Hwa Chong Institution
Project Work
Category 3 Inventions Log Book

Title of Project: JaCool
Group Name: 3-17
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1. Problem Finding

Before coming up with problems, we decided on a theme, which was to improve the quality and safety of lives. This theme guided us to come up with the following problems.

The first problem we came up with is that in coffee shops/ BBQs, there are a lot of flies or birds, causing annoyance. We realised that while eating at coffee shops, every now and then, we would have to stop eating momentarily and use our hands to scare away pesky flies. If we have to do this all the time, it would be hard for us to concentrate on eating or chat with our family members.

The second problem we came up with is that in countries like Singapore, it is unbearably hot and the UV radiation is exceptionally high. While walking along the pavement, people usually hold umbrellas to block themselves from the scorching sun. There does not seem to be better ways to solve this problem.

The third problem is that excess water from potted plants promotes breeding of mosquitoes. This problem is a very real problem as a lot of people in Singapore grow plants. Also, there has also been a lot of dengue cases in Singapore, which may result in fever or even death.

The fourth problem is that after mopping floors at home, the floor does not dry immediately. It can be observed that after floors are mopped, even after a while, the floor remains wet. This increases the chances of people, especially the elderly, slipping and falling, which may cause injuries.

Before selecting a problem, we did consider a few criteria. We firstly thought about the severity of the problems. This criterion is crucial as if the problem is not important enough, there is no point in us trying to solve the problem. For a problem to be considered important, it should have a target audience of an appropriate size and affect the target audience to a certain extent. For example, a problem like "Singaporeans sometimes miss the MRT trains" is considered a very trivial one.

Secondly, we questioned the feasibility of coming up with solutions to the problems. This means that the problem should not be too massive for us to handle and coming up with a solution should not be too difficult. We need to be able to complete the project. If the problem is too massive, we will have to put in a lot of effort such that we may not have enough time to cope with other schoolwork and activities, whereas if coming up with a solution or making a prototype is too difficult, then most likely, we will not do well for this project work.

Lastly, we asked ourselves if a solution would effectively solve the problem. This means that if we come up with a solution, will the target audience be affected positively? If a solution is not able to effectively tackle the problem, then we should seek alternative problems. For example, if our problem is "People are inconsiderate and throw a lot of rubbish around", it will score lower than another problem because it is very hard to control such things. It all boils down to the person himself.

We finally used a decision making matrix (Table 1.1) to weigh the problems. We realised that the problem of excessive heat and UV radiation was the most important to us.

2. Defining the Problem

After deciding on a suitable problem, we then went on to carry out research about this problem and existing solutions.

Singapore is a hot and humid country, the UVI (UV rays index) is also extremely high.

This causes people to be uncomfortably sweaty, or in more extreme cases, heat stroke and other health risks.

Firstly, the heat in Singapore is just going to get worse, with temperatures expected to increase by 6%, due to global warming (Listverse, 2018). Heat causes problems like heat rashes, headache, heat exhaustion and heat stroke. Heat stroke basically happens when the body's internal temperature exceeds 40 degrees Celsius. Humidity increases the chances of heatstroke by keeping sweat from evaporating, slowing the body's ability to rid itself of heat. Once the core temperature reaches 42°C for as little as 45 minutes, cells break down. (Listverse, 2018) There have been quite a lot of cases of heat stroke-related deaths in Singapore. Hence, something should be done to solve this problem.

Secondly, the issue of UV rays is also quite important in Singapore. UV rays are a huge concern as Singapore's ultraviolet radiation levels surpass a lot of countries. Ultraviolet radiation levels in Singapore had recorded "extreme" readings, reaching the highest of 15. Physicists at the University of Toronto have discovered that changes in the Earth's ozone layer due to climate change will reduce the amount of UV radiation in northern high latitude regions and increase the amount of UV radiation in other regions of the Earth, like Singapore. (ScienceDaily, 2018) UV radiation has very severe effects on the human body. It may cause skin cancer, suppress the proper functioning of the body's immune system and suppress of proper functioning of the skin's natural defences.

To further confirm the extent of this problem, we conducted a survey and gathered 95 respondents. As you can see from the chart (Figure 2.1), more than two-thirds of the 95 respondents responded to 7 and above. This shows that many people feel hot when outdoors, and they have limited solutions to keep themselves cool.

After this, we researched for existing solutions and have found 3 existing solutions to solve our problem.

Firstly, there are portable fans in the market which can cool someone down. Although it can cool you down and is small and easy to carry, it has a short battery life, you may sometimes forget to bring portable fans. It also does not protect you from UV radiation. Although the fans may be light, it is quite awkward to carry it all the time.

Secondly, there are Glacier Tek Cool Vests (Figure 2.2) in the market. The vest contains a gel pack which cools you down. It is good in the sense that it can cool you down to a comfortable 15 degrees Celsius and weighs less than 2.2kg. However, this vest costs a whopping $261.82, which is very costly. It can also only be used for up to 2.5 hours, and is neither energy efficient nor environmentally friendly. It also does not protect you from UV radiation.

Thirdly, there are Veskimo Water Cooled Vests (Figure 2.3) in the market. Chilled water is circulated through tubing. The water is circulated back to an insulated hydration backpack or portable cooler containing ice and a small high-efficiency pump after it has passed through the vest. Temperature of the water stays constant, and therefore so does the body cooling power. This is an efficient way of cooling a person down. However, the vest is expensive (SGD 301) It also will not protect you from UV radiation and you will need to carry a heavy backpack filled with ice and water, thus reducing mobility.

3. Our Solution

After reading up extensively on the existing products, we found out some problems with them. Hence, to solve these issues, we want our invention to be a UV-protective jacket with the following features.

Firstly, the jacket should be able to cool the wearer down on a hot day and protect the wearer from UV rays, which is the ultimate purpose of our invention. It can even be used in a cold environment to keep you warm. All current existing solutions are not specially catered to protect the wearer from UV rays.

Secondly, it should have a lightweight cooling system within it. Although the existing solutions are relatively light, we feel that we can bring the mass of our jacket down to about 1 kg, which is much lighter than other similar products. This way, the wearer is able to wear the jacket without feeling anything weighing the jacket down. The jacket should also not be bulky or people will find the jacket aesthetically pleasing and not want to wear it. Currently, a lot of the existing products we found come in the form of vests which are tailored more for construction workers who work under the scorching sun and may not be suitable for normal personal use.

Finally, it should be affordable at less than $100, so that people will be attracted to buy it. This is significantly cheaper than similar products in the market.

Our target audience is anyone who walks in the sun. Because the temperature in Singapore is increasing due to global warming, people will sweat a lot when walking in the outdoors. Hence, we want to invent this jacket to bring comfort to Singaporeans so that they can walk around in an “air-conditioned” environment. This way, users will no longer sweat uncomfortably. We hope that this jacket also has a low energy consumption that is sustainable in the long run. Also, as Singapore’s UV levels are high most of the time, people who constantly do activities outdoors may get skin cancer. Hence, we thought that the jacket could also be made of a material that blocks out UV rays. This jacket can also be used in colder areas, allowing this jacket to serve as a dual-function jacket.

We expect to face a lot of problems. Firstly, we may have problems in managing our time. As we have a lot of commitments, for example, CCAs, homework, debates, third language, science olympiad training and other miscellaneous projects, it will be difficult to find time to complete this project. Secondly, making the prototype may be difficult for us as we do not have much prior experience in making prototypes. Hence, we will have to quickly learn the ropes.

To make sure we have enough time to complete our prototypes, we created a timetable (Table 3.1) to make sure we stay on track and manage our time effectively.

4. Construction Process

We have created a total of 3 prototypes, each with improvements from the previous prototype, before ending with a final product. This is a quick summary of the construction process, more information is available in the appendixes.

<u>First Prototype</u>

Our first prototype was a rough demonstration of our big plan. Please refer to Figure 4.1 for our sketch. We used cardboard to form a box by the means of duct tape. This box contains the fan and the motor.(Figure 4.2) The battery is secured to the side of the box, also by duct tape. (Figure 4.3) On top of the box, we created a hole, stuck the straw and secured it using duct tape too. Finally, we used a glue gun and glued the whole box onto the shirt (Figure 4.4). The materials were chosen because we thought that they were suitable and are adequate to show if our concept works.

We did expect to face problems such as the incorrect positioning of the tubes, but there were some unanticipated problems, such as the vibration produced by the motor.

For more details about our first prototype, see Appendix A.

Second Prototype

This prototype was more of a proof of concept as we wanted to see if our ice packs are able to quickly cool down the tubes and for a long period of time.

We chose a small metallic KitKat box, with copper tubes and insulation which we added, to be our central cooling system. (Figure 4.5) However, the KitKat box was made of a metal, and therefore rather heavy and quite heat conductive, thus causing the ice packs to melt faster. We added ice packs in order to cool down the air. (Figure 4.6) We decided to use a 12-volt computer fan, however, the wind from the computer fan had low static pressure and was unable to pass through the tubes.

Moreover, we have been using commercial ice packs to build our prototypes. Perhaps, we should compare the freezing temperature and time to melt of such ice packs compared with saturated salt or sugar solutions. However, we did not use this method in out final product as after some research, we found out that this using these solutions may not really be practical for our situation. For more details, see Appendix D.

For more details about our second prototype, see Appendix B.

Third Prototype

Our third prototype was completed after we analysed our mistakes in the first two prototypes and found solutions to address the issues.

We went back to using cardboard as our material for the box due to how simple it is to manipulate it and its lightness. (Figure 4.7) The boxes can be opened and closed and there was added insulation and waterproofing to the upper box, which contained the ice packs. The upper box also contains copper tubes which are a good heat conductor in order to cool down the air passing through it faster. (Figure 4.8)

The fan used has unique blades which produces wind of high static pressure, therefore, more and stronger wind were felt at the end of the tubes, compared to the second prototype.

The rubber tubes which extend out from the boxes help direct the wind to blow at the sweatiest parts of the body, the neck and the body. Learning from our second prototype, we made sure the tubes do not bend too much as this may restrict air flow. (Figure 4.9)

From the previous prototypes, we realised the the fans did not provide sufficient pressure to circulate the air around. As the tubes are supposed to lead to all parts of the body and we had not found a fan suitable for our needs, we decided to use two fans instead, one for each side of the body.

For more details about our third prototype, see Appendix C.

Final Product

Our final product is created after we have modified our third prototype. We gathered some user feedback for our third prototype. Everybody who wore our jacket did not feel cooled down; they instead could not feel any wind at all. We knew of this problem and set work at once to solve it.

After experimenting with the tubes' positioning, we decided to move the tubes closer to the person and change the direction the tubes are facing. Instead of blowing the wind at the forehead and armpit, we decided to direct all the tubes towards the neck. This was because of the feedback from the judges, who said that the tubes leading to the forehead and neck were too weak. Therefore, we felt that it would be better if they all led to the neck.

We also decided to reinforce the pair of boxes with wood. This would make it more sturdy, and less likely to break down after a few uses. The wood is at the back of each pair of box, and also helps in insulating the box, as wood is a bad conductor of heat.

5. Modification and Evaluation

First Prototype

The first prototype was rather unsuccessful as when the shirt was worn, no wind was felt. This is akin to not wearing the shirt at all. Also, the motor produces a lot of vibration which can be felt when wearing the shirt and shirt is quite bulky and awkward when putting it on. For more details, see Table 5.1.

Second Prototype

Our second prototype was a proof of concept, which helped determine if our cooling system would be effective. The ice packs managed to cool the copper tubes down to a comfortable 18 degrees Celsius. However, the fan was not able to transport the wind throughout the entire system of curved tubes as air pressure was not high enough. For more details, see Table 5.2.

Third Prototype

Our third prototype was a significant improvement from previous prototypes. However, we have still yet to solve the problem of tube positioning, resulting in no wind felt at all, and the jacket's bulk. For more details, see Table 5.3.

Final Product

Our final product had an improvement of the positioning of the tubes. We decided to lead all the tubes to the neck, after feedback from judges and our mentors. We also reinforced the boxes so that it would be more sturdy.

6. References

Heatstroke. (n.d.). Retrieved March 29, 2018, from https://www.omicsonline.org/singapore/heatstroke-peer-reviewed-pdf-ppt-articles/

10 Ways The Body Reacts To Deadly Extremes. (2014, July 09). Retrieved March 29, 2018, from https://listverse.com/2014/07/10/10-extremes-and-how-the-human-body-reacts/

Changes In Earth's Ozone Layer Predicted To Increase UV Radiation In Tropics And Antarctica. (2009, September 16). Retrieved March 30, 2018, from https://www.sciencedaily.com/releases/2009/09/090915113534.htm

The Concealable Cool Vest. (n.d.). Retrieved April 02, 2018, from https://www.glaciertek.com/

Comparitive Examples of Noise Levels. (n.d.). Retrieved April 02, 2018, from http://www.industrialnoisecontrol.com/comparative-noise-examples.htm

(n.d.). Retrieved April 02, 2018, from http://www.nea.gov.sg/weather-climate/weather-information/uvindex

(n.d.). Retrieved April 02, 2018, from http://www.nea.gov.sg/training-knowledge/weather-climate/uvradiation-uvindex

Magary, D. (2015, June 11). The Top 10 Sweatiest Parts of Your Gross, Sweaty Body. Retrieved April 02, 2018, from https://www.gq.com/story/top-ten-sweatiest-body-parts

Keep your cool (The Straits Times, Mind Your Body, 23 August 2012, Pg 08). (n.d.). Retrieved April 02, 2018, from https://www.sgh.com.sg/about-us/newsroom/News-Articles-Reports/Pages/Keepyourcool.aspx

Huiwen, N. (2018, February 27). Ultraviolet radiation in Singapore hit highest extreme level of 15 twice in last 2 weeks. Retrieved April 02, 2018, from http://www.straitstimes.com/singapore/environment/ultraviolet-radiation-in-singapore-hit-highest-extreme-level-of-15-twice-in

Tables and Figures

Considerations for Selection	Problems			
	#1	**#2**	#3	#4
Severity of Problem	1	**2**	4	3
Feasibility	2	**4**	1	3
How much would a solution solve the problem?	4	**3**	1	2
Total Score	7	**9**	6	8

*Problem #1: In coffee shops/ BBQs, there are a lot of flies or birds, causing annoyance.
*Problem #2: In countries like Singapore, it is unbearably hot and the UV radiation is very high.
*Problem #3: Excess water from potted plants promotes breeding of mosquitoes.
*Problem #4: After mopping floors at home, the floor does not dry immediately.

Table 1.1

There were several reasons why we decided on low scores for certain problems and higher scores for others.

For the severity of the problems, we felt that Problem #3 was the most trivial problem, because it is the only problem which kills a huge number of Singaporeans every year and causes others to fall sick for extended periods of time. This is followed by Problem #4, which although causes people to slip and fall, people usually sustain some bruises at first and rarely get severely injured. However, this still an important problem if the elderly are the ones slipping and falling. This is then followed by Problem #2. Problem #2 is still an important problem despite its low rating, because there are cases of people dying of heatstroke in Singapore. However, this is rather rare so our whatever product we come up with will just be a solution to cool the person down. The most trivial problem is Problem #1. Solving the problem will allow meals to proceed more smoothly without any annoying disruptions by insects, but it is not an urgent problem that we need to solve.

For the feasibility of coming up with solutions to the problems, we felt that Problem #2 was the best at fulfilling this criterion. This is because we already had a rough idea of how to solve this problem in our mind. We just had to apply simple concepts like heat conductivity and so on. However, solutions for Problems #1 and #4 may involve sophisticated mechanism that may be higher than our current skill level. Meanwhile, for Problem #3, we were rather unsure on how to solve the problem, so we rated it a 1.

For how well a solution will effectively solve the problem, we thought #1 had the most promising solution, as we thought that people would not reject such an invention as it will be easy to set up and use. However, solutions of problems like #3 requires the user to periodically use the invention. If the user himself is too lazy to use the invention, then the invention will just be a white elephant.

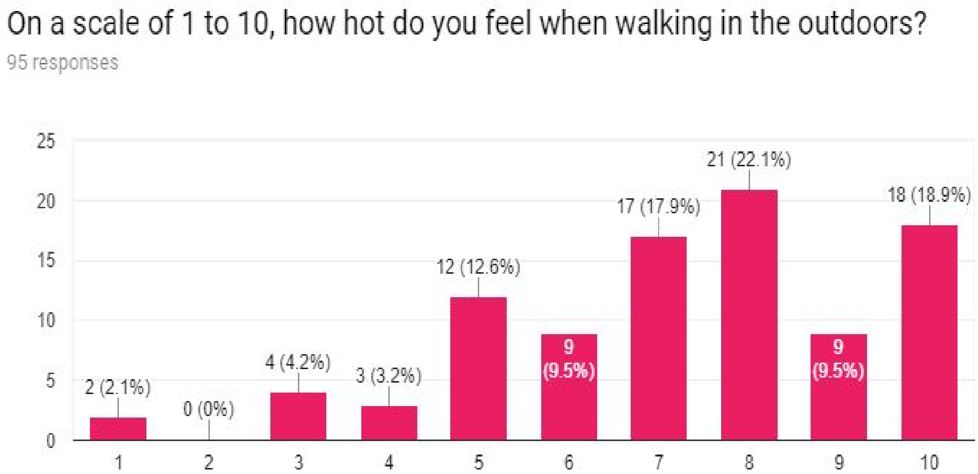


Figure 2.1

We did a survey with 95 respondents and found that more than two-thirds of the 95 respondents responded to 7 and above. Out of all the options, the greatest number chose 8 (22.1%). This greatly agrees with the fact that Singapore, being just one degree north of the equator, is an extremely hot and humid country. This also proves that there is a need for our product to bring comfort into people's lives.

Figure 2.2

This is the Glacier Tek Cool Vest. It has an average rating of four stars based on the 18 reviews in its official website.

works well

POSTED BY UNKNOWN ON 14TH AUG 2015

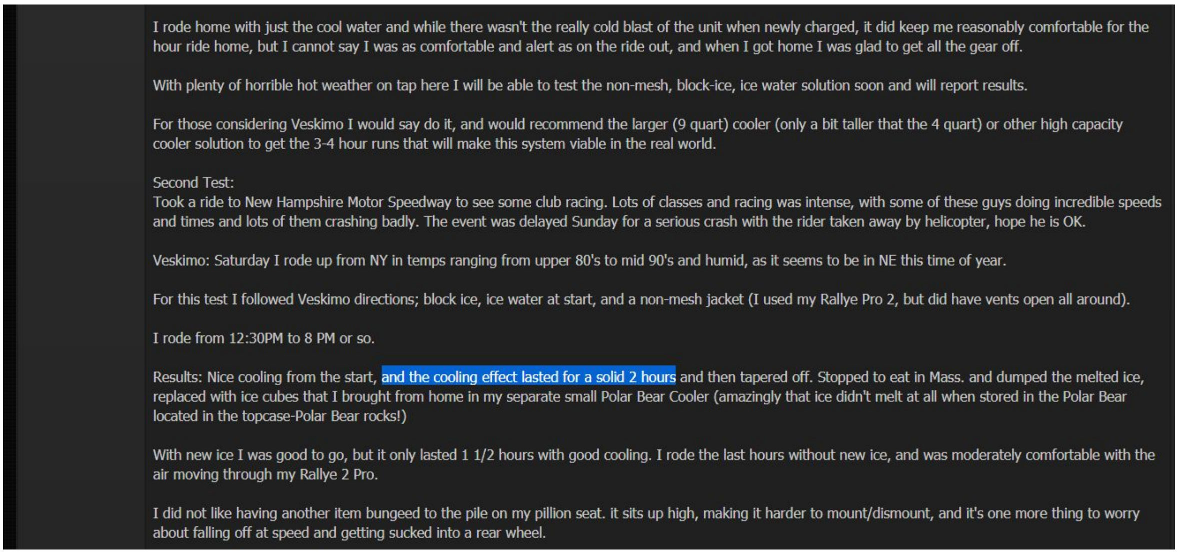
I put the vest in the refrigerator when I get home from work.
In the morning I put the vest on over my work shirt and ride to work, takes about 30 minutes.
I take it off and put on a chair.
10 hours later it is still solid, so I put it on and ride in 100+ degree weather home.
I am still hot, but I don't feel like passing out.
so it works for me.

Figure 2.2A

Opinions vary, some people feel that the vest is cool enough, but some do not feel so.

Figure 2.3

This is the Veskimo Water Cooled Vest. It has mostly positive reviews.



I rode home with just the cool water and while there wasn't the really cold blast of the unit when newly charged, it did keep me reasonably comfortable for the hour ride home, but I cannot say I was as comfortable and alert as on the ride out, and when I got home I was glad to get all the gear off.

With plenty of horrible hot weather on tap here I will be able to test the non-mesh, block-ice, ice water solution soon and will report results.

For those considering Veskimo I would say do it, and would recommend the larger (9 quart) cooler (only a bit taller that the 4 quart) or other high capacity cooler solution to get the 3-4 hour runs that will make this system viable in the real world.

Second Test:
Took a ride to New Hampshire Motor Speedway to see some club racing. Lots of classes and racing was intense, with some of these guys doing incredible speeds and times and lots of them crashing badly. The event was delayed Sunday for a serious crash with the rider taken away by helicopter, hope he is OK.

Veskimo: Saturday I rode up from NY in temps ranging from upper 80's to mid 90's and humid, as it seems to be in NE this time of year.

For this test I followed Veskimo directions; block ice, ice water at start, and a non-mesh jacket (I used my Rallye Pro 2, but did have vents open all around).

I rode from 12:30PM to 8 PM or so.

Results: Nice cooling from the start, and the cooling effect lasted for a solid 2 hours and then tapered off. Stopped to eat in Mass. and dumped the melted ice, replaced with ice cubes that I brought from home in my separate small Polar Bear Cooler (amazingly that ice didn't melt at all when stored in the Polar Bear located in the topcase-Polar Bear rocks!)

With new ice I was good to go, but it only lasted 1 1/2 hours with good cooling. I rode the last hours without new ice, and was moderately comfortable with the air moving through my Rallye 2 Pro.

I did not like having another item bungeed to the pile on my pillion seat. it sits up high, making it harder to mount/dismount, and it's one more thing to worry about falling off at speed and getting sucked into a rear wheel.

Figure 2.3A

This reviewer tested the Veskimo Water Cooled Vest and realised that although the temperature was quite cool at first, but afterwards it became warmer again.

Time frame:	Details:
Feb and Mar	Ideation and Preparation for Proposal Evaluation
Apr	Planning the prototypes
May	Building of first and second prototypes
Jun	Building of second and third prototypes
Jul	Preparation for Mid-Term Evaluation
Aug	Preparation for Final Evaluation

Table 3.1

This is our timeline for this year. As you can see, right after Proposal Evaluation, we plan to start work immediately on the sketching of our prototype and gathering the materials we need. In May and over the June Holidays, we plan to start constructing our prototypes and testing them. In July, we plan to complete our third prototype and start preparing for Mid-Term Evaluation. Finally, we will finish up our final product in July and August and gather some user feedback.

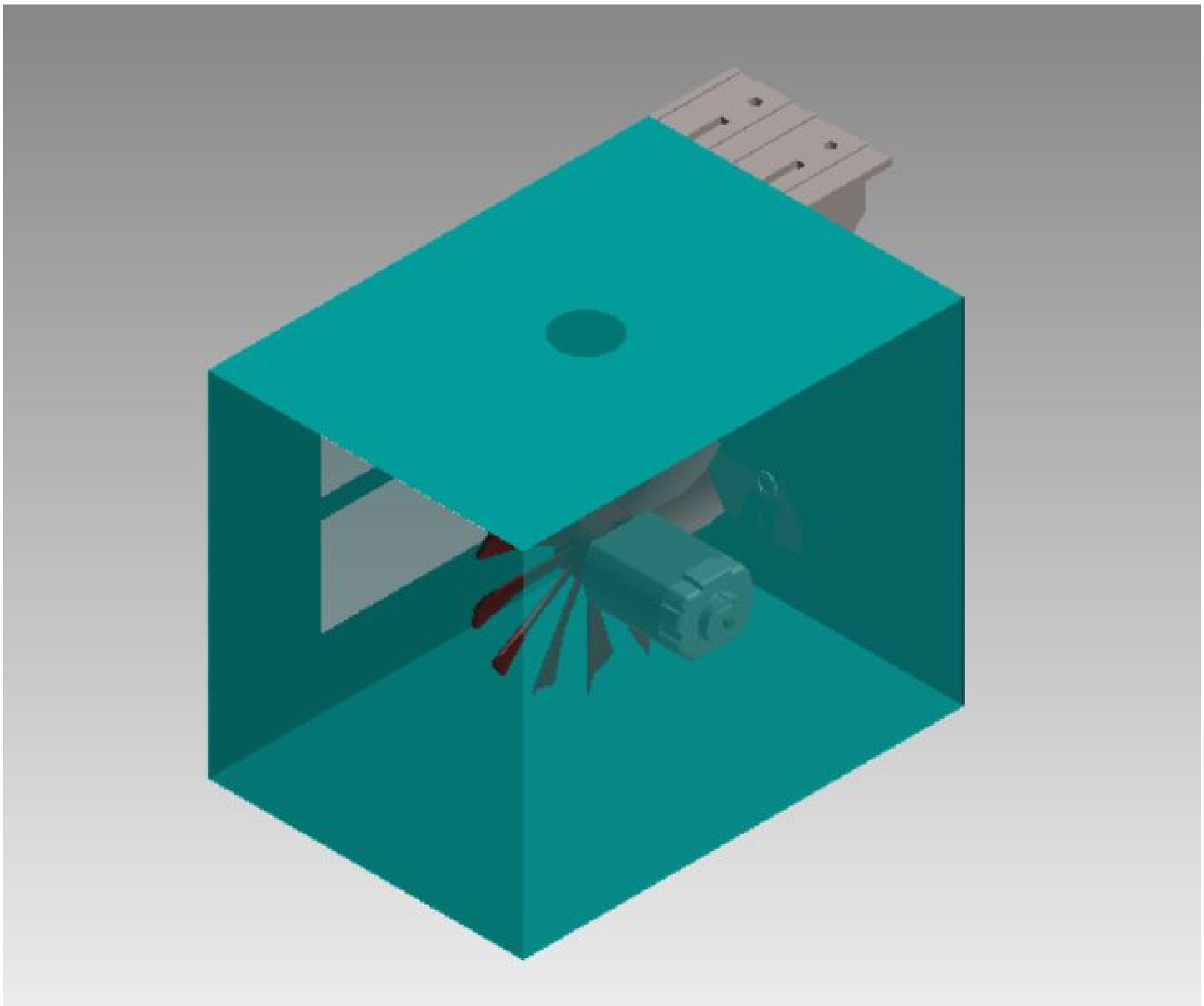


Figure 4.1

This figure show a 3D diagram that we made before we started building, in order to have a clear idea of what we are making and have something to refer to.

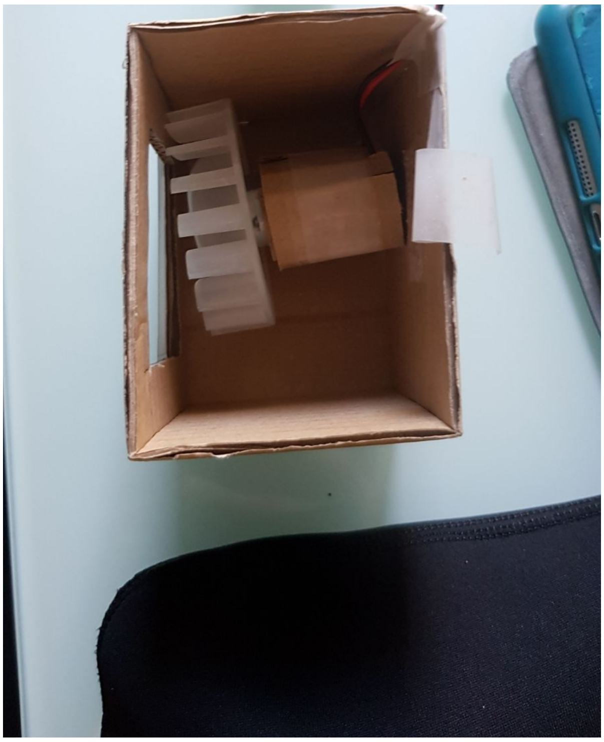


Figure 4.2

This figure shows the inside of the first prototype from the top. As seen from the figure, there is a fan blade and a motor in the box, with the battery box (not in picture, connected to the wires leading out of the box) attached outside if the box. There is a square shaped hole at the front of the box. That is for the fan to be able to draw wind, in order for it to blow wind.

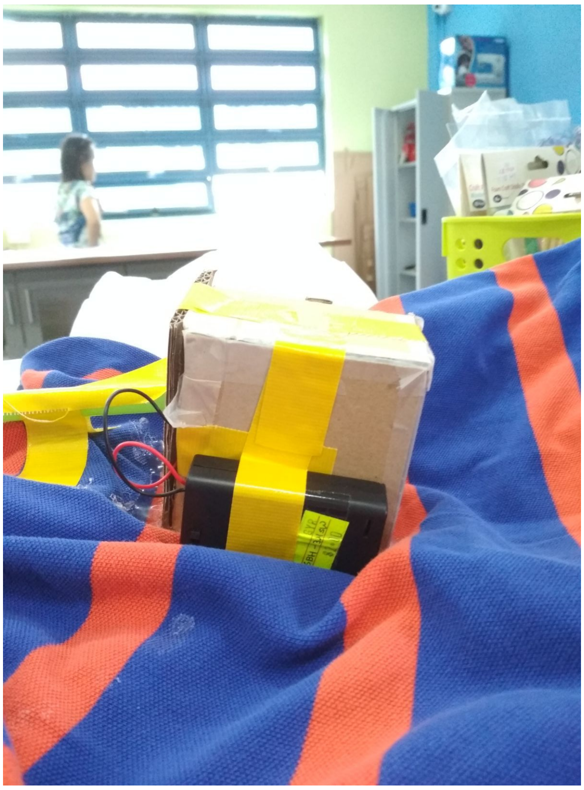


Figure 4.3

This is our first prototype, attached to the shirt using hot glue.

Figure 4.4

This is the front view of our prototype. As you can tell, the box is sagging downwards, which means when the shirt is worn, the shirt will feel like it is weighed down, which is not comfortable for the user.

Figure 4.5

This is the inside of our second prototype. The copper tubes, which are inflexible and therefore, we had to use rubber tubes in order for it to go around in the box.

Figure 4.6

In our second prototype, due to its high storage capacity, we could put a lot of ice pack in it at once, potentially prolonging the time before the ice packs gain too much heat until their temperature is the same as room temperature. However, with such a big container, the jacket will be more bulky too.

Figure 4.7

This is how the boxes look like when they are not in the pockets of the jacket.

Figure 4.8

This is the heart of our cooling system. The fan is in the lower compartment and blows air upwards into the upper compartment where the ice pack is. The ice pack cools down the extremely conductive copper tube which in turn cools down the air within the tube.

Figure 4.9

This photograph illustrates how air is circulated to all parts of the body. There are rubber tubes which extend out from the 2 pairs of boxes and leads to the position where the neck and the body is. The tubes are concealed as black cloth is sewn onto them, thus camouflaging the tubes.

Figure 4.10

The tubes now all lead to the neck instead of the other areas, as blowing at the other areas are not as effective. This is because of the imbalanced wind, where one of the tubes are not as strong as the other. Therefore, we felt that making the tubes lead to one area would be better than more than one area.

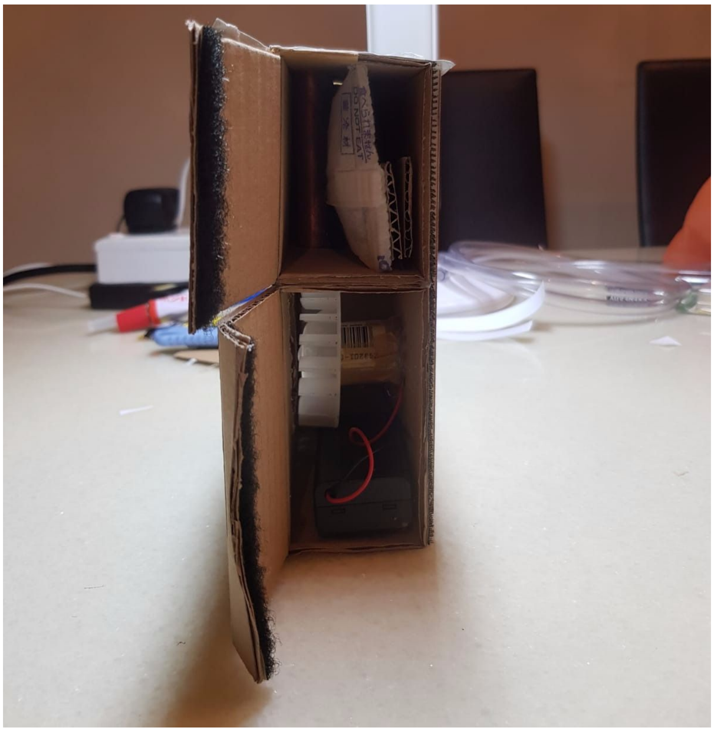


Figure 4.11

A thin layer of wood covers the back of this pair of boxes. This helps to insulate the box because of the low heat conductivity of the wood.

Test Iteration: 1	Tick			Remarks
Test Date: 8/5/18	Pass	Fail	Potential Failure	
Can enough wind be felt at the end of straw?	/			It will be better if the wind can be stronger.
Can enough wind be felt when wearing the shirt?		/		No wind felt at all when the shirt is worn. We need to replace the straw with something flexible.
Unbearable vibration?		/		A lot of vibration can be felt when the shirt is worn.
Is it awkward wearing the shirt?		/		The box containing the fan is too bulky.

Table 5.1

Test Iteration: 1	Tick			Remarks
Test Date: 7/6/18	Pass	Fail	Potential Failure	
Can enough wind be felt at the end of straw?		/		Air pressure was too low.
Could the ice packs cool the copper tubes down quickly?	/			However, the air inside the copper tubes may not have cooled down so quickly.

Table 5.2

Test Iteration: 1	Tick			Remarks
Test Date: 8/7/18	Pass	Fail	Potential Failure	

Can enough wind be felt when wearing the shirt?		/		The tubes are placed at the wrong places, so a way to position the tubes such that the wearer can feel wind is needed.
Is sufficient wind flowing through the tubes?			/	Sometimes, the fan may just suddenly stop moving if the blades come into contact with something.
Unbearable vibration?	/			
Is it awkward wearing the shirt?	/	/		It can be quite difficult to wear the shirt, but after that, it is fine.
Does it take a short time for air to be cooled down?	/			
Is the wind of acceptable temperature? (18-23 degrees Celsius)	/			
Is the jacket lighter than other cooling jackets? (around 2kg)	/			

Table 5.3

Test Iteration: 1	Tick			Remarks
Test Date: 16/8/18	Pass	Fail	Potential Failure	
Can enough wind be felt when wearing the shirt?	/		/	The tubes have been repositioned so they are now blowing at the right places. However, if they are shaken too much, they may go out of place.
Is sufficient wind flowing through the tubes?	/			Sufficient wind are flowing through the tubes.
Unbearable vibration?	/			Unlike previous prototypes, the vibration is at a minimum, because of the better attachment.
Is it awkward wearing the jacket?	/	/		It can be quite difficult to wear the jacket, and also switch on the fans, but after that, it is fine.
Does it take a short time for air to be cooled down?	/			It takes about 5-10 minutes, which is quite a short time considering the fact that a drive usually takes that amount of time.
Is the wind of acceptable temperature? (18-23 degrees Celsius)	/			Yes, because it is about as cool as an air-conditioner without using as much energy.

Is the jacket lighter than other cooling jackets? (around 2kg)	/			Yes, as it is less than 1 kg.

Table 5.4

Appendix A

Our first prototype was a rough idea of our big plan. Please refer to Figure 4.1 for our sketch. We used cardboard to form a box by the means of duct tape. This box contains the fan and the motor (Figure 4.2). The battery is secured to the side of the box, also by duct tape (Figure 4.3). On top of the box, we created a hole, stuck the straw and secured it using duct tape too. Finally, we used a glue gun and glued the whole box onto the shirt. (Figure 4.4) The cardboard and duct tape were chosen because the components of our prototype were quite light anyway and because of their versatility. Cardboard and duct tape were also easy to obtain. However, sticking the box onto the shirt using duct tape is impossible as the box is too heavy so we used a glue gun instead. When we did the prototype, we had not found suitable tubes to use for prototyping yet so we made do with an inflexible straw.

Although enough wind can be felt at the end of the straw, not enough wind can be felt when wearing the shirt, there is an unbearable vibration and it is awkward wearing the shirt. Hence, we decided that we had to replace the unbearable straw with flexible plastic tubes to circulate the air around the body. Also, we planned to find a better motor so that the fan will be more silent and will not vibrate too much. Finally, we wanted to decrease the size of the box, possibly by using a computer fan.

Appendix B

This prototype was more of a proof of concept as we wanted to see if our ice packs are able to quickly cool down the tubes and for a long period of time.

Box:

We chose a small metallic KitKat box to be our central cooling system. We added ice packs in order to cool down the air. To minimise unnecessary heat gained from the surroundings to inside the box, we also added a layer of styrofoam around the box as styrofoam is both insulating and lightweight. As you can see from Figures 4.5 and 4.6, we also used copper tubes for certain sections of the prototype because of copper's conductivity so that we can place the ice packs on the copper tubes so heat is transferred from the air inside the tube through the copper to the ice packs quickly. However, the fact that the system we are trying to build should be small and compact, and the fact that copper is not flexible just do not agree with each other, because we cannot bend copper such that it can squeeze inside a small box. Hence, we decided to use rubber tubes to connect the copper tubes together as rubber is flexible. Finally, two plastic tubes were glue-gunned to the sides of the box and are supposed to lead air towards the body.

Fan:

The fan we used in Prototype 1 was quite weak so we got a 12-volt computer fan instead which we believed would be stronger and enable our system to work. However, although the computer fan was stronger than our Prototype 1 fan, the design of computer fan does not allow air to blow through tubings; in fact, Prototype 1 fan exerts more pressure than the computer fan and will be more suitable to be used.

The Kit-Kat tin can was chosen really out of convenience but on hindsight, may not be suitable due to its heavier mass, and good conductivity. Metals are in general good conductor of heat but what we need should be a good insulator to ensure that the ice packs can remain frozen for as long a period as possible. A box made of plastics, being lighter and of poor heat conductivity, would have been better.

Moreover, we have been using commercial ice packs to build our prototypes. Perhaps, we should compare the freezing temperature and time to melt of such ice packs compared with saturated salt or sugar solutions.

However, after some research, we thought that using the salt and sugar solutions may not be a very practical solution. Due to the impurities in the saturated solution, the freezing point would be lower than water, and possibly lower than the ice packs. This would pose a few problems for our use. Firstly, the increased freezing point would result in the freezing of the solution taking longer in the freezer, and depending on the concentration, our freezers may not even be able to freeze it completely if the solution is saturated. Secondly, the increased freezing point would mean that the ice would melt faster at the same temperature, as compared the ice packs. This would result in the frozen solution being only able to cool the air for a short period of time, but cool it to a lower temperature during this period. This would not be as good as using the ice packs, since our product is mainly for long usage.

Appendix C

Our third prototype was completed after we analysed our mistakes in the first two prototypes and found solutions to address the issues.

The two pairs of boxes:

For the boxes' material, we went back to using cardboard for its simplexity and that it is easy to cut, piece together and make something out of it. Because of this, it is also highly customisable and relatively light. However, cardboard may not necessarily be the best material to make the boxes. This is because cardboard is not waterproof. Water which have condensed on the ice packs may seep through the cardboard, causing damage. Therefore, we used a method which would be elaborated below to waterproof the boxes.

In each pair of boxes, one box contains the fan while the other box, which is on top of the first box, contains the ice packs. Each box can be opened and closed via the means of velcro. (Figure 4.7 and 4.8)

The boxes containing fans:

In these boxes, there is a fan which was specially selected for its unique blades. There is also a battery holder below the fan which contains 2 1.5-volt batteries. The battery holder also has a switch on it so that the user can switch on and off the fan whenever he likes. Finally, there are copper tubes which transport air upwards to the second box containing the ice packs.

The boxes containing the ice packs:

In these boxes, there are two copper tubes which lead from the bottom to the top of the box. We chose this specific material as copper is a very conductive metal, which allows heat from the air in the copper tubes to be transferred quickly to the ice packs, which should be placed inside this box. To minimise heat entering the box and causing the ice packs to lose heat quickly, we completely covered the inner layer of the box with material cut out from an insulating bag. Also, we added a layer of wax paper which was sealed tight to the cardboard in order to waterproof the cardboard.

The rubber tubes:

We connected rubber tubes to the ends of the copper tubes that we used in the boxes containing the ice packs. As these rubber tubes are the ones that circulate air around the body, we decided to use rubber because of its flexibility. As it can be told from Figure 4.9, the whole system of rubber tubes are covered with black cloth, which are then sewed onto the jacket, so that the black cloth camouflages with the almost-black jacket and the jacket looks more aesthetically pleasing. These rubber tubes then branch out to the neck, head, and armpit so that the wind from the fan will be transported to those areas as based on our research, those are the sweatiest areas.

From the previous prototypes, we realised the the fans did not provide sufficient pressure to circulate the air around. As the tubes are supposed to lead to all parts of the body and we had not found a fan suitable for our needs, we decided to use two fans instead- one for each side of the body.

Appendix D

This final product was an improvement based on the increasing the amount of wind felt because the previous prototype had an imbalance of wind. This prototype is also more sturdy and less likely to wear out after a few times of use.

Improvements we made:

1) The tubes were repositioned for more wind felt

After testing our third prototype, we found out that no wind was felt when wearing the jacket. Hence, in this prototype, we shifted the tubes closer to the fan, and at a better angle, so the wearer will be able to feel wind, which is the main purpose of our invention. Also, our prototype previously had 2 of the tubes leading towards the back and 2 towards the neck, but after listening to advice from our mentors, all four tubes all lead towards the neck now, so that the neck and receive maximum wind.

2) The boxes are reinforced with wood

The previous prototype was made with cardboard, which is very flimsy and could be destroyed or malfunction after days of use. Therefore, we Initially wanted to use wood to construct the box, but because of the wood's inflexibility, we decided against it. Instead, we decided to use wood to help to reinforce the cardboard in this prototype. Now, the boxes are more sturdy, and would not break even if we dropped it. Moreover, according to tests that we did, wood slows down the melting of the ice packs. This would help the ice packs last longer than previously.

Appendix E

We gathered some user feedback by interviewing some of classmates and classmates. People generally liked the idea of this jacket because this jacket could provide some respite to those who have been walking in the hot and humid weather. However, some of them also felt that the jacket was slightly bulky and bulging. Below is an interview between a group member and his father.

Jun Yu: How useful do you think this jacket is?

Father: This jacket is quite useful...yah, because Singapore is indeed very hot. In fact, I'm quite impressed to see this product can cool down the air down to 18 degrees Celsius, in maybe 10, 15 minutes? It actually works, but maybe the wind speed can be improved, but for now it's not bad. <u>And it looks a slight bit ugly from the outside.</u> But at least it's quite light.

Jun Yu: How much are you willing to pay for this jacket?

Father: Well, this is quite an interesting concept, it uses something similar to the the water heater system, so hm… er… maybe $60, $70. It may not seem worth it but if you are exposed to real equipment, maybe the product will be way better than this.

Jun Yu: Thanks for the feedback!

As you can tell from this conversation, Jun Yu's father was concerned about the aesthetics of the jacket as he commented about the jacket's small bulge. This issue was also raised by our classmates. This is one of the problems that we have been unable to solve thus far.