1.0 INTRODUCTION

1.1 Background Information

St. Peter's residence at Chedoke is a long-term care facility located on Hamilton's west mountain that provides long term care for over 200 residents with a wide variety of disabilities. St. Peter's (the client) has tasked the first-year engineering students of McMaster University with finding a solution to several common problems encountered by the wheelchair bound residents. This includes navigating doors, doing laundry, and dining with other residents which is the challenge our group decided to undertake.

1.1.1 Situation at Dining Table

Due to the wide range of heights of the clients that are currently using wheelchairs, along with the large variety of wheelchairs that are used throughout the residence, there are some clients that are not able to slide their wheelchair underneath the dining table and others for which the table is too tall. Although the table at the residence is adjustable, there is room for 4 people at the table which still may result in a height difference, as the height of the table itself may not suit all the clients at the table. When the table is not meeting the client's height standard, this results in trouble when dining in as they cannot reach the table and therefore, cannot reach their food with ease. This difficulty when eating complicates their ability to remain independent and does not make the experience pleasurable or simple as one would like it to be. Due to this, the help of the St. Peter's residence staff is required which prevents the staff from doing work in other sectors such as serving the food, or cleaning up the tables. When the residents are not close together by the table, they find difficulty in enjoying the social gathering while communicating and spending time with each other. Therefore, clients are not able to socialize and eat independently, which takes away the 'home' feeling that many of the people hope to achieve at the St. Peter's residence.

The main problem with the situation at the dining table is the fact that the clients are not able to slide their wheelchairs underneath the table due to interference between the wheelchair arms and their legs. Even if it is possible, they may not be able to eat in a comfortable position due to the height of the table being either too low or too high. The height problem further branches out to the problems that the clients are not able to eat independently and are not able to socialize with other residents on the table. Therefore, developing a device that can adjust the vertical height of the table would assist the clients by allowing them to eat independently which would help them feel more at home as the St. Peter's residence aims to achieve.

1.2 Refined Problem Statement

The St. Peter's residents have diverse physical disabilities, which require a variety of wheelchairs of different heights. Due to the current tables at St. Peter's being only adjustable uniformly, residents with different height requirements are unable to eat together. This limits residents from dining-in comfortably, in addition to being able socialize with other residents at the dining table. To allow residents to dine with ease and comfort, the representatives of St. Peter's at Chedoke want us to design a device that will enable residents of diverse table height requirements to eat independently while staying close together during their meals.

1.3 Objectives and Constraints

The main objectives for the project design include comfort, safety, cost-effective, and adjustable. First of all, simplicity is important and considered at every step of the project design, as the users must feel comfortable when using the product. Due to the client's physical limitations, a complex design with many adjustments to be made by the user themselves would be ineffective, and potentially may not be ideal considering the user's capability with the device. Therefore, to make the device as comfortable as possible, the weight and durability of the product is crucial. The product must be lightweight which can be achieved through the choice of materials, as this would cause less stress and effort to be done by the user to move the product, such as moving the tray or even moving the device as a whole. In addition, any adjusting portions of the product must be made efficient and user-friendly, which can be done by using knobs that are as wide as the average palm, as finger dexterity will not be needed to adjust the device as many clients may not be able to form grip with their fingers on the knob. Another sub-objective is to make the device stress-bearing, meaning that the product must be able to withstand a large force, such as a person leaning on the device or applying a downward force with their hands. This will further make the product more reliable and durable, with no margin for error within the device when providing the comfort that the residents of St. Peter's seek to achieve.

Secondly, the device must meet all safety protocol and have no potential for any danger or harm to arise. Choosing materials that are of high quality of construction and are also durable will increase the duration of the products life. In addition, avoiding any sharp edges is important as it can be dangerous to the users. If any sharp edges do arise within the design process, a rubber lining can be used to cover the sharp edges. Ensuring the safety of the user further supports the fact that the product is reliable and durable, and can be used within the St. Peter's residence,

Thirdly, the cost of the product must be kept under a certain budget in order for the product to be cost-effective. This can be done by purchasing cheap materials that still have the same good quality and construction. This will also make it easier to replace any materials that do not function overtime due to damage or other potential causes. Making the product cost-effective is also directly linked to having a simple and concise project design. The more simple and achievable the design is, the cheaper the overall cost of the project will be. Therefore, using cheap and durable materials while keeping the product simple will together help to achieve a cost-effective design.

Lastly, the objective of having the product to be adjustable is important as this is the main function that the product must perform in order to solve the problem with the 'ladies at table two'. The vertical adjustability of the device can be achieved by a wide variety of materials, although using the most durable and cheap materials is ideal. The adjustability will usually require the device to have arms and a joint or pivot point, therefore ensuring that the joint allows the arms to efficiently move with no interference or problem is crucial throughout the construction of the device. To conclude, achieving these four objectives in the designing process will result in a successful and effective product.

1.4 Prior Art

1.4.1 Commercial Products

There are two main types of existing commercial products that perform the primary function of making dining accessible to wheelchair users. The first main type as described in [1], [4], [6], and [16] are devices that attach to a wheelchair either permanently as in [4], [6], and [16] or temporarily as in [1].

These devices take the form of a small table that rests in front of the wheelchair and is either removable or can fold to the side of the wheelchair. These devices serve the basic function of providing a platform for users to place their food and utensils and perform a number of secondary functions some of which have a negative impact on the users. By creating individual tables, they remove the social connection that is experienced by sharing a table. Another negative secondary function of the permanently attached wheelchair tables as in [4], [6], and [16] is that they add to the width of the wheelchair when folded to the side this may restrict the accessibility of the wheelchair in narrow doors and hallways that they might have negotiated easily otherwise. The removable table as in [1] has its own difficulties in that to be useful it must be transported with the user to the location where it is to be used. Also, large scale implementation of such devices is difficult because of the diversity of wheelchairs and these devices must be customized to each type and size of wheelchair. Due to the concerns addressed above, the design of a portable table permanently or temporarily attached to a wheelchair such as described in [1], [3], [6], and [16] is not an ideal model to base designs for satisfying the needs of "the ladies at table two".

The other main type of commercial product that performs the previously stated function are devices that attach to table tops as in [12] and [17] or are built into tables as in [9]. These devices extend outward and upward or downward from the table to provide a platform that can either slid over the top or fit between a wheelchair's armrests. They have positive secondary functions of encouraging users to eat at tables in community with people as well as enlarging table size allowing more space for other use. These products don't have the negative effects of limiting mobility that the attached tables do. They are also more applicable to large-scale implementation because tables tops are far less diverse than wheelchairs and attachable extension could be easily adjustable to fit the vast majority of table tops. Yet another advantage of this type of product is that it doesn't have to be transported with wheelchairs users, but can instead be stored in dining areas in the case of attached products such as in [12] and [17], or inside the table as in product such as that described in [9]. Due to these benefits, these designs may be helpful in satisfying the needs of "the ladies at table two".

1.4.2 Patents

Being confined to a wheelchair, be it as a result of old age or a tragic incident, can have a tremendous psychological impact stemming from the loss of independence and the innate difficulty in living in a world not designed for the physically handicapped. There has thankfully been a push in recent history to correct this oversight and create an environment that is accommodating of all levels of physical ability. This has, for the most part, been undertaken by private companies which design and create innovative yet often simple solutions to ease the lives of people in need.

The challenge which our group chose to undertake is titled ‘The ladies at table 2’ whose problem statement defines the need for a solution to the issue of loss of comfort and independence when seated around a four-person table of fixed and uniform height with a varied group of people seated in manual and electric wheelchairs, and chairs. A simple and reliable answer to the incompatibility of tables and wheelchairs is the wheelchair tray [14]. This patent describes a solid tray that is mounted to a wheelchair on a pivoting arm. When in use, it lays flat across the hand rests. When it is no longer needed, it can be pivoted to a vertical position and rotated downwards to rest unobtrusively at the side of the wheelchair. This is a clever design which would give both manual and electric wheelchairs bound residents the luxury of a private, portable table and allow any number of people to dine together. However, this design does not work well with tables and is not usable by people not in wheelchairs, rendering it incompatible with our constraints.

The most promising solution comes from a surprising source. Due impart to a number of studies published on the detrimental effects that prolonged sitting can have to human health, there has been a recent rise in the popularity of standing desks. The majority of these new desks are not simply tall tables, instead they are precise machines whose height can be finely adjusted, often at just the push of a button. There are three main types of mechanisms responsible for the adjustments. The simplest and cheapest is a geared crank that, when turned by the user, unscrews a long screw attached to the tabletop from its mount in the base, effectively raising the table [11]. This design is low maintenance and requires no external power source, unfortunately it may prove to be too strenuous for an elderly person to operate. A more ergonomic yet very similar design is presented by Hans Petterson who opted to replace the manual crank for an electric motor controlled by two buttons [3]. Nevertheless, this design also has some issues. It is heavier than the manual table and more prone to malfunction, and it must be plugged into a wall outlet to be operational. There is however another design that has the best of both worlds, and that is a pneumatic adjustable table. It requires no external power, yet because the piston is balanced to support the weight of the tabletop, it requires very little effort to adjust [21].

Although these are all single user tables, the various lifting technologies behind them will be key elements in our design for a better solution.

1.4.3 Injuries/Disabilities

Majority of the residents at St. Peters are affected by some sort of injury or disability. About 84% of the residents are dependent on care staff related to long term care, with dementia being the most prevalent diagnosis of long term care residents. Dementia is not a specific disease, rather it is a general term that describes a reduction in mental ability to the severe extent of affecting one's day-to-day lives [5]. Although dementia is very common throughout the residence, many people are also affected by physical disabilities, which results in a limitation of them to use their body. Examples of this include limitations in free-roaming, transportation, and accessibility. The physical disabilities of residents are the major problem affecting the "ladies at table two." Physical disabilities can be caused by disorders or by permanent injuries of various sorts. Some examples of disorders include spinal disorder and myotonic disorder (muscular dystrophy). Injuries can include severe brain injury or other permanent injuries that can cause paralysation and result in a physical limitation [23]. There are also causes where mental illnesses such as dementia cause various physical symptoms, known as somatoform disorders [20]. This can result in symptoms such as muscular weakness, paralysis, and pain in specific areas such as spine, legs, joints, etc. There has also been an increase in long term care residents with diagnosis or co-morbidity, causing complex continuing care changes.

All these causes of physical disabilities result in several residents at St. Peters to be confined to wheelchairs. Due to the large diversity of residents in addition to the various types of wheelchairs, every resident needs their own specific height adjustment at the dining table, although the table is only capable of moving as a whole or uniformly and not individually for one person. Many residents are not able to slide their wheelchair under the table, which can cause difficulty when eating independently, in addition to conversing with other people at the table due to being an increased distance away from the table [18]. To avoid or prevent these limitations, a product or device must be produced that is capable of individually adjusting the height of the table for every user to their own specific need. This will allow residents of varying heights of wheelchairs to be able to comfortably sit at the dining table with both ease and convenience. The device must be able to lock-in to several positions, and must be adjustable and easy to use for all people at the residence. Other factors that might be considered in the production of the device include durability, reliability, lightweight, cost-effectiveness, stress-bearing, safety, and easy-to-use or user friendliness [3]. In conclusion, the device must cater to the users needs with the objective of finding a solution to the user's problem, in this case being the "ladies at table two", or the dining table problem.

1.4.4 Materials

Pneumatic cylinder/gas lift bar: Pneumatic cylinders, also known as air cylinders are mechanical devices which are used to produce force combined with linear, usually powered by high pressure compressed air or gas [19]. It might be useful to address the problem because our objective is to make the table adjustable and Pneumatic cylinders are widely used in adjustable chairs. Since its force is produced by air, which is harmless. Also, cushioned cylinders are single-acting cylinders with a built-in shock absorber [10], which makes it more comfortable and safe to use. However, it might somehow costly.

Electric Adjustable leg: Adjustable legs are also widely used to adjust Ergonomic Table. And compared with the Pneumatic cylinder, it can be used electrically, which means it is easier to use maybe just by pressing a button. It is convenient but it is also costly.

Spring: Its elasticity can help to change the height of the table or, maybe the height of a device that could adjust the height of the wheelchair. It will be a good resource because it won't cost much money.

Rubber: It can produce a good friction that helps to stabilize our structure by putting it to the table legs. And it is tenable to get a rubber sleeve for a table or device.

Linen: It also can produce good friction to stabilize the device by wrapping up the object. And it is not expensive and it is easy to get.

Pine (Wood): Wood is strong enough to hold things but also not very heavy, if the device needs to be carried anywhere, it is better than some metal materials, which is widely used to make a table top. Even though Pine is not very strong, compared to other woods (such maple, chestnut), Pine has a uniform texture and is very easy to work with. It finishes well and resists shrinkage, swelling and warping despite having a wide grain [15].

Plywood: It is cheap, easy to get and it is easy to work with, but they are not as sturdy as hardwood [8].

PVC and uPVC Plastics top: They are Stiff, hard, tough lightweight plastic. uPVC is stabilized for outside use and is used for plastic windows and plastic pipes [22]. It is even easier to carry than wood.

Stainless steel vs. carbon steel: Stainless steels are generally more expensive than carbon steels. This is due mostly to the addition of a variety of alloying elements in stainless steel, including chromium, nickel, manganese, and others [13]. In this case, carbon steel will be a better choice for us, because it is a table used indoors and it is just used to support the table, will not exposure to some corrosive conditions.

Hinges: The height of the table can be changed by using a hinge to allow changing angle between two objects. Also, it can make the table foldable, which makes the shape more flexible.

2.0 CONCEPTUAL DESIGN

2.1 Brainstorming

At first when our team started brainstorming, to gather ideas of the objectives and potential methods of meeting the objectives, a morphological chart was created that clearly outlined the objectives and functions of the project. Afterwards, the 6-3-5 method was used to get a deeper understanding and potential outlook on the design of the product itself. This method consisted of each group member to create a brief design idea that formed a solution for the objectives that were gathered in the morphological chart. The ideas were passed throughout the group, with each member adding comments to further improve all of the different design ideas. From here, the design ideas were gathered and as a group, a final design idea was formed that met all the objectives on the morphological chart and the comments offered by every group member to the best of our ability.

Some of the main objectives that were on the morphological chart include adjustability, safety, and storability. First of all, adjustability is the main objective of the function as the height of the table is what needs to be adjusted based on the user's height. The functions that can help achieve this objective include containing pivot points or joints that can move within a certain angle range, allowing the device to be adjusted accordingly. Some of the ways that a pivot point or joint can be constructed include having two arms screwed and bolted, having a gear-mechanism, or having adjustable knobs at the pivot points which the user can adjust to their preference. Secondly, safety is another objective that should be considered throughout the design process. Although there isn't a specific function to achieve safety, using strong and durable materials with no sharp edges is crucial in having a safe device. Using rubber lining or protection on any possible sharp edges also eliminates the potential of any danger or harm to arise to the user. Lastly, storability is an objective that is a huge advantage to the design. Although the tables can be permanently altered at the residence, it is not the ideal solution. Therefore, having a device that does not take a significant amount of space of the dining table is ideal can be easily transported from one table to another, and is easily attachable or detachable will serve as a huge advantage by the staff at St. Peter's. There are several methods of making this happen, such as using clamps, knobs, hooks, or other sources of materials that can be both attached and removed from the table surface. Therefore, the design ideas created in the 6-3-5 method focused on meeting these objectives in order to have a reliable and functional device.

Throughout the brainstorming process, several well thought out ideas were brought to the table, although it was hard to compile the ideas into one design as the ideas were very diverse and different amongst one another. Therefore, there was more than one final design idea created and from here, the pros and cons of both were listed which served as a pathway to the final design. Metrics were used in order to rate the two separate design ideas based on the objectives in the morphological chart and the objective tree and constraints found in Figure 3 Appendix D.

2.2 Design Alternatives

2.2.1 Preliminary Alternative

During tutorial 7, our group had come up with two design alternatives to address the problem of the 'ladies at table two'. The first design alternative consisted of a gear mechanism that allowed the table to be adjusted vertically, found in Figure 1 Appendix D. The table would be separated into two main parts, the tabletop that can be adjusted accordingly and the base that is stationary. The table top contains a main drive gear, which rides on the vertical gear that is aligned on one side of the table. The gearing system includes metal rods or beams and a crank, which is connected to a spring-loaded locking mechanism which locks the tabletop at the desired height. The user spins the crank which is attached to a long metal rod topped by a gear which is connected to a second rod topped with another gear. The horizontal rotation is transferred to a vertical rotation by the second gear. This gear rides on the vertical gear within the base of the table to lift or lower the table surface. The table is locked to a certain height using the spring-loaded mechanism that blocks the main gear from rotating. This can be released by depressing a small lever by the crank, which is connected with the metal bicycle wire that runs inside the table base, and is wrapped around a pulley which is located alongside the gear in the frame of the base of the table.

The second potential design alternative consisted of an adjustable tray found in Figure 2 Appendix D that can be easily adjusted by the user to their preferred height. This design consists of two lock-on clamps that are located on the far edges of the table. These clamps are strongly grasped to the edge of the table and are not adjustable or to be disconnected when the device is in use. These clamps on the edge of the table are attached to metal beams (two on each of the two clamps) that extend outward and are attached to the adjustable clamps located at the pivot points of the device, which is further attached to the adjustable tray itself. This allows for the height and position of the tray to be adjusted both vertically and horizontally based on the metal beams and clamps. In addition, to make the design more durable, the tray is reinforced with stronger material to ensure that the tray does not easily move or adjust while eating. Also, screws and bolts are used to attach the adjustable clamps to the metal beams and headers that strengthen the design and allow it to withstand a larger force or weight upon the tray.

2.2.2 Secondary Alternative

In tutorial 8, our group had narrowed the design to focus on the second preliminary design alternative consisting of the adjustable tray as found in Figure 1 Appendix B. When checking the efficiency of the design alternatives using metrics, it was very evident that the adjustable tray is the more ideal solution. The gear mechanism is not only very hard to construct, it is also more costly, complex, and has more room for error, which contradicts the objectives of making the design cost-effective, and as simple as possible. The simpler the design is to the user, the more efficient and safe the user of the product would feel with the device. In addition to this, the second design alternative of the adjustable tray can also be constructed to be portable, which is also beneficial to the staff of St. Peter's residence. This would allow for the device to be easily attachable and detachable from the table and can be stored away if need be. Therefore, based on the metric and evaluating system, the adjustable tray design alternative was proven to be the more ideal solution to the 'ladies at table two' problem.

The one major change that was made between the design alternative and the final design alternative is the way the pivot points or joints were to be constructed. Initially, adjustable clamps were to be implemented on the pivot points that are connected by two metal rods: one metal rod connecting the clamp to the table where the lock-on clamps were fixed, and the other metal rod connecting the adjustable clamp to the adjustable tray. This was both difficult to do and was not realistic to be used as a pivot point, therefore our group decided to simple use bolts and screws two connect the two metal rods together forming a final pivot point or joint for the system. This is not only cheap, simple and durable, but also works very efficiently in moving the arms of the device both up and down, allowing the tray to be adjusted accordingly as well. To make the device portable, using lever clamps seemed to be the most realistic solution, as they are easily attachable and detachable and can be done by both the staff and the user themselves depending on their physical disability. The metal rods would be screwed to both the lever clamps and the adjustable tray. Not only are screws and bolts durable, but they are also cheap which met both the objectives of having a durable device that also is easy and comfortable to use for the user.

2.3 Design Evaluation

As said before, metrics was an important aspect throughout the conceptual design that helped our group develop a final design alternative. These metrics were used to evaluate how well each of the objectives functioned, as shown in Figure 4 Appendix D. Initially, the metric system used had a different scale for each of the objectives, but afterwards, our group decided to use a common scale of 1-10 for all the objectives evaluated. The stress-bearing of the object was especially important, as keeping the device strong enough to withstand any force is crucial in developing a reliable device. Supporting up to a 100kg is considered a 10, while the device not being able to support any weight was considered a 0. Another important objective is the cost-effectiveness, as our group decided to stay under a $100 overall budget. Therefore, a 10 would be spending no money at all, while spending approximately $200 would be considered a 0. Lastly, a crucial objective was the adjustability of the device, as the adjustability is the main function and the main purpose of the device itself. A 0 was considered to be if the device was not adjustable, while an adjustment of 40cm together in the upward and downward direction from the table surface would be considered a 10. Although some objectives can potentially be more important than others, our group strived to achieve all objectives listed in the metrics chart and objectives tree in both Figure 3 and 4 on Appendix D to the best ability.

3.0 FINAL DESIGN

3.1 Description

E-Tray is an extendable/adjustable tray device that acts as an assistance for the residents at St. Peter's that are confined to wheelchairs. The device consists of a tray that is vertically adjustable depending on the user's height requirement. This allows for any resident with a physical disability to easily eat their food independently by using the tray rather than the table surface, as they can easily slide their wheelchair underneath the tray and have their food and drinks within their hand-span. The materials used in the construction of the E-Tray is of strong, durable, and optimal quality, while at the same time being cost-effective, safe and lightweight. The E-Tray is made of steel beams as the arms that are bolted together at the pivot points, which serves as a strong structure for holding the tray at any given height. In addition, the device can withstand a force of approximately 800 N, therefore a person leaning or even applying a downward force will not cause the device to break. To see an in-depth labelling of the device, please refer to Figure 5 in Appendix B.

3.2 Users

The users of our device include anyone at the St. Peter's residence that has a physical disability and is therefore confined to a wheelchair. Our device is very simple to use, with a simple knob being adjusted in the direction in which they need the table to move: either up or down. This allows the table to be adjusted according to their height and so their wheelchair can easily be slid underneath the tray of the device. The knob is the same width as an average palm, therefore making it more user-friendly and accessible for a variety of people at the residence.

In addition, the device can be taken off and stored by the staff at St. Peter's by simply loosening the clamps that hold the device on both sides. This is done by simply unhooking the lever that is holding the clamp in a locked position in order to unlock or unhook the clamp. This can serve useful on occasions in the residence where the table must be cleared, or if a client with no disability of sufficient height is sitting at the table and doesn't require the use of the E-Tray device. Allowing the device to be locked into place on any table rather than a permanent solution is more efficient for both the users and the St. Peter's staff. Altogether, the design of the E-tray is directed to making the experience of the St. Peter's residence more favorable and beneficial.

3.3 Construction

The materials that we used to build the final product were all available at stores like Home hardware or Home Depot. Our device consists of two clamps that are adjustable and will be grasped to the table, which were bought from Home Depot; A rubber lining is also placed along the clamp for further stability and so the whole device won't slip off the table. The clamps are attached to two adjustable arms. The arms are made of a standard alloy beam. The alloy beams are cut to a moderate length for avoiding interference when the residents using it. The arms consist of 3 joints, which are designed to withstand any vertical movement. The middle joints made of metal plates. Two holes were drilled on each metal plate to be used to connect the two components of the arm by screws. There are two adjustable arms connected to the left and right side of a lap desk. The sharp edge of the metal arm was sanded to be not harmful for the residents. To make it easy for the residents to use the device, there is a handle attached to the edge facing the resident.

The construction of our final design requires the use of a drill, cutter, screwdriver, hammer, and sandpaper. The construction of the device is not very complicated since it is a simple design, but it somehow has taken a long time, which is approximately () a weeks. The final product is a very convenient and feasible device for the residents because it is lightweight and strong. All the materials that were used to build the device cost less than 100 dollars

3.4 Safety

Safety is one of our priority objectives. It is very crucial to take it into consideration when design the product, in order to avoid any potential dangers during the use of the device. When our final device was being designed, and built, to reduce the amount of force requiring lifting the desktop is the most important objectives. By achieving it, we have chosen some relatively lighter materials. Also, for the material for the arms was carefully chosen. There were some square brackets which are much heavier. And those brackets have some big holes along the brackets. It is actually easier for construction since it has already ready for screwing. But we think that it has potential danger that it might trap the fingers of the residents. Therefore, we chose relatively lighter metal beams that have smaller holes.

3.5 Description of Prototype

The first prototype that we have is made of cardboard. It aimed to show the approximate structure and to seek some adjustment for the dimension, because the width of the table and the length of the adjustable arms are very significant factors. The arm length of the first prototype turned out too long and cause interference between the arms and the legs of the users when trying to sit in front of it. The second prototype was basically based on the first prototype. We changed the arm length after we tested the first prototype. The final prototype is basically made out as the shape of the second prototype. And during the construction, we found there are interference caused by the metal plate, for the reason that the size of the metal plate is too big, it effects the movement of the arms

3.6 Discussion of Feedback from Design Reviewers

The design review was done twice in total. For the first design review, our design was presented to the student in the IMPACT program. After we explaining the structure of our device and how to use it, the reviewer proposed a few suggestions. They said we should consider that the arm length would impact the stability of the whole device, because the arm length of out prototype seemed to be too long. And also, they suggested that the size of the desktop should be big enough for the resident to put their food. For the reason that sometime the resident wants to lean on the table while eating, so the bearing capacity of the device is very important. To decide how much weight, the device should be able to hold, they suggested us to actually lean on the desktop to see if it is strong enough. We also presented our design to group 5. They mentioned that a lot of weight and pressure is placed on the joints that are attached to the clamp, therefore the choice of materials is very important and must be sturdy or durable enough to withstand the weight and work efficiently from the user's viewpoint. For the second design review, we presented our modified prototype to the student in the IMPACT program and group 8. When modifying the prototype, we shortened the arm length, the biology students mentioned the locking mechanism very stable, and that would be nice to put labels for clarifying of use. Moreover, they also suggested that for the sake of safety, there were should be no sharp edge. The group 8 also gave some useful suggestion as well. They said that an indent within the desktop could serve helpful as the food or drink can be more stable and the balanced when adjusting the table. They talked about the locking mechanism as well. They said the joint locking mechanism needs to be lightweight and durable to support the person's weight on the device, and the material are also a big concern as due to the large variety of weight and styles, therefore it is crucial to find correct material for the arm.

4.0 CONCLUSION

Our final design is a convenient, feasible, customized product for the resident to have meals more independently without any help from the staff. Considering the safety, instead of focusing on adjust the height of the wheelchair itself, we want to change the height of the table. After discussing different design, we chose this final design, which maintains the budget constraint and time constraints, in the meantime, it achieved our objective to the highest level.

Before designing, we set up several metrics to evaluate the final prototype in a more intuitive and quantitative way. We also set up a scale to measure the level the final design reaches in term of objectives. The scale range from 0-10, distributed evenly for all metrics. "10" stands for highly meeting the objectives while "0" stands for least level of metrics or failing to achieve.

The first chosen objective is adjustable, because the problem that we need to solve is that the height of the table is not suitable for every wheelchair. A moderate arm length must be decided so the device not only can move vertically as high as possible and it won't interfere with the legs of the residents. According to the setting of the scale, 10 score is for the 40cm, 0 score for not adjustable at all. The final prototype can move approximately 56cm overall in both directions, which gets a score of 10.

The final product is not at a manufacturing level, due to the limited time, limited knowledge and skills, the limited source of machine and tools. And the cost of the product is crucial for the aspect of our client. Therefore, it is necessary to focus on the cost of building the prototype. The metric of the cost is range from score 10 (0dollars) to score 0 (200 dollars). The total cost of the final design is $54.28. which is a reasonable price for building an extension for a table, and the score is 7.3.

Another objective is lightweight. For the user who has disability of their hands which might cause that they cannot lift heavy things. Moreover, if the device is too heavy, it will be inconvenient for the staff to take it off. We set 250g is 9points, and 10kg is 0point. The final prototype weighs 8.5kg, which is 2 score.

The next metric is for stress-bearing. Because the whole device act as a table, so the device is supposed to support the meals stably. Furthermore, it should even support some weight of the user, because people tend to lean on the table while eating. So, we set 10 score for 100kg and 0 score for not supporting any weight. The final product can approximately support 80kg, which is 8 score.

The last metrics is about portability. The tables in St. Peter's residence seat around 4 persons. So, this device is supposed to take over around a quarter of one table. Actually, the device is an extension of the table, therefore taking up space from the table and possibly more space from the extension of the device. The surface area of the device is accounted for to determine how much space the product takes altogether. We set 0.1 square meter as a 10 score, and 1 square meter is 0 score. The surface area of the entire device is 0.49 square meters, and receives a score of 6.1.

As proven by the metrics, our device achieves a fairly high extent of our objectives, in other words, our final design is the great adjustable device for the residents to adjust the heights by themselves.

There are many constraints were set when we set up our objectives, which is that no toxic materials, cost of less than 100 dollars, and no sharp edges. We had to maintain these constraints within a certain time period; otherwise, the whole device will be not practical.

Any Toxic materials will do harm to the residents, the staffs and even the people who manufacture it. If toxic materials were used, the whole device will be helpless, useless and even illegal. To maintain this constraint, we paid attention to the ingredients of materials every time we purchase materials to make sure any toxic material is avoided.

The second constraint that was the cost is less than 100 dollars. We think it is important to have a low cost because the clients want to minimize the cost. It is not feasible for the client if the cost is too large. And the cost of our design requires $54.28 in materials, which is within the cost constraint.

The whole device should be no sharp edge is the final constraint. We considered that even only one sharp edge potentially cause danger to the residents, and the staffs. We tried our best to sand the edges as much as we could.

After compared our two design alternatives, we figured this is the best design, which is easy for the residents to use, and is cost-effective, safe and lightweight. Our device is durable and has extensive range, allowing for more flexibility of the usage of the device.

5.0 REFERENCES

[1] A. Albers, "LAP DEVICE FOR WHEELCHAIR PATIENTS", US 4,436,339, 1984.

[2] B. Omessi, "ADJUSTABLE TABLE EXTENSION", US 5,317,977, 1994.

[3] C.L Dym “Problem Definition: Clarifying the Objectives” in *ENG 1P03 Engineering Design,* USA: EPAC, 2016, Sec 4.2, pp. 117-129.

[4] C. Koppes, "WHEELCHAIR TABLE AND FOOD TRAY FOR HANDICAPPED PERSONS", US 4,364,699, 1982.

[5] “Dementia – Signs, Symptoms, Causes, Tests, Treatment, Care ...” [Online]. Available: http://www.alz.org/what-is-dementia.asp. [Accessed: 20-Oct-2016].

[6] F. Minati, "PORTABLE TABLE FOR A WHEELCHAIR", US 4,779,884, 1998.

[7] H. Petterson, “Height-adjustable table stand”. United States of America Patent US 20120126072 A1, 24 May 2012

[8] J. Clax. (2016, May 29). What is the Best Wood for Table Top29 [Online]. Available: http://thebasicwoodworking.com/best-wood-for-table-top/. [Accessed 20 October 2016].

[9] J. Rohde, "TABLE WITH IMPROVED WHEELCHAIR ACCESSIBILITY", US 6,648,430 B2, 2003.

[10] Machine Design. (2002, November 15). Introduction to pneumatic cylinders---ANSSION Pneumatic, ANSSION [Online]. Available: http://www.anssion.com/shownews.aspx?id=3. [Accessed 20 October 2016].

[11] M. Agee, “Height adjustable table”. United States of America Patent US 8256359 B1, 4 September 2012.

[12] M. Daniels, E. Drogin Rodgers and B. Wiggins, "“Travel Tales”: an interpretive analysis of constraints and negotiations to pleasure travel as experienced by persons with physical disabilities", Tourism Management, vol. 26, no. 6, pp. 919-930, 2005.

[13] Metal Supermarkets – Steel, Aluminum, Stainless, Hot-Rolled, Cold-Rolled, Alloy, Carbon, Galvanized, Brass, Bronze, Copper IP Inc. (2016, October 13). The Difference between Carbon and Stainless Steel [Online]. Available: https://www.metalsupermarkets.com/difference-between-carbon-stainless-steel/ [Accessed 20 October 2016].

[14] M. F. Lang, “Systems and methods for a wheelchair tray”. United States of America Patent US 7210735 B2, 1 May 2007.

[15] P. Cahill. (2016, February 20). Furniture Materials [Online]. Available: http://www.onlinedesignteacher.com/2016/02/furniture-materials.html. [Accessed 20 October 2016].

[16] P. Pasternak, "WHEELCHAIR ATTACHMENTS", US 7,500,689 B2, 2009.

[17] P. Tazzia, "DESK TOP EXTENSION DEVICE", US 5,248,192, 1993.

[18] R.B, Robert Fleisig, “Lecture 3: The Design Project”, *McMaster University*, Sept. 14, 2016

[19] S. B. Thapa. Pneumatic Cylinder – A Brief Introduction [Online]. Available: http://www.selfgrowth.com/articles/pneumatic-cylinder-a-brief-introduction. [Accessed 19 10 2016].

[20] “Somatization/Somatoform Disorders. Anxiety neurosis; info ...” [Online]. Available: http://patient.info/health/somatisationsomatoform-disorders. [Accessed: 20-Oct-2016].

[21] T. G. Dewees, “Pneumatic adjustable-height table”. United States of America Patent US 8210109 B1, 3 July 2012.

[22] The-warren.org. Plastics [Online]. Available: http://www.thewarren.org/GCSERevision/resistantmaterials/plastics.html. [Accessed 20 October 2016].

[23] “Types of Physical Disabilities - Executive Class Travel.” [Online]. Available: http://www.executiveclasstravelers.com/1/types-of-disabilities.htm. [Accessed: 20-Oct-2016].

APPENDIX A - Steps for Using Extendable Tray Device and Materials Required

Table 1: Bill of Cost of Materials

Product	**Location**	**Price**

APPENDIX B - Final Design Alternatives and Prototypes

Figure 1: Final Design Alternative

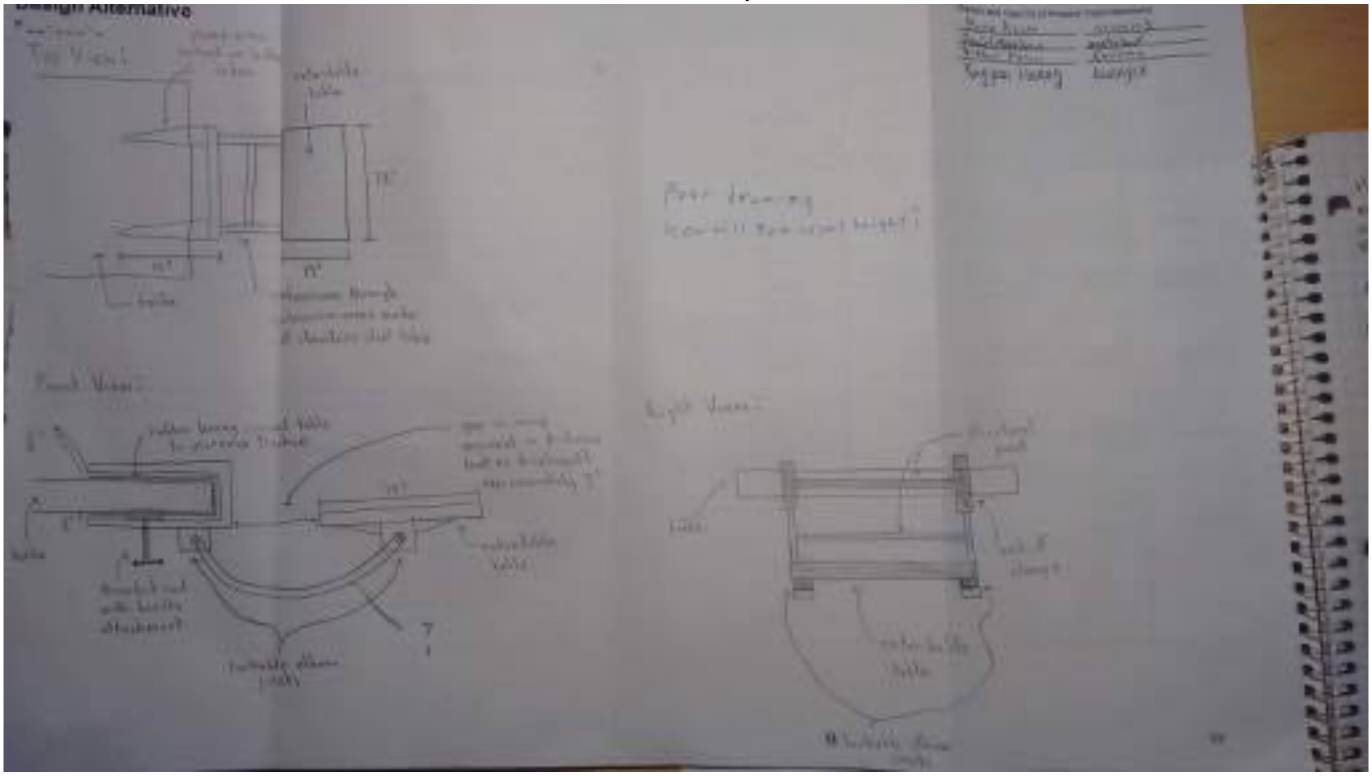

Figure 2: The First Prototype

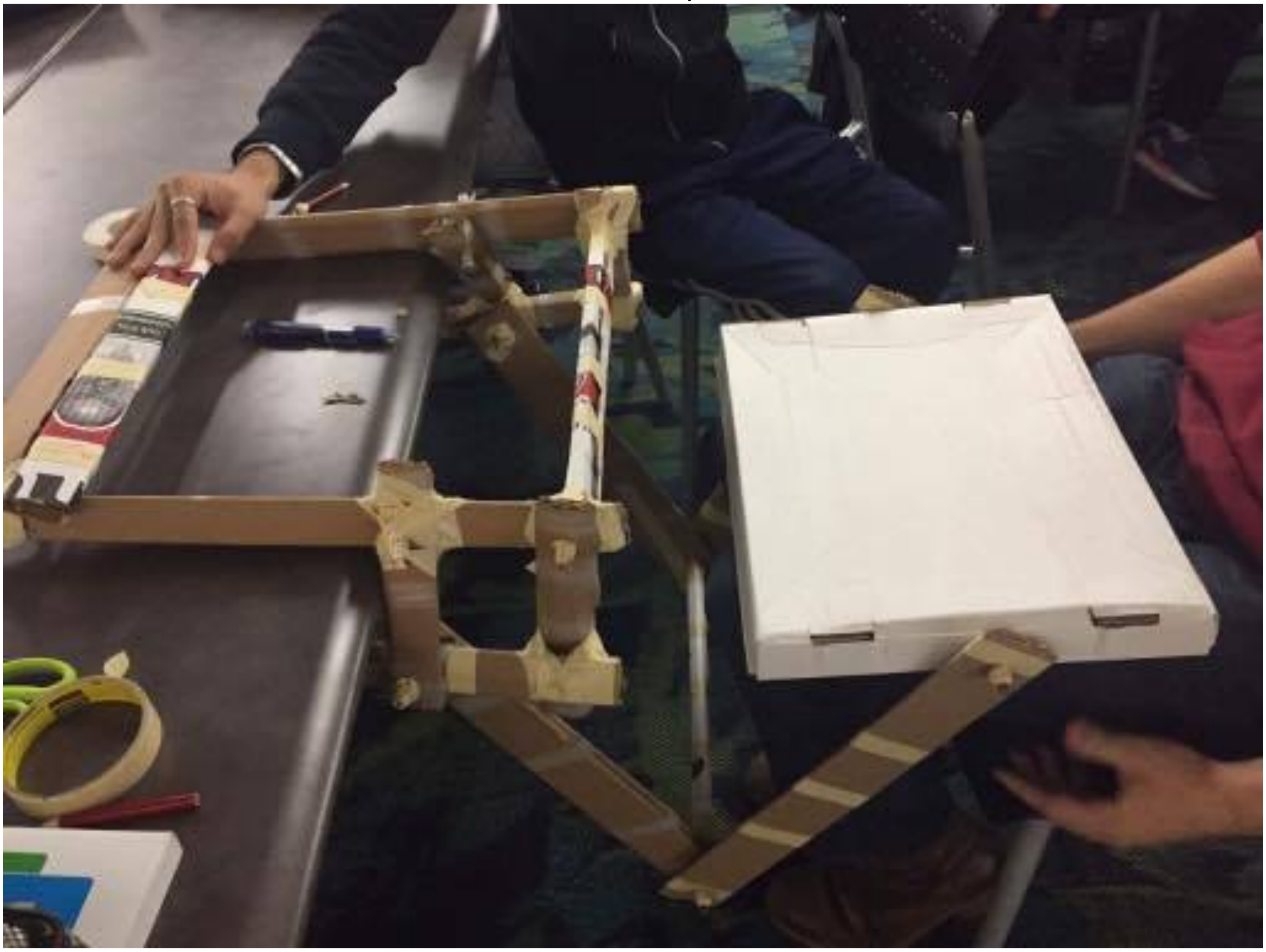

Figure 3: The Second Prototype

Figure 4: Labelled Final Design

APPENDIX C - Tutorial 10 Design Review Feedback

<u>Design Review with Expert</u>

<u>Reviewer: 1</u>

-stability of the arm
-shape of the tray and table itself
-the length of the clamp
-will the clamp be attached to the bottom or top of the table surface
-how will the locking mechanism of the device be ensured
-what materials will allow for a durable yet lightweight design
-safety, no sharp edges present

<u>Design Review with Peer Team</u>

Reviewer: Group #3

-where will the mounting point of the tray be, is it better to place it on the end of the table?
-how heavy is it going to be, and will the user be able to lift this weight
-a lot of the weight and pressure is placed on the joints that are attached to the clamp near the end of the table, therefore the choice of materials (type of clamp and rod/beam used) is very important and must be sturdy and durable enough to withstand the wright and work efficiently from the user's viewpoint.
-an indent within the tray could serve helpful for holding food or drinks while adjusting for balance.

APPENDIX D - Conceptual Designs

Figure 1: Initial Design Alternative 1

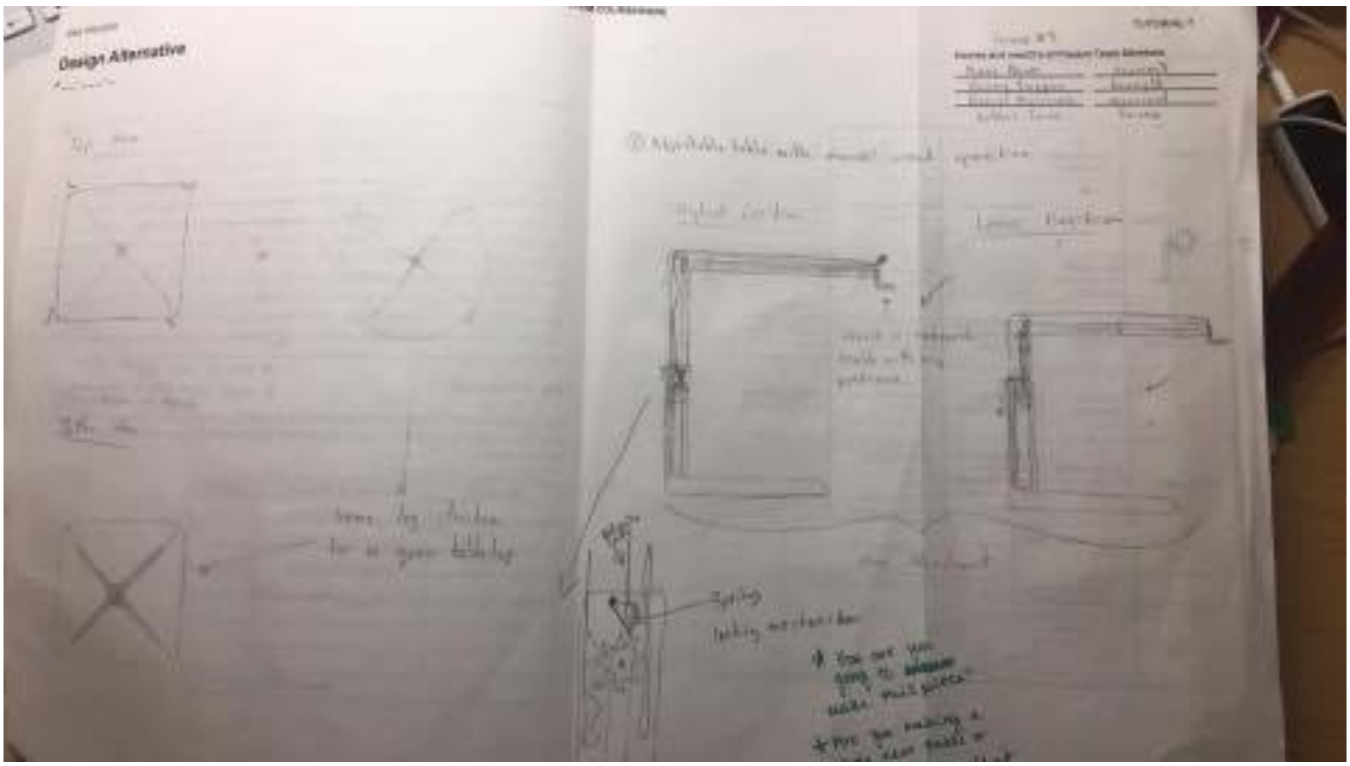

Figure 2: Initial Design Alternative 2

Extendable Tray Device

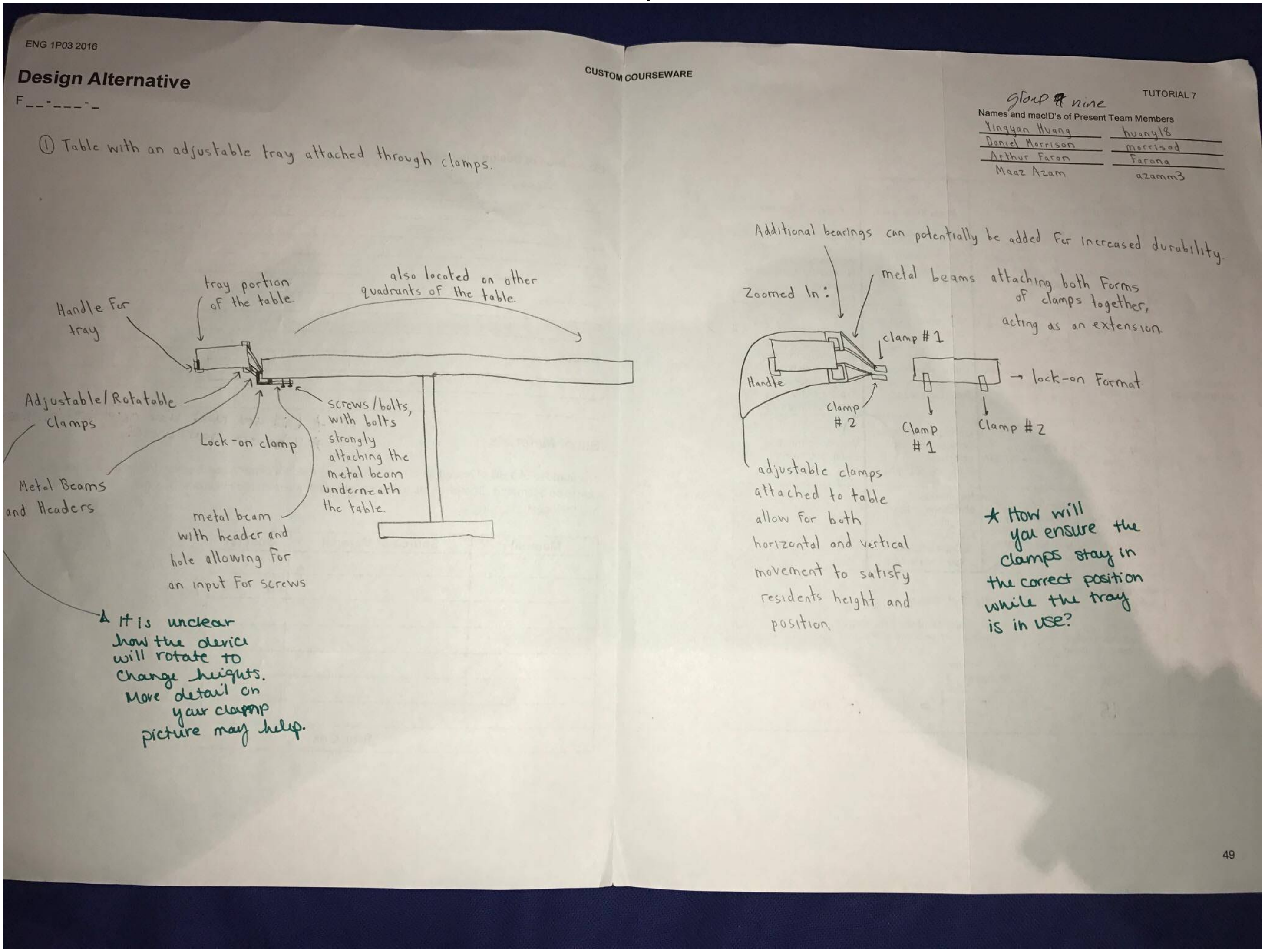

Figure 3: Initial Objective Tree and Metrics

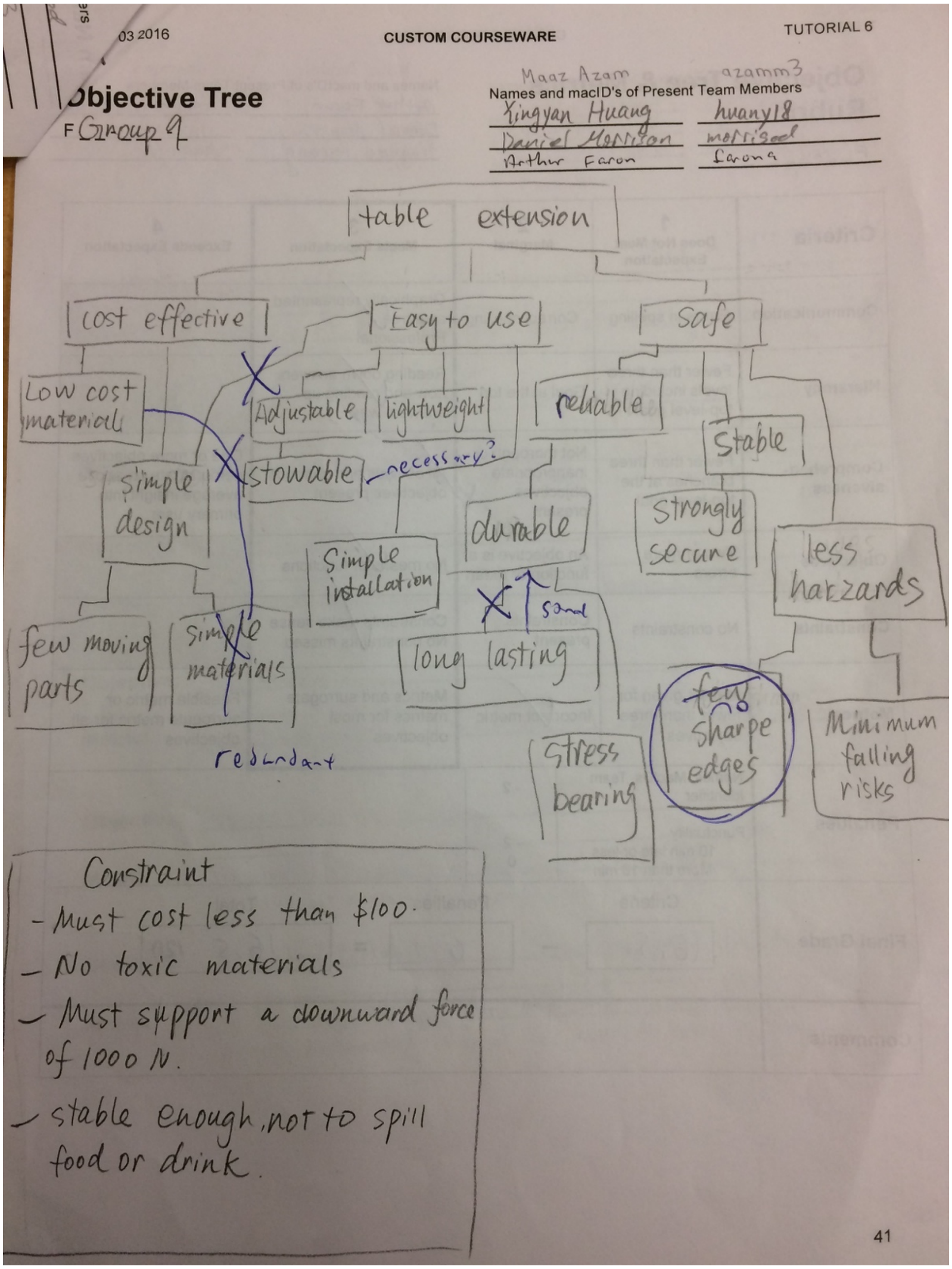

Figure 4: Metrics

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Metrics

F Group 9

Names and macID's of Present Team Members

Yingyan Huang	huany18
Arthur Faron	farona
Daniel Morrison	morrisod
Maaz Azam	azamm3

add middle points

Objective: Cost Effective

Metric: Measurement of money spent on materials (max = $200 = 0 points) min = $0 = 10 points

Objective: Durable — bad metric

Metric: Adequate Design with no drawbacks = 0 points
Weak, inadequate design with drawbacks = 12 points.

Objective: Lightweight

Metric: Very small weight (250 g) = 9 points, heavy (10kg) = 0 points.

Objective: Adjustable

Metric: adjustable height of ±40 cm = 10 points, not adjustable at all = 0 points

Objective: Stress-Bearing

Metric: Not capable of supporting any weight = 0 points
Can support a weight of up to 100 kg = 10 points

Objective: Storable / Portability — not a great metric

Metric: Takes up minimal space (no additional space taken from current table) = 8 poi
Nearly double the space of the current table is occupied = 0 points.

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