there is now space for a human to go under. There is also the potential that parts such as the supports may be replaced with more ease without needing to remove the soil from the collector. As the shape of the galvanized tubs is uneven, it would be difficult to create a perfect seal. However, adding the rim would mean that the compost tea would not escape and leak onto the floor around.

In my research section I discussed a product named Garden365 Mobile Garden which was the closest thing to competition that existed for this product. However, upon further evaluation of the competition, I believe that making a variety of similar products with various uses could further make it more competitive. Previously, I also did research on caster wheels which would make the product more versatile and portable. If I were to make a similar version of this product I would improve it by adding caster wheels to the bottoms of the supports as shown in the CAD drawing.

However, the design would have to be significantly smaller in size for the caster wheels to be able to hold the weight of the product and soil on top. With the maneuverability of the design, this product could even be used indoors if someone who is interested in starting their own garden does not have roof space. However, for those on the rooftops with limited space, this smaller, more mobile design would be perfect as it can be moved to make space for other events if necessary. The caster wheels would likely have to be premade and added to the design as a component which I would purchase. This is because I do not have the skills nor materials to create my own caster wheels and it would simply be cheaper to purchase them as a standard component. Each of the caster wheels will have full 360 swiveling abilities so that the product could be placed anywhere. Furthermore, they would all feature brakes so keep the product from rolling away.

Lastly, one of the largest flaws I noticed within the design was that given the size of the acrylic sheet, this product started to deflect when a weight was put on it. For this reason, I believe that adding an aluminium T beam to the underside of the base. The T beam would be connected between the supports, just as those underneath the catcher.



Although this image does not show it perfectly, it shows how the T beam would be unobstructive to the leaking of the compost tea from above the base. The beam would not be blocking any holes allowing the compost tea to flow freely. Although this is just one image, the same would be done for each of the legs. The brilliance of this idea is that it also solves one of my previous issues. There would need to be some further prototyping necessary to test how much soil this could hold. If this is not enough, more T beams could be added across.

I believe that with these revision, the product solves many of the issues which arose when I was evaluating the success of the product against the design specifications. In summary, the addition of the rim would expand the target audience beyond those who have the galvanized tub and make the product more competitive against those by Garden365. Next, creating a variety of models would mean that users do not need to limit themselves to a single type of product and are more likely to purchase one of them. Lastly, the lifespan of the product would be increased as the aluminium T beams would keep the soil from breaking the base under its weight.

Bibliography

Section A

"Garden365 Mini Elevated Garden." Garden365. N.p., 10 Mar. 2014. Web. 29 Feb. 2016. <http://www.garden365.com/products/raised-garden-planters/mini-elevated-garden/>.

"Garden365 Mobile Garden." Garden365. N.p., 10 Mar. 2014. Web. 29 Feb. 2016. <http://www.garden365.com/products/mobile-garden-planters/mobile-garden/>.

Section B

fastlaneusastore. "Set of 4 Casters." Ebay. N.p., n.d. Web. 29 Feb. 2016. <http://www.ebay.com/itm/Set-of-4-Casters-with-3-3-8-Heavy-Duty-Non-Mark-Wheels-2-Rigid-2-Swivel-Brakes-/281866439717?hash=item41a08c8c25:g:hdoAAOSwFNZWxK8I>.

"Corrugated Plastic Sheets." Corrugated Plastic Sheets, Panels, Pads, Rolls. N.p., n.d. Web. 29 Feb. 2016. <http://corrugatedplastics.net/>.

Section C

"PVC's Physical Properties." PVC. N.p., n.d. Web. 29 Feb. 2016. <http://www.pvc.org/en/p/pvcs-physical-properties>.

"Physical Properties." Physical Properties of Acrylite FF (2001): 2. Cyro. Web. 29 Feb. 2016. <http://www.sdplastics.com/acryliteliterature/1121DFFPhysicalProperties[1].pdf>.

"T-Slotted Aluminum Extrusions." MiniTec. N.p., n.d. Web. 29 Feb. 2016. <http://www.minitecframing.com/Products/Profile_Fasteners/T-Slotted_Profile_Fasteners.html>.

Appendix

Appendix 1.1

http://www.cdc.gov/nchs/data/series/sr_11/sr11_252.pdf

Table 7. Height in centimeters for children and adolescents aged 2–19 years and number of examined persons, mean, standard error of the mean, and selected percentiles, by sex and age: United States, 2007–2010

Sex and age[1]	Number of examined persons	Mean	Standard error of the mean	Percentile								
				5th	10th	15th	25th	50th	75th	85th	90th	95th
Male				Centimeters								
2 years	285	91.8	0.38	84.1	85.5	87.0	88.6	92.0	94.9	96.4	97.6	99.5
3 years	202	98.9	0.36	91.1	93.5	94.6	95.9	98.8	101.5	103.9	104.8	105.8
4 years	244	106.2	0.43	97.8	100.1	101.2	103.1	106.0	108.7	111.1	112.8	114.9
5 years	205	113.7	0.55	104.2	106.7	107.2	109.4	113.1	116.9	119.5	121.7	†
6 years	193	119.3	0.45	108.6	112.0	112.7	115.4	119.5	123.3	124.8	126.1	128.2
7 years	215	125.4	0.43	117.1	118.2	118.7	120.3	124.8	128.9	131.9	133.7	136.5
8 years	210	131.6	0.66	122.0	123.4	125.3	128.0	131.4	135.4	137.4	138.8	†
9 years	190	137.9	0.88	123.4	127.6	130.2	132.3	136.7	143.2	145.3	146.5	151.2
10 years	197	142.3	0.64	131.7	133.4	135.3	137.5	142.5	147.0	148.5	149.9	152.8
11 years	211	149.9	0.62	138.8	140.3	142.1	145.0	149.3	154.1	157.1	160.2	163.1
12 years	159	154.6	0.61	143.1	144.4	146.0	149.0	153.4	160.6	163.3	165.8	168.2
13 years	146	163.7	0.68	147.7	151.4	155.2	157.3	164.5	168.9	172.1	174.9	†
14 years	177	168.5	0.94	154.9	157.7	160.1	162.5	169.5	174.3	176.2	177.6	†
15 years	160	173.8	0.88	160.3	164.0	166.9	170.0	173.7	178.2	181.5	183.4	187.8
16 years	175	175.1	0.50	163.3	166.2	168.1	171.0	175.4	178.5	182.1	183.3	186.3
17 years	188	175.9	0.69	162.6	165.4	167.5	172.1	176.1	180.3	183.2	185.4	†
18 years	142	176.4	0.54	164.0	168.8	169.7	172.2	176.8	180.0	183.0	184.4	185.7
19 years	179	177.8	0.81	164.7	168.5	170.1	173.4	178.2	181.9	184.9	187.3	†
Female												
2 years	257	90.4	0.41	84.7	85.5	86.1	87.4	90.0	92.7	95.2	96.1	97.6
3 years	189	98.7	0.39	90.9	92.5	93.6	95.1	99.0	101.7	103.3	104.9	106.9
4 years	200	105.0	0.46	98.0	99.6	100.7	102.0	104.7	107.5	110.0	111.6	112.6
5 years	177	112.6	0.45	104.0	105.6	107.4	109.4	112.0	115.8	117.5	120.3	122.1
6 years	177	119.2	0.52	111.0	112.8	113.5	115.0	118.8	123.1	124.9	126.5	128.9
7 years	207	124.6	0.53	113.5	116.5	118.6	121.1	125.1	128.5	130.4	131.7	134.2
8 years	203	131.3	0.84	121.2	122.5	124.9	126.5	130.7	135.1	137.4	139.7	†
9 years	205	137.0	0.47	127.6	129.2	130.2	132.3	136.7	140.8	143.0	144.9	148.3
10 years	183	144.5	0.52	133.9	134.6	136.8	138.7	144.5	149.8	151.8	153.3	155.4
11 years	219	150.4	0.54	137.5	140.0	141.0	145.9	150.7	155.9	157.8	159.2	161.6
12 years	166	156.1	0.64	142.9	145.0	149.4	151.3	156.7	161.7	163.1	164.6	166.3
13 years	140	160.0	0.55	151.0	152.4	154.1	155.5	159.5	163.5	166.3	169.2	170.4
14 years	168	161.6	0.76	†	152.8	153.7	156.4	161.9	166.5	168.6	169.9	174.7
15 years	137	162.9	0.76	150.9	154.4	155.8	158.6	161.7	167.0	168.9	170.3	176.2
16 years	156	162.2	0.64	151.9	154.1	155.7	157.3	161.4	166.8	169.5	170.5	171.6
17 years	143	163.1	0.62	150.0	152.4	154.6	157.4	164.0	168.5	171.4	172.6	174.7
18 years	137	163.1	0.59	153.8	154.8	157.1	159.2	163.0	167.1	169.6	171.2	173.0
19 years	118	163.3	0.72	153.8	156.1	157.9	159.4	163.1	165.8	167.7	168.9	172.9

† Standard error not calculated by SUDAAN.
[1]Refers to age at time of examination.
SOURCE: CDC/NCHS, National Health and Nutrition Examination Survey.

Appendix 1.2

Table 9. Height in centimeters for females aged 20 and over and number of examined persons, mean, standard error of the mean, and selected percentiles, by race and ethnicity and age: United States, 2007–2010

Race and ethnicity and age	Number of examined persons	Mean	Standard error of the mean	Percentile								
				5th	10th	15th	25th	50th	75th	85th	90th	95th
All racial and ethnic groups[1]				Centimeters								
20 years and over	5,971	162.1	0.14	150.7	153.1	154.7	157.3	162.1	166.8	169.2	170.9	173.7
20–29 years	960	163.1	0.24	152.0	153.9	155.7	158.1	162.9	167.6	170.2	171.8	175.1
30–39 years	1,029	163.4	0.29	151.4	154.6	156.1	158.6	163.4	167.9	170.4	172.4	174.9
40–49 years	1,060	163.1	0.22	152.0	154.4	156.1	158.6	162.7	167.5	170.0	171.7	174.5
50–59 years	873	162.2	0.30	151.3	153.5	154.9	157.4	162.6	166.7	169.1	170.2	172.6
60–69 years	952	161.6	0.26	150.5	152.9	154.8	157.5	162.0	165.8	168.2	169.6	171.7
70–79 years	679	159.1	0.32	148.2	150.6	151.9	154.2	159.4	163.3	165.1	167.9	169.8
80 years and over	398	155.9	0.36	144.6	147.0	149.3	151.9	156.1	159.8	162.1	163.3	166.3
Non-Hispanic white												
20 years and over	2,764	163.1	0.15	152.1	154.4	156.3	158.7	163.0	167.5	169.7	171.6	174.5
20–39 years	824	164.9	0.25	153.9	156.6	158.1	160.6	164.8	168.9	171.7	173.7	176.5
40–59 years	861	163.8	0.27	153.6	155.6	157.2	159.6	163.7	168.0	170.0	171.7	174.5
60 years and over	1,079	160.3	0.22	149.2	151.8	153.4	156.1	160.3	164.5	167.1	168.6	170.7
Non-Hispanic black												
20 years and over	1,154	163.0	0.25	152.2	154.6	156.0	158.3	162.8	167.7	169.8	171.4	173.6
20–39 years	397	163.7	0.32	153.1	155.4	156.9	159.0	163.5	168.1	170.5	171.8	173.8
40–59 years	384	163.5	0.38	152.8	155.1	156.5	158.7	163.0	168.2	170.1	171.8	173.1
60 years and over	373	160.6	0.28	149.7	152.1	153.5	156.1	160.6	164.9	167.0	168.5	171.2
Hispanic[2]												
20 years and over	1,763	157.1	0.19	146.3	148.8	150.1	152.6	156.9	161.5	163.9	165.6	168.3
20–39 years	673	158.2	0.23	147.7	149.7	151.5	153.8	157.9	162.2	165.0	166.6	169.5
40–59 years	580	157.1	0.33	146.8	148.8	150.7	152.8	156.7	161.6	163.6	164.8	167.2
60 years and over	510	153.7	0.31	143.9	146.0	147.5	149.4	153.3	157.7	159.8	161.6	164.5
Mexican American												
20 years and over	1,074	156.6	0.17	145.3	148.4	149.8	152.2	156.4	160.9	163.1	164.8	167.7
20–39 years	427	157.5	0.27	145.9	149.5	151.2	153.3	157.5	161.4	163.9	165.4	168.4
40–59 years	348	156.6	0.41	145.9	148.6	149.9	152.1	156.0	161.0	163.1	164.6	166.9
60 years and over	299	153.3	0.40	143.8	145.8	147.0	149.3	153.2	157.0	159.8	161.4	163.6

[1]Persons of other races and ethnicities are included.
[2]Mexican-American persons are included in the Hispanic group.
SOURCE: CDC/NCHS, National Health and Nutrition Examination Survey.

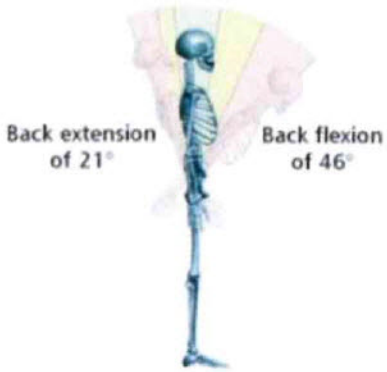
Appendix 1.3

Table 11. Height in centimeters for males aged 20 and over and number of examined persons, mean, standard error of the mean, and selected percentiles, by race and ethnicity and age: United States, 2007–2010

Race and ethnicity and age	Number of examined persons	Mean	Standard error of the mean	Percentile								
				5th	10th	15th	25th	50th	75th	85th	90th	95th
All racial and ethnic groups[1]				Centimeters								
20 years and over	5,647	175.9	0.20	163.2	166.0	168.0	170.9	176.1	180.9	183.6	185.4	188.2
20–29 years	895	176.3	0.33	163.6	166.4	168.8	171.2	176.3	181.7	184.3	185.8	188.3
30–39 years	948	176.4	0.36	163.6	166.1	168.3	171.5	176.5	181.8	184.4	186.3	188.5
40–49 years	934	176.8	0.42	164.9	167.7	169.1	171.8	176.8	181.6	184.4	186.7	188.9
50–59 years	938	176.6	0.32	163.9	167.1	168.5	172.0	176.9	181.1	183.6	185.0	189.0
60–69 years	932	174.9	0.25	162.2	164.6	166.9	169.9	175.3	179.7	182.6	184.5	187.0
70–79 years	646	173.2	0.34	161.7	164.0	165.7	168.5	173.1	177.7	180.2	182.6	184.7
80 years and over	354	170.7	0.39	158.7	161.9	163.5	166.0	170.9	175.7	177.6	178.9	181.6
Non-Hispanic white												
20 years and over	2,738	177.4	0.19	165.9	168.6	170.3	172.7	177.3	182.0	184.5	186.3	188.8
20–39 years	797	178.4	0.35	168.0	170.0	171.5	173.3	178.2	183.0	185.3	187.0	189.0
40–59 years	836	178.3	0.28	167.7	170.2	171.7	173.9	178.3	182.2	184.8	186.8	189.5
60 years and over	1,105	174.6	0.22	163.1	165.0	166.8	169.8	175.0	179.2	182.0	183.9	186.4
Non-Hispanic black												
20 years and over	1,091	176.4	0.25	165.4	167.5	169.0	171.8	176.3	180.8	183.4	185.5	188.0
20–39 years	356	176.9	0.39	166.4	168.2	170.1	172.4	176.4	181.4	183.8	186.1	187.9
40–59 years	373	176.7	0.53	165.0	168.0	169.1	171.9	176.8	181.3	183.7	185.8	188.7
60 years and over	362	174.4	0.42	163.1	164.9	166.8	169.5	175.1	178.5	181.6	183.2	185.8
Hispanic[2]												
20 years and over	1,541	170.4	0.34	159.0	161.4	162.8	165.3	170.1	175.1	178.1	180.0	183.9
20–39 years	573	171.1	0.48	159.0	161.7	163.5	165.6	170.9	176.3	179.2	181.9	185.0
40–59 years	577	170.3	0.36	160.0	161.7	162.8	165.5	170.3	174.7	177.2	179.0	181.5
60 years and over	391	167.3	0.45	156.8	159.5	160.6	163.0	167.5	171.2	173.5	174.7	177.8
Mexican American												
20 years and over	990	169.8	0.39	158.8	160.8	162.4	165.0	169.3	174.0	177.4	179.8	183.3
20–39 years	386	170.5	0.61	158.7	160.8	162.5	165.2	170.0	175.4	178.6	181.7	184.9
40–59 years	371	169.5	0.35	159.7	161.2	162.8	165.3	168.9	173.3	176.2	177.8	180.8
60 years and over	233	167.2	0.54	157.2	158.9	160.5	163.0	167.4	170.6	173.1	174.0	177.3

[1]Persons of other races and ethnicities are included.
[2]Mexican-American persons are included in the Hispanic group.
SOURCE: CDC/NCHS, National Health and Nutrition Examination Survey.

Appendix 2



http://www.allsteeloffice.com/SynergyDocuments/ErgonomicsAndDesignReferenceGuideWhitePaper.pdf

Appendix 3.1

High School Garden Tubs

I am sending this survey as part of my Design Technology course. Your response will be much appreciated.

How many times a week do you visit the high school garden?

- Never
- Once
- Twice
- Three times
- Four times
- Fire or more

Do you often use the tubs for gardening?

These are the large grey tubs where larger plants are grown

- Yes
- No

Do you find that the soil in the tubs is too low?

- Yes
- No

Do you find it annoying that compost tea is leaked out of the tubs?

- Yes
- No

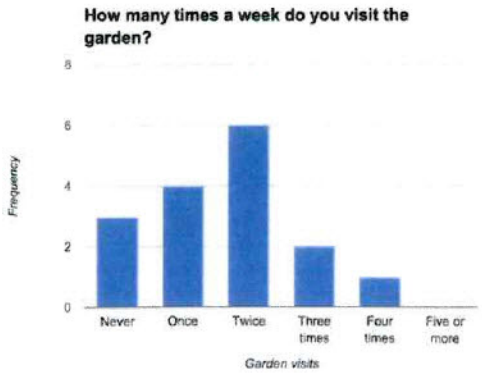
Do you think fixing either one or both of these issues would make you more productive in the garden?

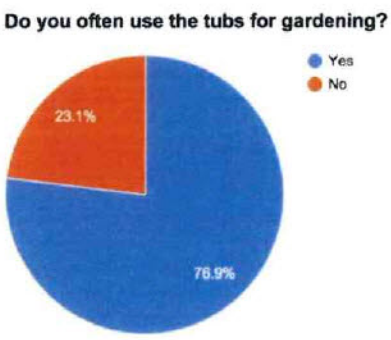
- Yes
- No

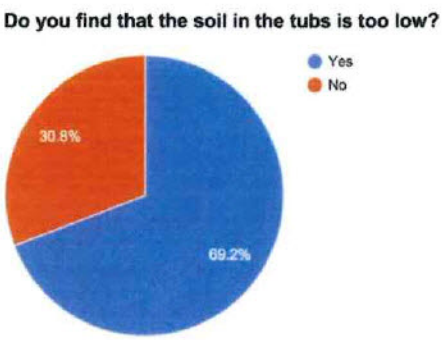
Appendix 3.2

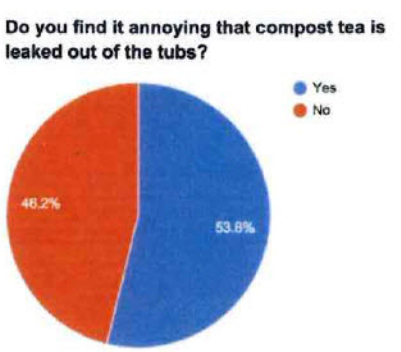
How many times a week	Do you often use the tul	Do you find that the soi	Do you find it annoying th	Do you think fixing either one or both of these issues would
2	Yes	Yes	Yes	Yes
1	Yes	Yes	Yes	Yes
2	Yes	Yes	Yes	Yes
2	Yes	Yes	Yes	Yes
3	Yes	Yes	Yes	Yes
4	Yes	Yes	Yes	Yes
2	Yes	Yes	Yes	Yes
2	Yes	Yes	No	Yes
1	Yes	Yes	No	Yes
3	Yes	No	No	Yes
1	No	No	No	Yes
2	No	No	No	No
1	No	No	No	No
Never	No	No	No	No
Never	No	No	No	No
Never	No	No	No	No

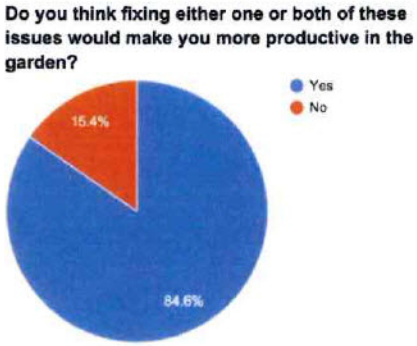
Appendix 3.3











Appendix 4

Metals are an ideal material for use in mass production. They can be:

- bent
- welded
- stretched
- cut
- drilled
- twisted
- cast
- folded
- riveted
- pressed.

STEEL – A FERROUS ALLOY

Steel is an alloy of iron and carbon. Mild steel, stainless steel and silver steel are all ferrous alloys. Only a small amount of carbon (0.3 per cent) in iron will change the mechanical properties significantly.

Other elements such as chromium and vanadium can be introduced to improve resistance to corrosion. A small addition of silver will improve its ability to retain a cutting edge and this material – silver steel – is often used for cutting tools and kitchen implements.

Appendix 5

Iron and steel

Metal	Composition	Properties/characteristics	Uses
Iron	Pure metal	• Soft and ductile • Weak in tension	• Alloyed with carbon to make steel
Mild steel	Alloy of iron and carbon (0.15 – 0.3% carbon)	• Tough, ductile and malleable • Good tensile strength • Easily joined by welding or brazing • Poor resistance to corrosion • Cannot be easily heat treated • Easily worked in school workshop	• Structural steel girders • Car body panels • Nails, screws, nuts and bolts, general ironmongery
Stainless steel	Alloy of steel (12% chromium, 8% nickel)	• Hard and tough • Excellent resistance to corrosion • Difficult to use in school workshop	• Cutlery • Kitchen sinks • Pots and pans
Silver steel	Alloy of steel (0.8 – 1.5% carbon)	• Very hard and less ductile than mild steel • Difficult to cut but easily joined by welding	• Scribers • Screwdriver blades

BRASS – A NON-FERROUS ALLOY

Brass is a non-ferrous alloy and has improved resistance to corrosion. It also casts and turns easily and is therefore ideal as a material for boat and plumbing fittings.

Appendix 6

PROPERTIES AND USES OF THERMOPLASTICS AND THERMOSETTING PLASTICS

Plastic	Type	Properties/characteristics	Uses
Acrylic	Thermoplastic	• Stiff, hard and durable • Easily scratched • Good electrical insulator • Available in a wide range of colours • Polishes and finishes well	• Baths and bathroom furniture • Car indicator covers/reflectors
Polythene (low density) – LDPE	Thermoplastic	• Tough • Resistant to chemicals • Soft and flexible • Good electrical insulator • Available in a wide range of colours	• Squeezy bottles for shampoo and washing-up liquid • Toys • Carrier bags
Polythene (high density) – HDPE	Thermoplastic	• Stiffer and harder than LDPE • Surface has a waxy feel to it • Can be sterilized • Good resistance to corrosion	• Buckets • Bowls • Milk crates • Bleach bottles
ABS	Thermoplastic	• High impact strength • Lightweight and durable • Resistant to chemicals • High quality of surface finish	• Telephones • Kitchenware • Toys
Polyester	Thermoplastic	• Stiff, hard and brittle • Very resilient when laminated with GRP (glass reinforced plastic) • Good heat and chemical resistance	• Product cases such as hair dryers • Paperweight castings • Boat hulls with GRP
Epoxy resin	Thermosetting plastic	• Good resistance to wear and chemicals • High strength when used as a bonding agent on **fibrous** materials	• Adhesives • PCB (printed circuit board) material • Lamination of woven sheets such as fibre glass

Appendix 7

ACRYLITE® FF acrylic sheet is a continuously manufactured acrylic sheet. It is produced by an innovative process, resulting in a sheet offering the easy handling and processing of extruded sheet, along with the high optical characteristics and low stress levels expected of cast products. Colorless ACRYLITE FF sheet carries an exclusive 10-year limited warranty on light transmission – your assurance of a quality product. A printed copy of the warranty is available from CYRO Industries or wherever ACRYLITE® acrylic sheet is sold.

The clarity and light stability of acrylic resin make it possible to manufacture crystal clear ACRYLITE FF sheet.

Characteristics

ACRYLITE FF sheet is a lightweight, rigid and weather-resistant thermoplastic. ACRYLITE FF sheet is dimensionally stable and resistant to breakage, and can be easily sawed, machined, heat-formed and cemented.

Because of its virtually distortion-free clarity, it is well suited for use in a variety of applications.

- Skylights
- Signs
- Window Glazing
- Window Frames
- Picture Framing
- Store or P-O-P Displays
- Optical Displays

Availability

ACRYLITE FF sheet is available in thicknesses from 0.060" (1.5 mm) to 0.944" (24 mm) and actual sheet sizes from 48" x 96" (1.22 m x 2.44 m) to 100" x 150" (2.54 m x 3.81 m). Custom sizes are also available. All sheets are protected with polyethylene film or paper masking.

Safety

ACRYLITE FF sheet is more impact resistant than glass. If subjected to impact beyond the limit of its resistance, it does not shatter into small slivers, but breaks into comparatively large pieces. ACRYLITE FF sheet meets the requirements of ANSI Z97.1 for use as a Safety Glazing Material in Buildings (for thicknesses 0.080" to 0.500" [2.0 mm - 12.0 mm]).

Weather Resistance

ACRYLITE FF sheet will withstand exposure to blazing sun, extreme cold, sudden temperature changes, salt water spray, etc. It will not deteriorate after many years of service because of the inherent stability of acrylic resins. ACRYLITE FF sheet has been widely accepted for use in school buildings, industrial plants and outdoor signs.

Dimensional Stability

Although ACRYLITE FF sheet will expand and contract due to changes in temperature and humidity, it will not shrink with age. Some shrinkage occurs when ACRYLITE FF sheet is heated to forming temperature, but post-forming stability is excellent.

Light Weight

ACRYLITE FF sheet is only half the weight of glass and 43% the weight of aluminum.

Rigidity

ACRYLITE FF sheet is not as rigid as glass or metals. However, it is more rigid than many other plastics such as acetates, polycarbonates or vinyls. Under wind load an acrylic sheet will bow and foreshorten as a result of deflection.

For glazing installations the maximum wind load and the size of the window must be considered when the thickness of a panel is to be determined.

If ACRYLITE FF sheet is formed into corrugated or domed shapes, rigidity will be increased and deflection minimized.

Cold Flow

Large, flat ACRYLITE FF sheet, if insufficiently supported, may deform permanently due to continuous loads such as snow, or even their own weight. Increased rigidity obtained by forming will minimize cold flow.

Strength and Stresses

Although the tensile strength of ACRYLITE FF sheet is 10,000 psi (69 Mpa) at room temperature (ASTM D 638), stress crazing can be caused by continuous loads below this value. For glazing applications, continuously imposed design loads should not exceed 750 psi (5.2 Mpa) at 73°F (23°C). Temporary loads of up to 1,500 psi (10.4 Mpa) may be imposed for short durations of time at 73°F (23°C).