INTEGRATION OF HUMAN FACTORS INTO ENGINEERING DESIGN

by

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This work is dedicated first and foremost to my Lord and Saviour, Jesus Christ, without whose love, grace, and sacrifice I could not be here.

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Abstract

Usability has been shown to increase the success of design projects, but is routinely left out of the design process. Through an investigation into the history and value of usability, experiential design project, analyzing the target users of commercially available products, and a case study into a successful project by novice designers, it was found that a tool would be helpful for guiding students to include human factors. This tool is in the form of an app, and prompts the students to incorporate usability from their initial research and project requirement development to the implementation and testing of their design. This tool will allow both educators and students to practice human-centred design to increase the usability and desirability of their design projects.

List of Abbreviations Used

HFE	Human Factors and Ergonomics
ISO	International Standards Organization
UXPA	User Experience Professionals Association
UCD	User-Centred Design
HFES	Human Factors and Ergonomics Society
PEAR	People who do the task, Environment in which they work, Actions they perform, and Resources they require to complete the task
CEAB	Canadian Engineering Accreditation Board
DC	Discovery Centre
PISEC	Philadelphia/Camden Informal Science Education Collaborative
LED	Light Emitting Diode
IO	Input/Output
PWM	Pulse Width Modulation
UV	Ultraviolet
MEC	Mountain Equipment Co-op
ANOVA	Analysis of Variance
ABET	American Engineering Accreditation Boards
METS	Modular Egress Training Simulator
CEO	Chief Executive Officer
SUS	System Usability Survey

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Chapter 1 – Introduction

1.1. What is usability and Human factors?

Good design has been defined as intelligence made visible (Bayley & Conran, 2007). Usability can sometimes refer only to the definition of making something easier to use (International Organization for Standardization, 1998), which is considered to be a limited view. Defining usability is said to be similarly subjective as defining beauty (Bayley & Conran, 2007) (Soegaard, 2012), where the investigation into the field of what users desire reveals connection between professions and aspects of design previously thought to be unrelated. The effects of usability and the professions involved in advocating for usability in design are far reaching, and the comprehensive systems approach of human factors is almost unlimited in the contexts in which it could be applied (Dul, et al., 2012). Entire industries have come into existence to help users operate the systems with which they currently experience frustration or inefficiencies during interaction (Rubin, 1994). An example are training videos for confusing software or the service offered by many electronic stores to set up a new laptop.

The diversity of the multi-disciplinary base of human factors and ergonomics (HFE) has been viewed as both a strength, but also a potential weakness as there is no united front to present to the external world (Dul, et al., 2012). Professional associations whose members are involved in usability include the User Experience Professionals Association (UXPA) whose goals include becoming an authoritative source on usability, user-centred design (UCD), and user experience, as well as promoting the business value of user experience (User Experience Professionals Association, 2013). Others include the Human Factors and Ergonomics Society (HFES), founded in 1957, whose mission is to promote the investigation of characteristics of humans which pertain to the creation of systems and designs (Human Factors and Ergonomics

Society, 2016). Members of the HFES include psychologists, engineers, designers, and scientists with the common interest of creating usable systems and equipment (Human Factors and Ergonomics Society, 2016).

Human factors, ergonomics, human consideration, user-centred design, and usability are considered to be descriptive of the same field and the goal of making the interaction between humans and designs better (International Ergonomics Association, 2016). The terms will be used interchangeably within this thesis. By taking the user into consideration through the entire creation and design process, it ensures that humans stay central to the decisions being made.

1.2. History of Usability:

Vitruvius, a military and civil engineer in Rome in the first century BC, was one of the first to define the principles with which to govern design in order to make a successful project (Pollio, 1914). These three principles were firmitas, the strength and durability of the design, utilitas, a design's usefulness and suitability for the needs of its intended users, and venustas, the beauty and desirability of the design (Soegaard, 2012). Usability and the consideration of the human user are clearly seen in the aspects of usability and suitability as well as the beauty and desirability. Through the documentation of the human body aspect ratios and design principles, Vitruvius is one of the first recognized usability and ergonomic students (Soegaard, 2012).

Leonardo da Vinci was also an early student of human centred design in both the decorative realm of painting and sculpture but also through the functionality of projects including useful canals, a body of work that is a combination of both creativity and functional purpose (Bayley & Conran, 2007). By analyzing the work of da Vinci, we can see that he analyzed both the structure and function of the human body, considering both the abilities and safety of his users (Reti, 1969). He also seems to have recognized the need for a breadth of information as his

anthropometric data, the measurements of the human body, are given for multiple people (Panofsky, 1995).

Hand tools have also been under the influence of ergonomics, even if the word was not officially used until 1857 (Karwowski, 1991). The force and effort required by humans to crush, cut, smash, pierce, and slice were a limiting factor, leading to an increased demand for tools which would reduce the human effort required (Helander, 1997). However, many early tools and machines did not take into account the physical limitations of the operator and demanded that the user withstand uncomfortable or dangerous temperatures, materials, sound levels, and levels of exhaustion (Adams, 2012).

Decreased work week hours was shown in 1894 by Mather to increase productivity and decrease lost time (Mather, 1894). This finding did not lead to a scientific study in this area or an adoption of this principle in industry (Schilling, 1944). In 1909, Frank Gilbreth, an industrial engineer, published a study which decreased the necessary motions of bricklayers and increased the ergonomic considerations in bricklaying (Glbreth, 1909) (US Department of Transportation: Federal Aviation Administration, 2008). From 1910, Lilian and Frank Gilbreth also investigated how to reduce human error in medicine, through research into the increased efficiency and optimization of movements of both nurses and surgeons in the operating room (Baumgart & Neuhauser, 2009). There was also efforts by the Industrial Health Research Board in Britain, whose mandate in 1918 was to consider the relationship between working hours, environmental conditions, methods of work, and the effects of fatigue on efficiency and for the preservation of health among workers (Schilling, 1944).

Machine operators in the beginning of the 1900's were chosen for their personality characteristics, as this was thought to reduce their propensity to incur errors on the job (Helander,

1997). However, because accident proneness and personality features change due to time, environment, and level of expertise (Shaw & Sichel, 1971), the idea that an operator could be insulated from accident-causing activities through selection, classification, and training was abandoned after approximately 20 years (Helander, 1997).

Likewise, before the world wars, soldiers and pilots were selected based on their ability to fit with the cockpits of planes and tanks, whether they were ideally fitted to the machines or not (Soegaard, 2012) (Werby, 2010). After the Second World War, there was an increase of research into the human aspect of design as machines and weapons were optimized for soldiers and battlefields. Due to increased numbers of personnel required, it was no longer feasible to find users who fit the machine. This required that the design of machines and equipment take the physical size, cognitive limitations, and fatigue of the human users into consideration.

The early 1900's also saw the Orville brothers specifically focus on plane controls to decrease the work required by the pilots (US Department of Transportation: Federal Aviation Administration, 2008). Since the first Army airplane crash and subsequent fatality in 1908, errors in aviation have been especially pronounced due to the tragic outcomes resulting from failure (Dille & Morris, 1966). Many of these errors were designated as the fault of the pilots or aviation crew. 1947 saw a specific study done on the effect of control knob styles on human error (US Department of Transportation: Federal Aviation Administration, 2008) which moved beyond the idea that human error is the cause of the accidents to the idea that safety needs to be designed as human error is indicative of a poor design (Dekker, 2001). The two world wars and the particular focus on aviation helped shift towards the idea that consideration for humans could be built into the design, rather than requiring that human behaviour and anthropometrics be selected to fit with the machine.

One of the first books published in the specific area of human factors and ergonomics was "Applied experimental psychology: Human factors in engineering design" by Chapanis, Garner and Morgan in 1949. Their objective was to more fully define and develop an area of science which would be able to deal with the operation of machines by humans (Chapanis, Garner, & Morgan, 1949). McCormick, argued in 1969 that the human factors area is not a discipline that exists in isolation, but is an intersection of disciplines which have an interest in human implications regarding physical products or facilities (McCormick, 1969).

With the decreased price of electronics in the 1980's, computers became a commonly used tool, and many employees, not only those specifically interested trained in technical vocabulary and system architecture, now used personal computers (Soegaard, 2012) (Rubin, 1994). Early users were similar in characteristics with those who were developing the products, a hobby user who enjoyed tinkering and solving the problems they ran into within the systems, users who rarely complained about compatibility issues (Rubin, 1994). Published literature on usability focused on the field of human-computer interactions, making software, computers, and websites user-friendly. The primary challenge experienced by computer designers was getting them to work, with usability seen as a secondary, optional feature (Rubin, 1994). It was estimated that in the 1980's, 10% of workers' time was wasted solely due to usability issues within computerized offices (Allwood, 1984). Usability thus became a goal of those who designed interactive software targeted towards those who were not technical experts (Soegaard, 2012). Many companies, realizing the demand for usability, have started labeling their products as user-friendly or usable without changing their methods or adopting requisite models within their design process (Rubin, 1994).

The definition of usability is given by the International Standards Organization (ISO) 9241-11 as "the effectiveness, efficiency and satisfaction with which specified users achieve specified

goals in particular environments," where effectiveness is the accuracy and completeness with which specified users can achieve specified goals in particular environments, efficiency is the resources expended in relation to the accuracy and completeness of goals achieved, and satisfaction is the comfort and acceptability of the work system to its users and other people affected by its use (International Organization for Standardization, 1998). This standard applies to users, the tasks, the equipment used- including hardware and software, as well as the physical and social environments. The guide suggests methods how to measure usability, but it does not investigate the activities to be taken, or how to integrate the usability into the design pattern (International Organization for Standardization, 1998). However, even though computer-human interaction has been the subject of research in human factors, the matter of understanding what users desire and require continues to be a priority that is lacking in many internet-based designs (Garrett, 2003).

While the research often specifically investigates those areas which are required in a job, there have also been recent advances into the usability of products regarding those who have no specific training or regularity in using the design (Norman, 2007). Jordan (1998) argues that usability should be designed into products as a responsibility those producing designs owe to those who use them. Bayley (2007) similarly argues that it is the designer's responsibility to improve lives through designs that are functional, affordable, and beautiful. The 1990's found it necessary to include consideration of emotion within the user experience (Dandavate, Sanders, & Stuart, 1996). It was thought that empathic design in the forms of observation, data collection, analysis, and prototyping would identify user demands which may have been unspoken or unmet in previous methods of usability inclusion (Leonard & Rayport, 1997). By solving user needs which were not able to be expressed or previously solved, the inclusion of empathy within design assured an increase in design success (Battarbee, Suri, & Howard, 2014). Even though much effort

is put into understanding and predicting emotional response, mathematics, analysis, and computer simulations fail designers when they are trying to deal with emotions (Adams, 2012). The pursuit of empathy within design also encourages products to mimic and consider the diversity of users who are on ends of the spectrum, with regards to physical or cognitive disabilities, age, or different cultural backgrounds (Dul, et al., 2012).

1.3. Factors to Consider

Ergonomics is the discipline which seeks to understand the interaction between humans and other aspects of a system. It is also the profession that applies this understanding to design to increase the performance of the system and optimize human well-being (International Ergonomics Association, 2016). These can be broken into several domains, such as physical, cognitive, and organizational. Human factors, the discovery and application of information about humans, can also be described in part using the PEAR model: People who do the task, Environment in which they work, Actions they perform, and Resources they require to complete the task (US Department of Transportation: Federal Aviation Administration, 2008) (Sanders, 1993). Examples of factors within these subheadings are given in Table 1.

Table 1: Human Factor examples given by the PEAR Model
(US Department of Transportation: Federal Aviation Administration, 2008)

Subheadings:	Examples:
People	Physical, Psychological, Physiological, Psychosocial
Environment	Physical environment, Organizational
Actions	Steps, Sequences, Skills, Knowledge
Resources	Tools, Materials, Manuals, Equipment

Vincente (2003) breaks down the factors to consider in designs for a fit between humans and technology into a "Human-Tech" ladder consisting of physical, psychological, team,

organizations, and political levels. He argues that understanding the factors which levels are relevant to the problem allows the designer to avoid the daunting task of understanding the complexity of human needs and behaviour (Vincente, 2003). Examples of the levels, given in increasing complexity, are given in Table 2.

Table 2: Human Factor examples given by the Human-Tech Ladder (Vincente, 2003)

Level	Examples
Physical	Shape, Size, Physiology, Strength, Dexterity, Physical Capabilities, Physical Limitations
Psychological	Short- and long-term memory, intuition, mental calculations, pattern recognition, cause-effect, confirmation bias
Team	Goals and priorities, coordination, communication, consensus
Organizational	Vision and leadership, incentives and disincentives, informational flows
Political	Public opinion, social values, cultural norms, legislative controls

There can also be four classifications in which human factor considerations can fall, according to Adams (2012). He begins with the interaction of the human body with built things – the physical. The second category is the senses of hearing, seeing, touching. The third is the interaction between the mind and the machine which he describes as cognitive, and the last is the difficulties and misfits resulting from system complexity. Above a certain complexity, it is considered certain that accidents will happen when there are humans involved (Perrow, 1999). It

is up to the designer to determine if the consequences of that human error are acceptable to society of a whole, or, if they are unacceptable- to change the direction of the project (Adams, 2012) (Perrow, 1999).

1.3.1. Principles of Usable Design:

Usability includes an understanding of users from a variety of cultural backgrounds, genders, and ages to better optimize a system design that is compatible with human limitations and abilities (International Ergonomics Association, 2016). Several considerations must be taken into account because of their effect on usability. These include user knowledge of the appropriate subject matter, cultural background which may affect instinctive behaviour in situations of high stress, differing physical and cognitive ability levels, and age and gender of the user (Jordan P. W., 1998).

Many of the principles Jordan (1998) presents are born from a need in software and computer-based designs, although they translate to considerations for other products and systems as well. These include the consideration of user resources which ensure that the environment and method of operation is taken into account to limit the demands placed on the user by the interaction.

The limitations of the human brain and cognitive abilities demand consistency and predictability while designing a product, ensuring that similar tasks are done in similar ways (Jordan P. W., 1998). Many microwave ovens serve as an example where this principle is poorly done. Users rarely accomplish the task desired the first try when using a new microwave, whether it is warming food or setting a timer. Even if the user is familiar with the microwave, new but similar tasks are rarely accomplished efficiently as the tasks do not follow a similar path of buttons on the machine. Similarly, error prevention is recommended to decrease the likelihood of user

error. In the inevitable case of error, creating a product which recovery is quick and easily accomplished is ideal (Jordan P. W., 1998). This can be seen in confirmation messages when a user selects to delete a selection, or a recycling bin from which a file can be retrieved in the case of an error.

Experience, either with the product or in related fields will also impact the usability and adoptability of designs. Compatibility, therefore, should be attempted so that the method of operation is in line with the user's expectations or previous experiences (Jordan P. W., 1998). Examples of this principle include the consistency of the brake pedal on the left-hand side regardless of a left- or right-sided driving country. By keeping the layout consistent, even drivers in an unfamiliar country or driving setting will default to depress the correct pedal in instances of stress. If a similarity is built into the design, users can, building on previous experiences, use skills developed in other context to improve the use of the current product (Jordan P. W., 1998).

By allowing the user to have access to the important functionality and information, they are able to prioritize the tasks required. This should be done in a way that can be done without causing confusion. Feedback is given by giving the user indication about the completion, status, and result of their actions, so that the user has command over which actions they are taking (Jordan P. W., 1998). These feedback indications should be explicit and clear so that the method is understood, preferably without the use of manuals or explanation (Jordan P. W., 1998) .

1.4. Why is Usability Important?

Similar to understanding the capabilities and limitations of the manufacturing processes that will be used in a project, designers must understand the people involved with their design. Thorough research must be done into the market- where and how people live, and how the design is expected to change their lives (Bayley & Conran, 2007). A fascination with technology and

expecting too much out of human worker can cause neglect of important human limitations and the risks inherently associated with safety and human welfare (International Ergonomics Association, 2016). Functionality is a required minimum for any design, however the greatest functionality will fail if the user cannot understand how the tasks should be accomplished (Garrett, 2003). Lack of usability can cause a range of problems from user frustration to life-threatening errors (Jordan P. W., 1998). In addition, industrial, domestic, transport, and up to 80% of aviation maintenance errors are caused in some part by a lack of usability and human error (US Department of Transportation: Federal Aviation Administration, 2008) (Jordan P. W., 1998). Through good design, it is possible to compensate for types of human error and mitigate the risks which lead to accidents (Oppenheim & Shinar, 2011).

The most relevant justification for including user experience is because it matters to the clients and users of the design (Garrett, 2003). Benefits of human factor design within a product or service include a better experience, decreased learning times, fewer use errors, and better fits between the needs of the user and the design (Dul, et al., 2012). If designs were simply a linear progression of steps to accomplish a task, there would be no need to incorporate users into the design considerations. In design, rational analysis alone does not identify what areas are necessary to analyze, or how designs are going to work in conjunction with pre-existing designs (Gould & Lewis, 1985). Indeed, usability may be one of the few areas left to manufacturers where it is possible to gain a strong commercial advantage over the competition (Jordan P. W., 1998). Of the factors involved in the product creation process, usability issues can be amongst the most significant in terms of influencing the commercial success of the product (Jordan P. W., 1998).

Usability should not be something that comes up now and then; it should be at the very core of the design (Jordan P. W., 1998). Without taking human factors into consideration there is an increased chance of error, lost time, cost, and labor turnover, as well as decreased productivity

and quality (Gallimore, 2004). Jordan argues that usability is one of the few areas left to manufacturers in which designs can be given a strong competitive advantage over their competitors (Jordan P. W., 1998). The first advertisement which included usability as a feature was in 1936 when the Palm Beach Post advertised a Frigidaire, challenging readers to "compare it with others" (Sauro, 2013).

More examples of areas where usability is directly involved include user annoyance and frustration, which can defeat the purpose of the design if it is not addressed, financial implications in both sales and productivity, and safety- especially in the area of human error avoidance (Jordan P. W., 1998).

1.4.1. Example of Beneficial Usability

Vision Zero is an initiative started in Sweden with the goal of eliminating fatalities and serious injuries, under the premise that the human factor is always there, and that systems must always take human fallibility into account (Whitelegg & Haq, 2006). Their core principle is that only by designing the entire transport system to cater for human fallibility can the risks experienced while on the road system be overcome. Companies and areas of development are recognizing the importance of acknowledging the human factors within their industries and how this can decrease the number of injuries and deaths experienced. Vision Zero principles, including the idea that deaths are not "accidents" but a failure of design, have been adopted in New York with a record low number of pedestrian deaths one year after implementation (Belkin, 2015). This example demonstrates that an increased focus and design consideration for those who are using the system can help protect those who are the most vulnerable when the system breaks down.

1.5. Measuring Usability

It is easy for designers to focus on the functionality of their product without considering the relationship between the design and those who will interact with it (Rubin, 1994). Usability is an interaction between the design, the user, and the tasks to be accomplished (Jordan P. W., 1998). In order to obtain a successfully usable design as outlined in ISO 9241-11, the effectiveness, the efficiency, and the satisfaction with which specified users achieve specified goals in particular environments must be evaluated. For effectiveness, as well as the quality of output must be evaluated. Effectiveness can be evaluated through task completion rates, which can be a combination of both binary and quality outputs. These should have pre-defined success criteria, as well as a defined context in which success must occur (Jordan P. W., 1998). The tests for effectiveness should focus on completion and the end outcome rather than the path taken to accomplish the task (Sauro, 2011). Efficiency can be measured through productivity, or through the deviations from the critical path to accomplish the given task. Learnability is considered an efficiency metric, as the user should be able to learn the product through exploration and should be able to sustain a high level or productivity once the process is learned (Sharp, Rogers, & Preece, 2007). Therefore, having to consult a manual would be considered a decrease in efficiency (Jordan P. W., 1998). Single Usability Metric (SUM) can also combine the metrics into a score that analyzes the completion rates, task-level satisfaction, and task time (Sauro, 2011). The specified users must be understood by the designers. This can be done by understanding the cognitive, behavioural, anthropometric, and attitude characteristics as well as through a study of what tasks need to be accomplished (Gould & Lewis, 1985). Users are beginning to demand that those who design products ensure that the users and the corresponding limitations are considered within the design of products (Jordan P. W., 1998).

1.6. How does Usability relate to design?

Product and software designers are increasingly expected to have an awareness of usability and how to put the users at the centre of their designs (Jordan P. W., 1998). This cannot be added at the end of the project by an outside designer as one could add a new coat of paint. The success in usability can be seen to contribute to the success of the product, and this is due to the inclusion of human factors and user considerations from the beginning. IDEO now publishes booklets and courses on human-centred design, encouraging designers to begin their projects by thinking about humans from the first investigative step rather than slight adjustments near the end of the project.

Designers often minimize the requirement for time needed in testing as many believe potential problems can be solved through the design process without the need for user input (Adams, 2012). However, many problems cannot be identified by those who have designed it, especially when the designer is not representative of the target user group (Dul, et al., 2012). Functionality does not equal the usability of the design, and it is naïve to think that analysis and simulation alone will predict all that could go wrong (Adams, 2012).

1.7. How do engineers typically fit with design?

Design has said to be the defining difference between a science education and an engineering education (Hodge & Steele, 1995). Design is an integral part of an engineering education, though much of the literature defines engineers and designers as two different groups of people. It has been stated that designers make things look good, while engineers make them work (Curry, 2007). For example, Jordan (1998) states that the greatest conflict occurs between the interests of designers and that of engineers, separating the two into distinct camps. These conflicts are stated as being related to the more creative aspects of the design; engineers are seen

to limit the creative scope in the design process, as well as finding the more fanciful proposals as causing technical complications (Jordan P. W., 1998). There are added complications as well from the qualitative and quantitative aspects traditionally associated with each of the disciplines. Others argue that in order to be a good designer, one must be both a good engineer and a good artist, able to cross the boundary into business, and able to work in a team, a combination of both social and technical skills (Adams, 2012).

Although there is available literature on the concepts and data which demonstrates the value of making products that fit their user, there is a lingering problem where humans are unable to interact well with many designs (Adams, 2012). Through the increase in the success of the internet, companies like Google and Microsoft delegated the management of products to engineering teams, which have a traditionally technology centric approach to product strategy (Kolko, 2014). The engineering approach to product design has been observed to be focussed on the technology and the unique features the team can bring to the solution (Bjornberg, 2013). While this does not mean that other areas are ignored, for example marketing, it places a higher priority on the quality of code, quality assurances, feature development, and requirement definition (Kolko, 2014). Curry has observed that those who are considered designers respond to challenges subjectively rather than engineers who transform the challenges into ones that can be objectively tackled (Curry, 2007). The philosophy of engineering is viewed by those who are not engineers as a reductive activity in which the uncertainty is eliminated towards a single end. This is contrasted with design which is seen as a creative and generative activity which builds on variations of ideas rather than reducing them. Kolko (2014) does not appear to envision a role in the innovation and ideation stage of design for engineers. This version of engineering defines the role of an engineer within the design process as the step in which the ideas of others are brought

to reality and fruition. This view eliminates the possibility that engineers can be involved in or even spearhead the creation and generation of ideas.

Those in the International Ergonomics Association (IEA) place engineers in a stakeholder group labeled as system experts, which include a variety of professionals from both technical and social sciences (Dul, et al., 2012). They specifically single out industrial engineers as belonging to this group, but also include other professions such as architecture, computer sciences, psychology, design, and management (Dul, et al., 2012). Simon (1982) states that design is done by everyone who changes current, existing conditions into preferred ones. By this definition, engineers in all disciplines can and should be considered designers.

1.8. Design projects include Usability

Product development has often focused on the activity the design will perform to the exclusion of the human and context considerations, or the relationship of the three components to each other (Rubin, 1994). One of the fundamental characteristics of human factors is that it applies theoretical principles to design, where its practitioners contribute to the planning, design, implementation, evaluation, redesign and continuous improvement of systems (International Ergonomics Association, 2000). When human factors are not included in the design, sub-optimal systems with quality deficits, decreased efficiency, and dissatisfaction among the users is possible, yet the incorporation of human factors into the design process is still resisted (Dul, et al., 2012).The traditional methods by which students are taught engineering science leads them to difficulties when approaching design, including how to appreciate the iterative nature of design, and coping with incomplete information (The Royal Academy of Engineering, 2005). As designs endeavor to reach a broader and less educated user base, the challenge in designing usable products increases with the user's expectation of usable design (Rubin, 1994). This is in addition

to the fact that the nature of design itself can be challenging to designers, as there may not be a single, correct solution (Self, 2012).

Often, engineers have been sought after and praised due to their technical abilities rather than their ability to navigate the ambiguous issues surrounding humans (Rubin, 1994). Engineers move projects away from the unknown and uncertain towards a point of clarity and understanding (Self, 2012). The separation of disciplines which can be observed in universities has contributed to the effect that causes engineers to see uncertainty in problems such as design in the same way that art is viewed- as an intuitive application of knowledge and therefore outside the scope of what is applicable to their education (Muster & Mistree, 1989). The inconsistency between logical responses and the emotional responses of users is hard to understand and is a source of discomfort for many engineers and businesspeople (Adams, 2012). Therefore, some would view human factors and ergonomics as an unnecessary inclusion within engineering because it focuses on the subjective area of interaction of people with technology rather than only focusing on the technology (Oppenheim & Shinar, 2011). Alternatively, when the material is presented to the students in engineering schools, the content is seen as obvious and common sense. Though the students view the presented human engineering principles as obvious, the principles are then forgotten or directly violated when they go to their jobs (Adams, 2012). It has also been observed that human factors are incorporated within the larger disciplines of engineering or psychology but is limited in scope, or there is no mention of the larger field of human factors which connects the different disciplines needed to fully understand the discipline (Dul, et al., 2012).

Usability requires the use of an iterative process, as it is both arrogant and often incorrect to believe that a designer will have the perfect insight into the user on the first try. For this reason, the idea that cheap prototypes should be created quickly and often comes into practice. By

constantly and critically reflecting on the process, the designer can construct solvable problems

from unique and uncertain situations (Schoen D. A., 1993). Gould and Lewis (Gould & Lewis, 1985)

state that they have been recommending user-centred practices since the 1970's, albeit in

software applications. They also noted, like Adams did of engineering students, that design

experts respond that the principles and practices are obvious and common sense (Adams, 2012).

They also observed that the incorporation of human factors was not used within the design of the

system, despite being so evident and necessary. They questioned, then, whether the principles

were sufficiently apparent to include in the design of the system, or whether they only seem

obvious once they are presented (Gould & Lewis, 1985). They found that the principles were not,

in fact obvious, or used by their surveyed set of product designers. Designers become distracted

by considerations like cost, appearance, and design functionality, which when combined with

often tight schedules lead to a decrease or an unintentional abandonment of usability (Gould &

Lewis, 1985) (Adams, 2012). Usability falters when the focus becomes on the designed product

itself rather than on the effect the design should achieve, and the user receives too little focus

and consideration (Rubin, 1994).

Ultimately, the creation of a desirable product is not about revolutionary ideas as much

as it is about correctly analyzing and observing existing behaviour and understanding how to

change that behaviour into one which is desirable (Kolko, 2014). While the understanding of

human behaviour requires some uncertainty and may be uncomfortable for engineers, many will

assume responsibilities for usability due to the increased demand for usable products (Rubin,

1994).

Human factors can help engineers reach their goals because of the increased user

acceptance of designs, increased performance and efficiency, improved user consultation during

the design process, and a better fit with standards relating to human users such as accessibility as well as health and safety (Dul, et al., 2012).

1.9. What is missing from what's currently done?

Human factors and ergonomics has large potential in the amounts of knowledge it can contribute to the design process, but it still faces challenges in the application of its wisdom, as well as the acceptance of the ideas by the applicable markets (Dul, et al., 2012). The potential benefits, then, are limited by the lack of perceived value that human factors appear to add to disciplines such as engineering and management. Disciplines which do not traditionally have dedicated human factors considerations, all but industrial and human factors engineering, are left out of intended audiences for the instruction of usability, even within the books themselves (Rubin, 1994).

Engineering curriculum does not typically include a specific course on human factors within engineering design, with the exception of industrial engineering. According to McCormick, industrial engineering is to be given credit for being the first group who systematically approached the subject with supportive research efforts into human engineering considerations (McCormick, 1969). However, even if the subject of usability and its importance is included as a lecture, Gould and Lewis (1985) have showed that it is not enough to only have a knowledge about the human factors, but also a plan to include them in the design process. While the emphasis today is on the usability aspect of design, many engineers and other types of designers are focused primarily on the technical implementation (Rubin, 1994).

The ability to recognize and incorporate human factors is not specifically addressed in any of the attributes required by the CEAB, Canadian Engineering Accreditation Board for graduating

engineers (Engineers Canada Accreditation Board, 2015). However, the inclusion of human factors would beneficial for the following attributes:

- 3.1.3 Investigation- an ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data, and synthesis of information in order to reach valid conclusions (Engineers Canada Accreditation Board, 2015)

- 3.1.4 Design – an ability to design solutions for complex, open-ended engineering problems and to design systems, components, or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural, and societal considerations (Engineers Canada Accreditation Board, 2015)

- 3.1.5 5 Use of engineering tools: An ability to create, select, apply, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations (Engineers Canada Accreditation Board, 2015)

- 3.1.8 Professionalism: An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest (Engineers Canada Accreditation Board, 2015).

- 3.1.9 Impact of engineering on society and the environment: An ability to analyze social and environmental aspects of engineering activities. Such ability includes an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society, the uncertainties in the prediction of such interactions; and the concepts of sustainable design and development and environmental stewardship (Engineers Canada Accreditation Board, 2015).

- 3.1.10 Ethics and equity: An ability to apply professional ethics, accountability, and equity (Engineers Canada Accreditation Board, 2015)

- 3.1.12 Life-long learning: An ability to identify and to address their own educational needs in a changing world in ways sufficient to maintain their competence and to allow them to contribute to the advancement of knowledge (Engineers Canada Accreditation Board, 2015)

Organizations, in an attempt at efficiency, have broken development steps into different components that are acted upon independently. Unless engineers are both communicating with the other development processes and integrating human factor considerations into their design steps, the specialization will cause the product to clash with the user's expectation of a usable and integrated design (Rubin, 1994).

1.10. What do we want to do about it?

Due to the potential for increased success of design projects that successfully incorporate human factors into the design process, this research endeavors to help engineering students and novice engineer designers better incorporate usability into their designs. It has been observed that the contribution of human factors depends on the demand for the incorporation of these factors by those involved in the system design (Dul, et al., 2012). It is the practice of creating effective and efficient experiences for the user that is the cornerstone of human-centred design. These experiences should come from purposeful justifications and decisions made to increase the ease of use for those involved. While compromises will need to be made due to resource limitations, these compromises should be purposeful (Garrett, 2003). Incorporating considerations for the user at every step of design ensures that the concessions made during the design process do not accidentally eliminate the usability during the decision making process.

By thinking about the user experience, breaking it down into its component elements, and looking at it from several perspectives, it can be ensured that the ramifications of design decisions is known or at least considered. The biggest reason user experience should matter to

the designer is that it matters to the design users (Garrett, 2003). By creating an environment where a designer with limited resources has to concentrate on the significant factors without a champion of human factors to take that role, the learning can be sped up, enhancing the creativity and resolve to include usability considerations (Rubin, 1994).

For the first part of this thesis, Chapter 2, I describe the undertaking of a design project specifically related to user experience. By going through the process and doing a design project, I will be able to better understand what aspects of usability are needed in different sections of the design. Through investigation and documentation into the process, a better understanding of the role of usability in the different sections of the design process can be established. After the project, a retrospective observation of the project will show where the usability was incorporated and what effect I believe it made on the project. This client led project allowed me to observe first hand where different aspects of usability are applicable within the design process, as well as understand how the consideration of a number of stakeholders, rather than just the end users, can impact the project.

The discovery centre project in Chapter 2 worked from the beginning of the process towards the end. However, due to the truncation of the project, end product usability was not able to be assessed. Chapter 3 of this thesis is an investigation into several end products available on the market. By assessing products that were already available, the assumption was made that they were, at least in part, successful designs. These were analyzed to quantify the hypothesis that differing experiences with an area or product will cause the user to select different attributes as priorities. This will further confirm the idea that users' experiences and design priorities must be understood to design for them effectively. The priorities of the users were seen to be complicated and therefore it was determined that products could not be assessed only

retrospectively. From the study, it was seen that usability could not be assessed or added at the end of project. It therefore needs to be incorporated throughout the project.

To see how projects successfully incorporated usability Chapter 4 is a case study involving the execution of a successful fourth year project. The project had several human factors incorporated into the final presentation and it is believed that these considerations helped make the design successful. I will investigate what these students did in their project process to incorporate usability, what they did differently than their peers to make their project a success. I also wish to investigate the source of the human factors within their design project, and where the considerations came into their design process.

Because it was seen through the case study, the discovery centre project, and the analysis of sleeping mats that usability needed to be incorporated throughout the entire design process. After all of these chapter are considered, the information was brought together in an instructional tool to help engineers increase the integration of human factors into their design processes. It will be more involved and interactive than simply a lecture, but will be a way for the students and those who are novice designers to incorporate human factors. A challenge arises when trying to apply usability to a broad spectrum of engineering disciplines as usability and functionality is closely tied to context. Due to the differences in design applications of the engineering disciplines, the tools to help the students apply usability techniques must be broad enough to be applicable to a variety of design projects in a variety of engineering disciplines.

Chapter 2 – Discovery Centre

2. 1 Background

2.1.1. Client

The Discovery Centre is located downtown, Halifax, Nova Scotia. It is "Nova Scotia's only hands-on science centre whose mandate is to stimulate interest, enjoyment and understanding of science and technology through innovative, exciting, hands-on experiences for all Nova Scotians" (Discovery Centre, 2014). The Centre has introduced a new project, the reDiscovery Campaign (Discovery Centre, 2014), prompted by a gift of space on the Halifax waterfront. The Discovery Centre (DC) will be almost doubling its size but only plans to take 10-15% of their current exhibits with them to the new space because the exhibits are too old or too dated (McCarron, 2012).The remaining exhibits will likely be thrown away despite demonstrating important scientific principles (McCarron, 2012). In the plan for the new Centre are main galleries focused on Health, Energy, Flight, Innovation, and Water (Halifax Discovery Centre, 2015). The Discovery Centre had been in discussions with the Faculty of Engineering at Dalhousie University about collaborating on the design and development of new exhibits.

2.1.2. Project Background

Because the visitor's experience while at science centres is so vital to its purpose and the emphasis on the experiential, engaged, hands on learning is so strong, we thought it would be a good idea to demonstrate the need for understanding one's audience in the design process. Understanding the aspect of user-centered engineering design, how to integrate human factor considerations into the design process, is of great interest to this research. Because this project necessitated the understanding of the experiential learning within the design process, seemed to be a good fit for this research. Russell warns that exhibit designers can shortchange the

experience of the user when too much emphasis is focused simply on the outcomes (Russell, 2012), and due to this encouragement, it was thought it would be a good project for an increased emphasis on the experiential, user aspect of the design process. The task given was to design and build an exhibit that would be placed in one of the new galleries of the Discovery Centre.

2.1.3. Exhibit Design

Before I met with the clients in person to formally discuss the project and requirements in detail, I read literature on how to make exhibits interactive, educational, and engaging, both specifically in science centres and also in traditional museums. The body of work regarding the subject is large as it incorporates such topics as science education, interactivity within pedagogy, museum curation, the influence of play on children, circulation of people through spaces, group dynamics in learning, engineering psychology, and exhibit design. While I focused mostly on what was written about exhibit organization and design as this is the most applicable to this specific project, it should be noted that other fields may also have an impact on the success.

Some literature focused on creating order through the use of effective labeling (Bitgood, 2000). Others on how to minimize distraction and confusion with clues to help make concepts and exhibits immediately apprehendable (Allen, 2004). Others focused on engaging the users, piquing curiosity with real objects and phenomena based on how the visitor could interact with them using their five senses (Oppenheimer, 1972).

There are several attributes that should characterise exhibits that are in family-friendly centres, given by the Philadelphia/Camden Informal Science Education Collaborative (PISEC) (Borun, et al., 1998). These exhibits should be multi-sided so the family can cluster around the exhibit, and multi-user so that several sets of hands and bodies can simultaneously interact with the exhibit. Exhibits must be accessible to adults and children of all abilities with text arranged in

easily understood segments. The exhibit should be multi-outcome and multi-modal so that the interactions are sufficiently complex to encourage discussion and so that the exhibit appeals to different levels of capacity. In addition, demonstrations that do only a single, repeating task at the push of a button with no ability to manipulate the outcome are found to be quite unsatisfactory (Oppenheimer, 1972). Exhibits should also be relevant so that there are links between what is shown in the exhibit and the pre-existing knowledge the visitors have. When the characteristics of relevancy and ability to manipulate are added to existing exhibits, learning was increased (Borun, et al., 1998). Two factors used to evaluate usability include initial and prolonged engagement. Initial engagement indicates that the ability for a visitor to approach and immediately comprehend how to begin interaction, while prolonged engagement indicates the degree to which visitors can experiment, manipulate, and explore beyond the initial discovery (Allen & Gutwili, 2004). Prolonged engagement typically follows if there are aspects of the exhibit that can be manipulated to change the outcome of the exhibit. These factors need to be quickly obvious, changing the outcome quickly so that the visitor does not assume they have done a meaningless task (Allen & Gutwili, 2004).

There exists a cognitive 'sweet spot' between having too few features, thereby failing to engage users, and having too many which can lead to confusion, disruption, and a feeling of having too many choices available (Allen & Gutwili, 2004). Human factors beyond the surface level of anthropometrics and ergonomics also need to be considered in the design of an exhibit. In the same way that an exhibit can have too little interaction for the visitor, there can also be an overwhelming or confusing level when it comes to interactivity. Examples given include having too many manipulated variables which can cause visitors to miss the intended experience all together. Other examples include variables that do not seem to connect to the original physical

principle being taught or encourages visitors to interact with the exhibit in a way that interrupts the physical principles (Allen & Gutwili, 2004).

Social or etiquette factors also must be taken into account when designing exhibits for crowds as science centres and museums are primarily experienced as a social activity. Multiple users being able to experience the exhibit simultaneously is seen as a positive aspect (Borun, et al., 1998), but if the users interrupt each other's interaction with the exhibit, the manipulation of variables may not be understood or frustration in the users may occur. The design of some exhibits encourages multiple interactions, but does not specify that these should be done by a single user. As a result, users may attempt to manipulate the exhibit simultaneously, eliminating the effect of a singular manipulation (Allen & Gutwili, 2004). In a similar way, if any exhibit holds the attention of a limited number of visitors for too long, the wait may not be considered worth it and the science principles may be left undiscovered. For these reasons, the exhibits must be evaluated while in use by visitors of the varying demographics that visit the science centre in question. Evaluating exhibits must be a priority to determine and improve the relevance, functionality, and effectiveness of exhibits (Russell, 2012). As always, it is important that the final testing not be by those involved in creating it, as 'incorrect' uses may be possible but not foreseen or understood by the designers. It is this imperative that highlights the importance of usability in this design project.

2.1.4. Discovery Centre Specific Research

In order to better understand the current environment within the DC, I visited their current site to observe visitors to the centre, as well as collect information about the state of the current exhibits. The first visit was during a day in which school was in session, which the DC informed me was a lower attendance time for visitors. I interacted with each of the exhibits to

the best of my ability and made notes about whether there were opportunities to interact with it in different ways, or whether multiple people could interact with the exhibit simultaneously. I also photographed and cataloged each exhibit, marking the amount of text and appearance of each one. The values for each can be seen in Table 3.

Table 3: Exhibit Cataloging - Visuals

Visual:	
Text:	1- Labels Only
(T)	2- Up to one Paragraph
	3- More than one Paragraph
Appearance:	1- Up to date
(A)	2- Needs updating
	3- Needs complete makeover

During the subsequent visit, I observed visitors in the DC. These visitors were mostly comprised of families with a ratio of one adult per child. The observed, immediate apprehensibility was translated into assumed understanding in three categories: User understands what to do, Concept is Understood, Exhibit is Interactive. Using a combination of observations of the DC visitors and my own experiences, the values which were distributed for the exhibits in this category as shown below in Table 4.

Table 4: Exhibit Cataloging - Observed Understanding

Understand:	
What to do:	1- always performed correctly
(W2D)	2-sometimes performed incorrectly
	3- either always performed incorrectly or not at all
Concept	1- the concept taught is understood by all
(C)	2- concept taught is understood by some
	3- concept remains elusive even after explanation
Interactive:	1- no action or one action only, ie a button
(I)	2- several variations, no manipulation of outcome
	3- action can cause a change in outcome
	4- completely open-ended

Although many of the current exhibits would not be transferred to the new space, also indicated in the catalog were the scientific principles the exhibits were designed to convey. I thought that if the DC felt it important to include them in their current exhibits, it was more likely that these would be prioritized principles to convey in future exhibits. I also used these principles to determine a grouping in which another exhibit could fit, to ensure that it would be complimented by other exhibits rather than a stand alone exhibit. The entire catalog of the 56 permanent, current exhibits, can be found in Appendix A –Catalog of Current Discovery Centre Exhibits, 2012. Pictures, not included in Appendix A, were also taken to act as a reference as many of the exhibits did not have specific titles, and I wished to be able to transfer the knowledge between myself and the DC.

It was also desired to perform a user survey at the DC to determine several factors including the demographic of visitors, whether visitors were repeat visitors or new, which exhibits were enjoyed and remembered, and what was known specifically about energy and energy transfers. However, due to the ethics involved with interviewing children, an independent survey was not deemed feasible for the amount of information it would add to the research. It was proposed that a survey could be performed and administered by the DC, but this was also rejected due to the amount of resources required.

2.2 Concept Generation:

2.2.1. Project Concept Development

As part of this process I met with the staff at the Discovery Centre to discuss a beta plan developed for the new space. During the first in-person interview, the client stated that they wanted me to work specifically on the gallery "Introduction to the concept of Energy", which

would explore the concepts of kinetic, potential, elastic, chemical, nuclear, or electrical forms of energy. It was hoped that there would be a design for a group of exhibits, where two would be retrofitted or upgraded, one would be a new design of an existing concept taught at the Discovery Centre, and one would be a completely new design based on a science concept not currently covered by another exhibit. The client gave an overview of the aims and objectives of each of the new galleries with basic ideas of how they envisioned portraying those different scientific principles. The Energy exhibit was to portray several main concepts:

- Energy is the ability to do work

- Energy is in everything and we need it for everything we do

- Energy comes in different forms

- There are two types of energy: working and stored (McCarron, 2012)

The Key Elements they wished to use to get these across were interactive demonstrations of the different forms of energy, and experiences that highlight the range of ways we use energy. This information was given to me as a document which outlined their initial ideas for the galleries and the concepts they wished to convey, as well as ideas for exhibits to portray these concepts.
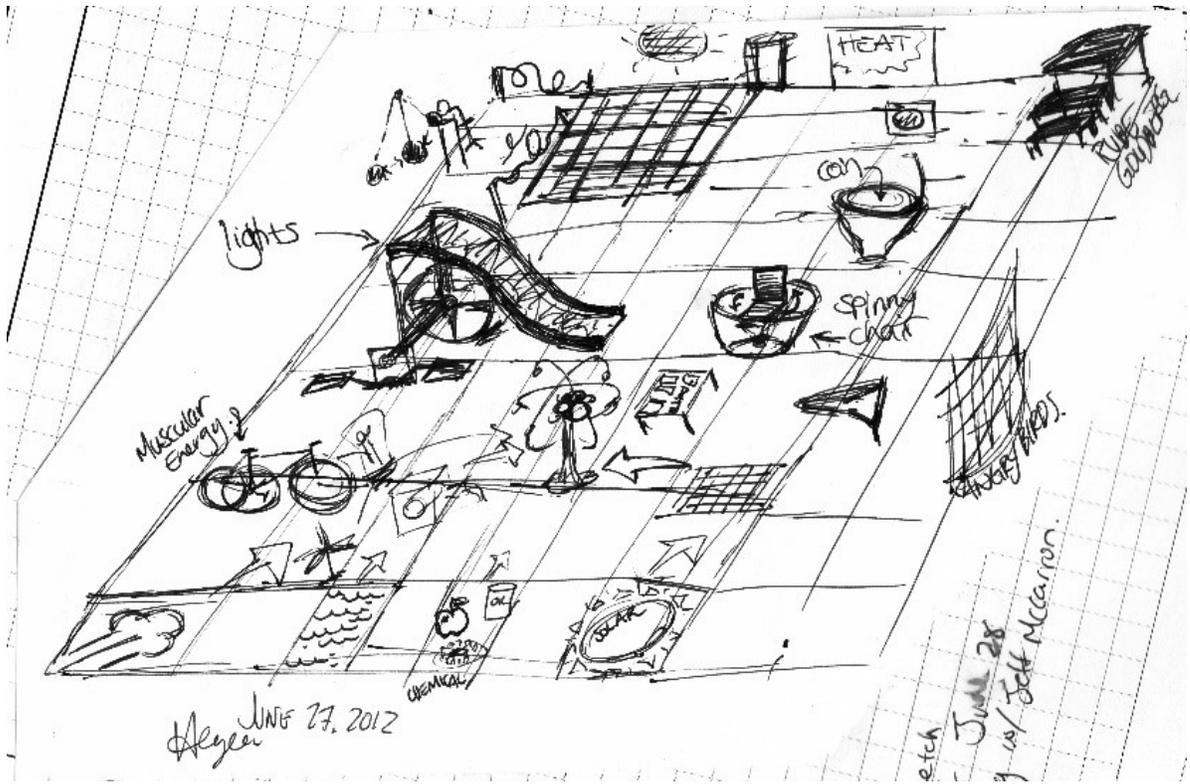
Figure 1: Energy Gallery - Brainstorming Sketch

After reviewing the document, I went through the process of developing concepts for new exhibits. In my initial brainstorming, instead of focusing on developing new ideas, I designed an entire gallery of exhibits to display energy types and incorporate exhibit ideas they had stated in the document provided. Figure 1 and Figure 2 show sketches of my concepts for ways to create an entire gallery or cluster of energy related exhibits. During a later interview with the main
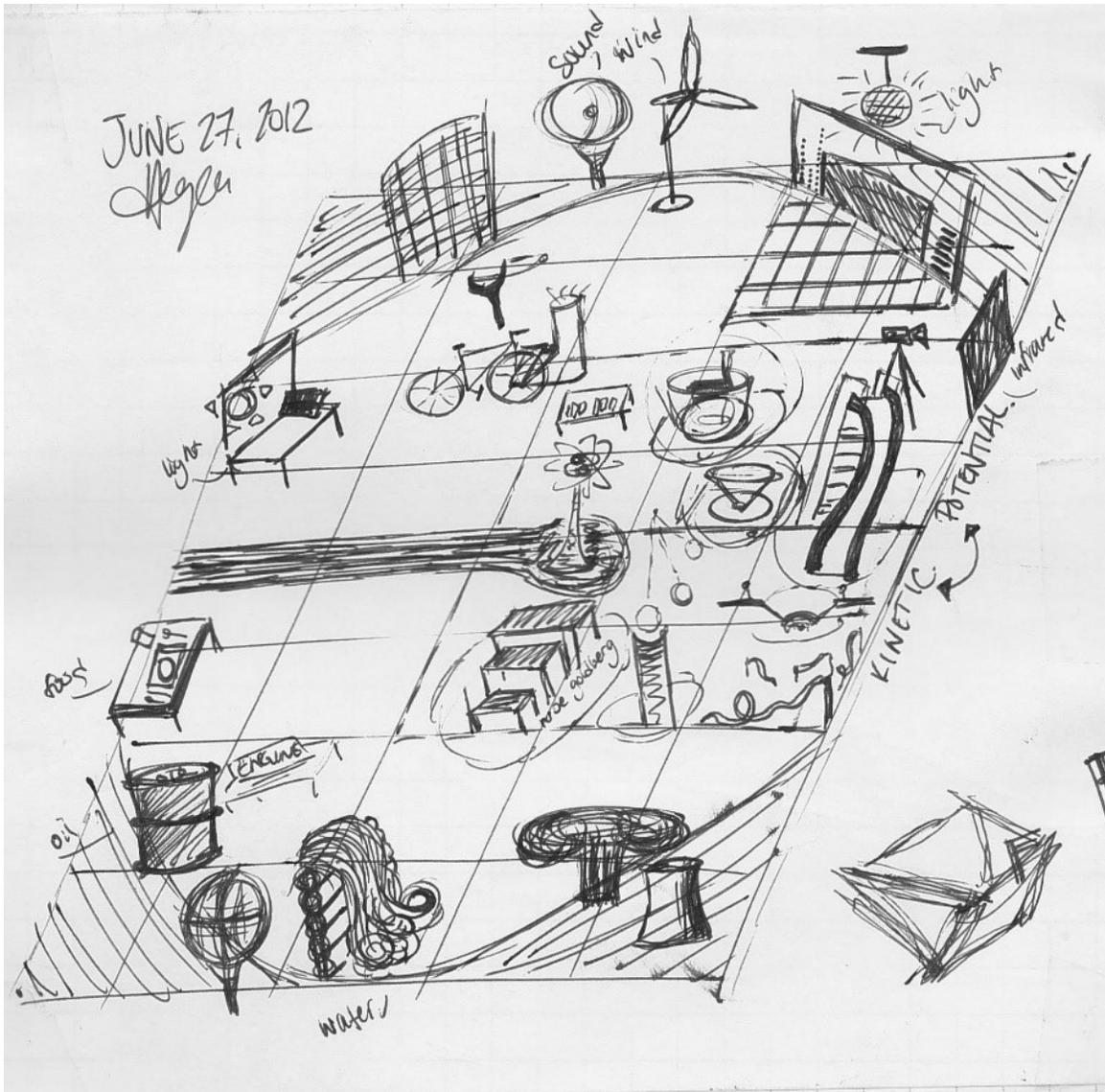
Figure 2: Energy Gallery - Brainstorming Sketch

contact for the client, it was clarified that they did not want a design for the entire gallery, and

that they were interested instead in one exhibit rather than the entire gallery.

2.2.2. Requirements and Constraints

The client contact identified some challenges to keep in mind, including the struggle to

make sure that, while intended to be entertaining and fun, the exhibits are also educational at

the core. The Discovery Centre identified their current age range of guests to be under eight which

they wish to increase to at least 14 (McCarron, 2012). Creating age-appropriate exhibits is a

challenge because the different age groups benefit differently from layers of complexity, but explanations of the principles must do so without being misleading or oversimplifying the theories. If possible, exhibits are to be designed with a deep enough base that there can be expanded learning if the user desires it, without overwhelming those who do not. Another challenge they identified was the use of text in the exhibits. The current exhibits were cataloged in terms of presence of text, with many of the older exhibits having over three paragraphs of text, which, upon observation of the guests at the Discovery Centre, was not being read. Many of the exhibits whose primary teaching methods included reading were quickly abandoned or ignored completely. For this reason, the presence of text was to be limited, with any incorporation justified. From these meetings with the client, I created a list of requirements and considerations for the exhibit, some of which were given by the Discovery Centre and some of which I thought were priorities. Those specifically given and identified by the Discovery Centre were:

- Must provide an understanding of the fundamentals of energy

- Create an exhibit that is highly interactive

- Scientific principles demonstrated must be graspable

- The exhibit must be non-confrontational and non-accusatory

- Must be relevant to Nova Scotians

- Must be encouraging of critical thinking and solution development

- Must conform to appropriate standards

- Must be designed for high-use, 'indestructible'

The considerations I believed were important additions to this list were as follows:

- Cost-effective

- Minimum amounts of text

- A good balance between attracting and holding powers

- Should be able to be moved

- Interactive

- Appearance that fits with updated look of the new centre

- Multiple outcomes

- Accessible to all ability levels

- Memorable experience

- Unifying elements to other exhibits

- Usable and Understandable with minimum or no instruction

- Not gender specific

These requirements were never officially confirmed with the client, nor were quantifiable validation tests created for each of these requirements. Many of the given requirements were qualitative, and difficult to objectively measure, resulting in the success or failure of the design being somewhat subjective. There was a singular meeting in which requirements were discussed, but the limitations of acceptable ranges or a definition of a successful project was not agreed upon. As a result, the project was always quite vague and ill-defined.

2.2.3. Decreasing the Scale of the Project:

It was quickly understood that the design of an exhibition, and even a single exhibit, is a large job, so it was decided that instead of the proposed four 'cluster' of exhibits, it would be better to focus on a single project. The Discovery Centre was most interested in the conversion of energy from potential to kinetic energy and asked me to design a slide to demonstrate this principle.

2.2.4. Clustering and Text

Exhibits have been shown to be more effective at teaching concepts when they are clustered together in themes of similar principles (Peponis & Dalton, 2004). For this reason, exhibits are most often grouped into exhibitions to provide an overarching theme linking the individual exhibits to enforce how the principles are related. While a slide could stand alone as an exhibit, it would be more effective if it was clustered with other exhibits focused on energy in the Discovery Centre. Due to the presence of several other exhibits which were related to the physics of energy shifts, I felt like the slide could have a grouping to complement it without the necessity of designing an entirely new gallery of exhibits. For example, there currently exists a build-your-own roller coaster set, a spinning chair which teaches the conversion of momentum, and a spiral coin drop.

There is existing literature to support the idea that the layout of museum exhibitions affects the behaviour of the visitors, encouraging designers to take this into account when creating and setting up exhibitions (Peponis & Dalton, 2004). However, while an increase in the number of related, grouped exhibits can help increase the understanding of a concept through concrete, relevant examples of a specific principle, it is not always understood by the visitor at a science centre that grouped exhibits are all demonstrating similar principles (Falk, 1997). When visitors are provided explicit signage defining the major ideas of the exhibit or exhibits, it has been shown by Falk that this greatly increased their ability to recall the messages which the exhibit intended to demonstrate (Falk, 1997). This proven concept reinforcement through clear signage indicated to me that text should not be completely avoided in the development of the exhibit and exhibition, but used sparingly to cue visitors of intended outcomes to increase concept understanding. A requirement was to use the exhibit created to increase the awareness about different energy types. To help reinforce to the visitors the connection between the exhibits, I

also decided that a unified mini-gallery with the slide and the other exhibits must include unified signage and state reasons for the chosen groupings.

Compared to some of the other suggestions for exhibit designs, the visitor's experiences with a slide are very hands-on and interactive. Due to this obvious application of basic human factors, it was felt that this type of design would be a good introduction into how human factors fit into engineering design. While science centres cannot demonstrate underlying mathematical analysis to clarify the world, they can provide an engaging environment for visitors to interact with physical principles in the natural world (Oppenheimer, 1972). Due to the presence of playgrounds in the typical life of a Nova Scotian resident, the application of this exhibit can be understood and has direct transference to other areas of life. Because the scientific principle the slide demonstrates is a fairly simple conversion of one energy type to another, the exhibit can be understood by a wide variety of users while having the opportunity to add other, more complex principles to it. As Wellington points out, a visit to a playground, a sports field, a golf course, a kitchen, the back garden or the garbage dump has enough experiential science for everyone to investigate, if the users are shown or know how to relate these things back to science and technology (Willington, 1990).

2.2.5. Understanding the User:

If we want to design products with the user in mind, it is important to understand who it is that will be using the end product. A user-centred design approach that is not clear on the characteristics of the users is useless (Jordan P. W., 1998).

The target group of this project was to be children, particularly those in the ages that the Discovery Centre was trying to recruit in the age range of 10-14. To try and incorporate the importance of understanding the users into the slide design, I observed several playgrounds

containing slides while children were present. These playgrounds were mostly in schoolyards, which may have a different effect on the children as they are engaging with the same equipment every day as opposed to it being a new experience for them. Many of the children I observed also appeared to be much younger than the 10-14 year range that the Discovery Centre was trying to target. However, I did not talk with them to confirm their ages, nor did I try to recruit children of these ages to survey about their interaction with slides. One observation was that while some children used the stairs, there were also other methods of reaching the top of the slide, including climbing other parts of the slide. While this is not a recommended practice in the design of the slide, it should be noted and designed for and around, as the children tend to utilize the slide surface, the supports on the slide, and the backside or the sides of the steps to climb in addition to the intended one. It would have been beneficial to this project to speak with those who design playgrounds and who teach the children in the age range targeted. Observation alone can only show you what people do, but does not include the motivations behind their actions (Kolko, 2014). I decided not to formally investigate children due to the lengthy ethics process required to do so, and due to the belief that the breadth of understanding I had of children was sufficiently broad. It was thought that the effort would not be matched with a sufficiently large increase of understanding.

For young children, physical and mental interaction increases the engagement and level of understanding when presenting concepts (Harlan & Rivkin, 2012). If there are different methods of interaction, the children tend to understand the concepts better than if they were simply to read or hear someone teach on the subject. An observation made was that there was typically only one outcome when a slide is used in the traditional sense: the user climbs the stairs or ladder and slides down the other side. A revised Bloom's taxonomy has re-labeled the structure as Remember, Understand, Apply, Analyze, Evaluate, and Create (Krathwohl, 2002). If there are

no ways to change the experience, the principle becomes one that is remembered and perhaps understood, but it is unlikely the experience will move the visitor towards the further stages of analyzing, evaluating, or creating. I, therefore, brainstormed how variables could be changed so the visitor could change the exhibit's outcome. Open-ended exhibits would then have a deeper educational value than those which simply have one outcome or one option of activity.

Some ideas for altering the experience for the visitor include changing the friction on the way down through use of sliders, carpets, or other materials of varying friction values. Another idea was having multiples sliding surfaces that may have an equal length but differing paths. I felt that more layers of complexity, increased activity levels, and multiple outcomes would appeal to a wider audience and would be better received than simplicity.

Some challenges I identified early in the project were the balance between being educational and being entertaining, how to properly target the identified age range of visitors older than 14, how to incorporate text in a way that it will get read, and how to simplify complicated scientific principles to be understandable without presenting them incorrectly.

2.2.6. First iteration and Brainstorming:

The initial design for the slide tried to incorporate several principles of science, including the effects of friction, losses of energy in conversions and related efficiencies in addition to kinetic and potential energy conversions. Two slides with the same profile but different sliding surfaces, placed beside one another- one a traditional, single material surface, while the other would have the user go down a series of rollers on ball bearings- would show the difference between sliding surfaces and the effect on friction and resultant speed. The decreased friction on the rollers was to be shown by both an increased speed on the roller slide compared to the traditional slide as well as through an infrared camera, which would capture the heat trail showing the increased

heat loss on the traditional slide. The video of the guest's rides down the slides, with the heat trail left on the slide, would be able to be downloaded or sent to the visitor for a "Take Home" reminder of the principles learned. It would be especially interesting to see two guests going down the slide at the same time to compare and contrast the difference in friction on each of the different slide surfaces. Due to discussions around efficiency, I thought it would be interesting to include that aspect into the exhibit as well, to demonstrate the loss of usable energy in every conversion. Using Equation 1, the efficiency of each user can be determined based on their velocity at the bottom of the slide, calculated by measuring the time between two sensors at set distances.

$$Efficiency = \frac{Output}{Input} = \frac{Kinetic}{Potential} \tag{1}$$

By measuring an efficiency rather than an energy, the need to calculate a user's mass can be eliminated, which could lead to embarrassment for some users. All variables are known, as the velocity is measured, height is given by the height of the slide, and gravity is a constant. The user's individual efficiency for one run can be displayed, and they have the opportunity to try to change their efficiencies in subsequent runs.

The main purpose of the exhibit is to demonstrate the difference between potential and kinetic energy types and the conversion of one to the other. To give a visual demonstration of the potential and kinetic energy levels, lights running both up the slide steps and down the slides, synchronized with a bar graph on the wall were to be used. The words 'POTENTIAL' and 'KINETIC' were to be spelled letter by letter through the lights along the steps and the slides, respectively, with the expectation that this would increase the linkage in the minds of users between types of energy presented. I also researched generators to see if the lights could be powered through the movement of the users down the slide.

2.2.7. Client input:

During a later meeting, the representatives from the Discovery Centre identified that they wanted to only have one slide, preferably a roller slide that was at least 10 feet long, and a maximum of three (3) feet tall. The height restriction was a result of having a current ceiling height of 8 feet in one of the galleries. They did not see the purpose of having lights on the slide, and wish to have only a bar graph which would be visible to bystanders and the person on the slide. The lights on the slide to spell out POTENTIAL and KINETIC up the stairs and down the slide respectively was dismissed.

During this meeting, the client mentioned that, in addition to a slide exhibit, they wished to have a table created that allowed the visitors to 'identify a type of energy' where things are displayed and the user must decide if it is either a potential or kinetic energy source. This secondary table is in line with the original idea to create a grouping of exhibits, but not with the new scope of one exhibit. This also added to the uncertainty of this design project as the scope of the project continually shifted and was never formally confirmed in its requirements of success. Notes in my design logbook show that the client wanted me to create their specified solution, not design my own or participate in a discussion of what was most appropriate or needed. Regarding the simplification to a single slide, I understood that they did not want to confuse users but did not understand how this would be effective at targeting an age range of 10-15, as this approach seemed very simplistic. By only having one roller slide with a bar graph, with no way to change the experience from one trial to the next, I felt that the ability to manipulate the outcomes were eliminated. By removing the ability of the user to change the outcome of their experience with the exhibit, I believed there was also an elimination of the ability to incorporate higher order learning.

The client expressed that they wished to, at the end of the project, receive a fully functional, to-scale exhibit that could be placed within the DC as presented. When asked about the possibility of presenting partial prototypes, they indicated that they were not interested in these. Prototypes suggested included a demonstration of the technological aspects, or a document outlining how they could create a full scale model from a prototype, including a comprehensive shopping list. The portion of the project which made it topical for this research was the usability aspect of the design, which I did not see being incorporated into the design. The elimination of the aspect of usability, or experiential design, which was the original point of including the project in this research was of particular interest.

There are two parts to a design- the desirability and the feasibility. As I could no longer prove the desirability of my design to my client, I decided to focus on the feasibility. In order to move forward with this research, it was decided that a small, prototype model of the exhibit would be created rather than either truncating the project or going on to make a full, working exhibit.

2.3. Design Description and Testing:

2.3.1. Scale-model Prototype

Due to safety standards that regulate the construction and design of playground equipment, it was decided that any centre exhibits would have to be created by professional playground equipment manufacturers. It was thought possible to purchase the base of a double slide, one roller one traditional, and then modify it in the ways required for the explanation of the energy differences. However, the thought to create a full- scale, working model was abandoned due to the high cost of production, demonstrated by the vendor quotes that are seen in Appendix B – Vendor Quotes. Other features, such as the integration of an infrared camera, the calculation

of efficiency, and the presence of two slides, were eventually discarded when the construction of the first iteration was about to be undertaken, due to the high cost of construction coupled with a lack of funding from the Discovery Centre. It was decided to create a prototype to demonstrate to the Discovery Centre the principles of the exhibit, which they could later scale up to a working model if they so choose. A science educator at the Discovery Centre identified that if the two slide geometries were not identical, the comparison of having two slides would not be intuitive to what the basic principle of the exhibit was supposed to convey, namely a conversion of potential to kinetic energy. It was thought that we could still identify the efficiencies for both slides if we included velocity sensors for both slides.

Roller slides were found to be very expensive and not readily available on a small or sample scale. One quote was willing to provide only the slide, without the added expense of an entire playground structure. Another quote included the required railings and the safety surface under the slide as required by the Canadian playground standards. Both quotes I received from roller slide providers can be seen in Appendix B – Vendor Quotes, and both were out of the range of resources that were able to be allocated to this project, either by the Discovery Centre, or by allocated research resources at Dalhousie.

Because of the high cost of the slide, the decision was made to use just one sliding surface to demonstrate the functional principles behind the exhibit, so the coding and back end programming could be scaled up for use in the full exhibit. For these reasons, a Little Tykes slide, as seen in Figure 3, was purchased from a children's store as the base for the exhibit prototype.

Figure 3: Base for Slide Prototype

2.3.2. LED Lights

Because there were no longer rollers on the slide surface, the idea to attach generators to power LED lights as the user went down the slide was rejected. This also would have created an increase in the cost without any increase in functionality or additional demonstration of the principles. Instead, it was decided that sensors would detect where the user was on the slide, and display the appropriate light array. Because there were so few steps, the original plan included

twp LEDs on the step per sensor where each sensor on the slide would correspond to a single LED, as seen in Figure 4: Two LEDs corresponding to one Sensor on Step.

Figure 4: Two LEDs corresponding to one Sensor on Step

I hoped that, through this addition of LEDs, the curve would be able to be seen more easily as a smooth transition rather than steps. If the steps were smaller and more plentiful, as would be expected in a full-scale model, the sensors could follow a 1:1 ratio for the number of sensors on the steps to number of sensors on the slide, as is seen in Figure 5: One LED corresponding to one Sensor on Slide.
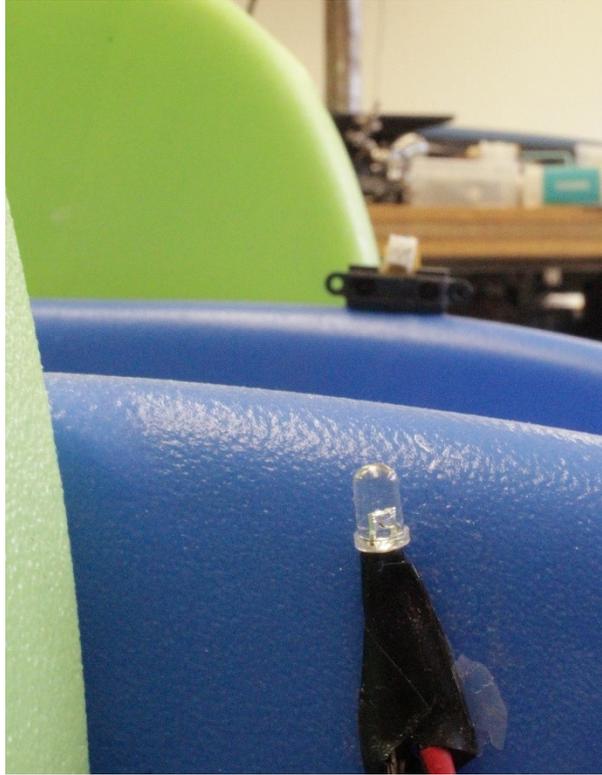
Figure 5: One LED corresponding to one Sensor on Slide

2.3.3. Programming Platform

The entire programming was decided to be done through an Arduino board, an open-source platform with simple hardware and software useful for interactive projects (Arduino, 2014). Because the Arduino Due Board had the greatest number of digital IO, digital PWM, analog input, and analog output pins compared to the previous versions we were looking at during the time of decision- 54, 12, 12 and 2 respectively- we decided to use this as the microcontroller for the system. An Arduino Due board was purchased for less than $50 and was chosen because it has the capacity to run this program either for the prototype or the full-scale version.

Originally, the plan was to have five (5) sensors going up the steps of the slide, and 10 going down the slide to indicate more smoothly the incremental energy changes. Because each

of the sensors on the slide were to control two (2) LEDs, I counted on the fact that I needed to have 40 separate, variable outputs, more outputs than even the Due had the space to accommodate. For this reason, two TLC5940s breakout boards were added, multiplexes to expand the number of Pulse Width Modulation (PWM) outputs from 4 to 16. By putting them in series, a sufficient number of output channels was obtained. However, after all the lights were attached, problems arose when it was discovered that the Arduino Due was not able to run the board as the default directories and libraries for the TLC5940 were created before the invention of the Due controller. Even when the updated libraries were downloaded for the Due, none of them were found to be compatible and able to drive the LEDs. This problem, combined with the sensor issue described in the next paragraph necessitated the redesign of the original circuitry.

To indicate the user's position on the exhibit, both force and infrared sensors were considered. The sensors eventually decided upon were short range, infrared proximity sensors, Sharp GP2D120XJ00F, as shown attached to the slide in Figure 6.
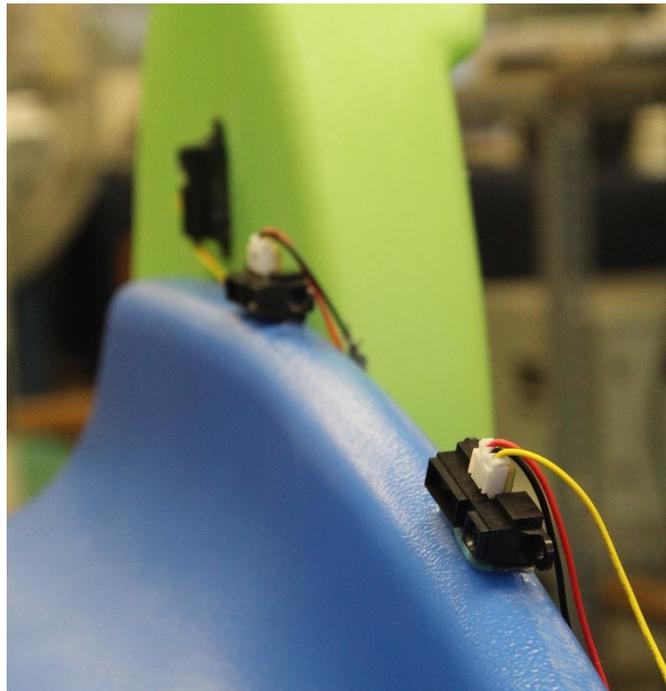
Figure 6: Sharp Sensors attached to Slide

These sensors were chosen due to their range, 3-30cm, along with their relatively low cost. Another advantage was the ability to be placed alone, as opposed to having to line up a transmitter and a receiver on either side of the slide. Due to the number of analog input/output pins on the Due being limited to 12, it was necessary to change the analog output of the sensors to a digital signal through the use of a comparator for the 15 sensors. However, the comparator chosen was also not functional with the controller board, which resulted in both a problem with the input of data from the sensors as well as the appropriate output of information to the LEDs.

2.3.4. Troubleshooting

When neither the LEDs nor the sensors worked, it was discovered that both the input and output needed to be reconstructed. Because of this, the system was completely disassembled and reassembled in smaller pieces, testing each of the components on breadboards at each step. Once I started to work with the sensors individually, I found they worked best without the comparators, in an analog input. However, the Due only had enough analog inputs for 12 sensors instead of the 15 originally designed for the exhibit to have. The plan was always to have twice as many sensors on the slide as on the steps, so the number of sensors on the steps and slide were reduced to four (4) and eight (8) instead of five (5) and 10 respectively to reflect the constraints of the Arduino Due. Many of the problems with the breakout boards could have been avoided if I had communicated my intentions to those helping me build the slide. If I had clarified that I only needed twice as many on the slide as on the steps, we could have started the project with 12 sensors instead of 15. This proves again the importance of communication during the project to determine the reasoning behind design decisions.

The bar graph was wired directly into the lights on the slide to keep consistency and timing correctness, which led to a total of 16 separate outputs. This meant that all the LEDs were able to

be attached to the Due board directly instead of needing to increase the number of outputs using the non-functional TLC5940. However, because the Arduino Due board could not provide enough power as was needed to turn on the lights, transistors were used to open the grounding circuit when the signal came from the Due, with an alternate power source used to provide the current for the lights. The sample bar graph can be seen in and the exhibit prototype is shown in Figure 8
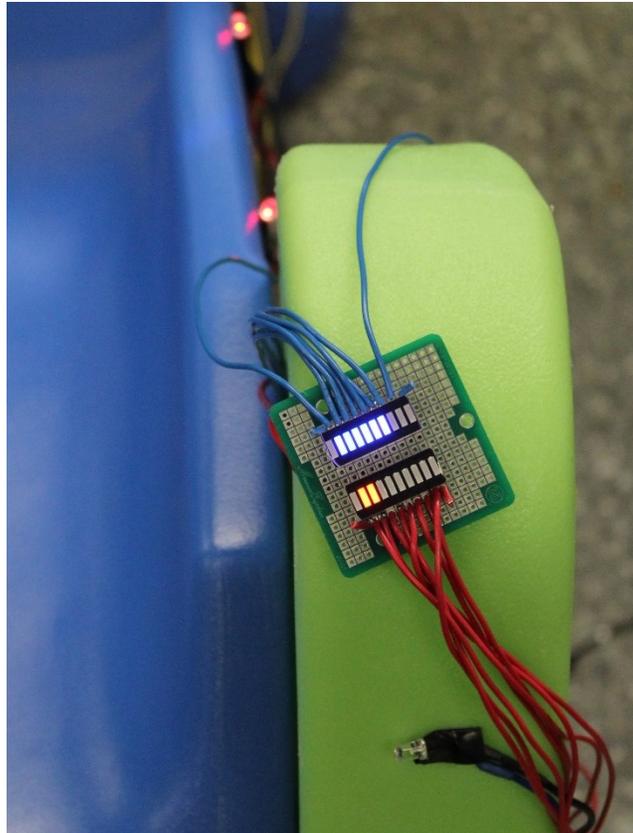
Figure 7: Sample Functional Bar Graph

with the bar graph mimicking the lights on the stairs to demonstrate the relative position of potential versus kinetic energy.

Figure 8: Demonstrating the transition from Potential (Blue) to Kinetic (Red) Energy

2.4 Future Steps

Continuing problems with the prototype slide include having a permanent way to hold on

both the sensors and the lights, as both were fastened on the prototype with superglue which

was prone to failure, especially when exposed to UV light. Additionally, while the sensors proved the technical feasibility for this type of application, they were prone to error due to light and noise. These inconsistencies in functionality make it a first, but not final step for a working prototype. While each component works individually, the prototype as a whole never worked seamlessly with a subject going down the slide. Due to the nature of the construction, the prototype quickly fell under disrepair when it was determined that the Discovery Centre would not be using the prototype for further exhibit development.

2.4.1. Identified Problems

Originally I believed that the best way to determine the success was to develop two complete exhibits, one as the slide the Discovery Centre proposed and requested with only a single sliding surface, either a traditional or roller slide, and a bar graph. The other exhibit would have been more indicative of what I had originally designed after reading the exhibit design literature which would incorporate multiple or open outcomes including the use of two or more sliding surfaces as described in the designing phase of the project. I believed that I could add more layers of features like infrared cameras, efficiency calculators, and light-up text to have increased the order of learning, adding aspects of interest which would hold the attention of the users beyond the original appeal of it simply being a slide.

I thought by creating two exhibits, I would have been able to test out the different ideas I had for the exhibit design that were different than the clients. It would have been informative to test out what makes a good exhibit by surveying the change, if any, in what users knew of energy and energy conversion before and after using each of the exhibits. By being able to compare two functional exhibits, we could have compared the differences in the usefulness of text, whether confusion resulted from too many different principles being presented at once.

However, the price of creating two final prototypes is unrealistic, both in resources of money and time. It would have been more functional to define the project with quantifiable requirements with the client before making final design decisions.

2.4.2. Engineering Projects

If this project had ended with a successful product with which the client was satisfied, I do not believe I would have searched so hard into the mechanisms of success as I have the reasons for its failure. Failures like this project can often point out inadequate processes, incorrect assumptions, and what does and does not work (Kolko, 2014). This project can therefore only be counted as a success if the reasons and methodologies behind the failure are evaluated and if it is not counted as an anomaly and the process is repeated, hoping for a successful project next time.

At the time of the original project, I blamed the failed attempt on several factors. First was a mismatch between the type of prototyping that I believed needed to be done and that which the client was expecting. What I defined as successful was a prototype that showcased the technicality of the principle, but I now believe that they were hoping to receive a fully functional, to-scale exhibit that they could use in the new Discovery Centre.

I also believed that communication was not as thorough as it should have been, as there was a lack of understanding between the client and myself as to what would constitute a successful project. I believe it was too early for them to give me specific requirements, but there was also a lack of investigation into what was appropriate and needed at the time of the project. I believed that due to my investigation into what makes a successful exhibit through a literature search, that my ideas for features and functions were better than their stripped down version. Through the project, I see how I tried to implement my own ideas which were rejected by them.

Instead of investigating through conversation and discussion with experts into what was needed for the exhibit to be functional and educational, I assumed that my understanding of experiential learning and target audiences through reading and observation would suffice.

The project is now at the point of initial construction, but at the time of commission, the client was still in a fundraising stage of their development. The smaller, technical exhibit design would have been more useful once space, gallery, and cost requirements could have been more clearly stated, whereas a bigger picture design may have been more beneficial to them in the beginning stages than smaller-scale prototypes.

2.5. Conclusion

The Discovery Centre approached my research group to help design material to fill the new space into which they are moving. Through reading literature, I investigated the processes involved in the creation of exhibits, and the roles science centres play in the scientific education of children. Because science centres and their exhibits are so heavily focused on the user experience and how to combine educational content with engaging interactivity, it was thought that this would be a good project for this research.

The project varied in intended scope, as project requirements for success were never confirmed by the client. The desire of the client was to receive a fully functioning exhibit which they could use as-is in their gallery, however, due to budget constraints from both parties, this was not a feasible solution. The final product was decided to be a small prototype using a child's slide to demonstrate the technical feasibility of the exhibit, as well as a shopping list of vendor quotes and technical elements which the Discovery Centre could use to create a full-scale exhibit. This was not a desirable project endpoint from the client's perspective, but in order to complete

a portion of the design process, in this case the technical feasibility of the idea, a small prototype was created.

While both the client and I would have preferred a different outcome to this project, I believe the failure made me look more closely into my design process than a successful project would have. I was intentional about incorporating human factors and looking into the desirability of projects, and still missed doing those aspects of the design successfully during this project. The process of going through the design shows that it is not enough to simply desire to incorporate human factors, but that there must be a strategy. This strategy should also include championing human factors so they will be prioritized within the design. If I wish to help engineering students incorporate human considerations into their design projects, it must be done through a framework which will encourage and guide them to include ergonomics in their design processes.

Chapter 3 – Sleeping Mat Study

3.1. Introduction

3.1.1. Background

As users continually increase the demand for products and services that consider their needs and capabilities, usability becomes increasingly important to the design process. To design for users, it is necessary that the designers make every effort to understand who the users are, what motivates their choices, what circumstances make up their lives (Kolko, 2014). According to ISO 9241, usability is defined as the "extent to which a system, product, or service can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use (ISO/IEC, 2010)." In order to determine how to best design for this effectiveness, efficiency, and satisfaction, an understanding of the intended users is key. Gould and Lewis purport that this understanding is obtained through observation and direct study of both the user's thoughts, behaviours, anthropometrics, and attitudes and of the essence of the work to be accomplished (Gould & Lewis, 1985).

A study into the effect of user demographics and motivations must also lead to a discussion of inclusive design, in which the designers consider as many different user profiles as possible. The goal is, by considering varied mental and physical capabilities as well as diverse ages and experience levels, to design non-specialized products and services that are usable and accessible to as many users as possible (British Standards Institution, 2005). Most commonly used in applications involving users with a disability, or for an aging population, it is a concept that has applications for any design problem that involves more than a single user. It is a common critique that designers often use a single model of the user, without making the effort to discover whether this is a correct representation of the range of users present (Newell & Cairns, 1993).   By

understanding the different groups present in a user profile, it can be seen whether there is a greater proportion of the population that would be better served by one product instead of one for each subsection. In order to make assumptions about what people will want in a product, we need to understand what attributes and characteristics they prioritize. Inclusive design is not implying that it is always possible, or appropriate, to meet the needs of the entire population with the design of only one product (University of Cambridge, 2013), as it is not feasible to make one design which will suit all users if their needs are disparately different.

3.1.2. Study into Products

After the first project did not successfully include usability considerations, I decided to analyze the usability appeal of existing products. To further explore the idea that users should be considered and understood when designing, an instrument was developed to better understand the connection between user experience and their corresponding product preferences. I assumed that the products available in stores would have considered human factors and this is what led to their commercial availability compared to versions which did not make it past the implementation phases. By asking a spectrum of users to rank their preferences of a variety of products, it was thought that the target audiences would be understood for each of the products. After the identification of the audiences into groups based on demographics and experiences, the distinguishing traits of the different products could be identified to understand which was the highest priority to specific users. The point I believed would differentiate the users and, therefore, the products they ranked highest, was their experience in the area of the targeted product.

3.1.3. Product Target Area

Although it can introduce a significant bias, being an active participant in the target community is believed to make a better, more effective designer, as assumptions are no longer

based mainly on stereotypes or fads (Kolko, 2014). Most insight for design problems comes from real users and the people who have experience with the area of interest (IDEO, 2009). Due to this, it was decided that the study would be in an area in which I was both knowledgeable and actively involved. After narrowing down the scope to camping and the outdoors, I decided to research sleeping mats because they are relatively simple, low cost compared to other forms of camping equipment, and serve an understandable need. Even those who do not camp understand the function and able to form an opinion about the sleeping mats based on their previous experience with the act of sleeping. Furthermore, participants with limited camping experience are still able to identify the attributes that are most important to them, as sleeping mats are not intimidating, complicated products which require a detailed use process. The intent of this research is to question people with a variety of camping expertise levels, ranging from novice campers to experts, to determine if there is a correlation between prioritized attributes and expertise levels.

Many people think of sleeping mats as only serving a role in comfort, a buffer from whatever ground they are sleeping on. Some beginner camping lists recommend sleeping mats only if you need the cushioning, and they can be seen as unnecessary if the camping occurs in a tent trailer or a cabin. However, they are considered to be worth their packed weight and space as proper heat retention is dependent on the presence of a proper sleeping mat (Thrall, 2013). An insulation rating of a mat can be a deciding purchasing factor due to dangerous heat loss to the ground through radiation and conduction, even in the summer. This is often presented as the principle justification for bringing them on more intense trips (Englund, 2012) (Kirtley, 2010) (Jordan R. , 2005) such as backpacking treks where the weight and space of items carried are carefully considered. Because of this easily understood nature of the product, a variety of eight (8) sleeping mattresses were selected. The mats were all chosen because they displayed a diversity within the area of sleeping mats.

3.1.4. Sleeping Mat Types

The three basic types of sleeping mats are air mattresses, foam pads, and self-inflating pads (REI - Recreational Equipment, Inc. , 2014). Air mattresses do not include any additional insulation. Foam or Closed-foam is an uncompressible foam, which uses an egg-carton pattern to decrease the packing size. These are seen as beneficial as they do not deflate with punctures, but are also an increase in insulation from bare ground or only air. The foam roll is especially popular due to its low price and durability. Self-Inflating or Open-Form is a type of mat with compressible foam encapsulated within an airtight fabric that inflates once the valve is opened (Thrall, 2013). These are often used in backpacking because of their small packed size, comfort and an insulating value that allows them to be used in a variety of conditions. Ultralight is a style of backpacking in which the participants carry the lightest and simplest gear safely possible (Cole, Dixon, & Jordan, 2005). As a result, these products are often designed with high performance and minimized packed size and weight but with less consideration for cost. Due to their increased specialization to a certain type of camper, I hypothesize that it is unlikely they will be seen as a favorable option for most participants.

One leading brand of camping sleeping mats is Therm-a-rest, whose website has a tool to help customers select a sleeping mattress through an identification of their priorities and experience which then offers possible choices they believe favorable and appropriate to the user (Cascade Designs, Inc, 2014). This tool for choosing a sleeping mat, along with another offered by REI (2014), start with the types of activities which will be done with the gear. This initial question differentiates between car camping, a guest bed at home, backpacking, ultra-lite, canoe trips, or family camping. Many of the lists of 'best' sleeping mats have recommendations based on the level of the participants' experience, or by what type of camping they were intending to do. I believed that this would also be the basis of many of the attribute preferences we would see

among the participants. After selecting the activity, other attributes including weight, warmth, cost, and comfort are presented as winnowing factors to the user, which were included in my instrument as well.

I posit that those who are identified as experts, average, and novices will have different preferences in their ranking of sleeping mats as compared to those who are identified as in the other groups. This is a specific outcome of the more general idea that different experiences will lead participants to prefer different attributes in sleeping mats.

3.2 Method

3.2.1. Product Selection

Two mattresses were chosen from each of the four (4) groups: air mattresses, closed-foam, open-foam, and ultralight. They were chosen from two chain stores who have locations in Halifax. The two air mattresses were purchased from Walmart, and the rest from Mountain Equipment Co-op (MEC). Their insulating value, packed size, sleeping area covered, weight, cost and mattress type are given in Table 5.

Table 5: Sleeping Mat Specifications

Name	R-Value	Packed Size	Sleeping Area	Mattress Type	Weight	Cost
Intex Recreation 6879E Vinyl Air Mattress		23X8cm	184x67cm	Air Mattress	1.4kg	14
Intex Twin Downy Air Mattress with Mini Hand Pump			190x99cm	Air Mattress	2.7kg	24
MEC Reactor 3.8-Women's	3.7	26cmxØ16cm	171x51cm	Open-cell foam	0.660kg	71
MEC Reactor 5.0 Sleeping Pad	4	69cmxØ18	198x66cm	Open-cell foam	1.53kg	93
Therm-a-rest Z lite Sol Sleeping Pad	2.6	51x14cm	183x51cm	Closed-Cell Foam	0.410 kg	46
Zotefoams Blue Foam	1.4	53cmxØ15	140x50	Closed-Cell Foam	0.22kg	15
Klymit Inertia X Frame Sleeping Pad	1.5	15.2cmxØ7.6	183x46	UltraLite	0.301kg	70
Therm-a-rest Luxurylite cot		43xØ15cm	183x66cm	UltraLite	1.7kg	235

The mats were all coded using their prominent colors as names. This was done for two reasons: to decrease confusion of the participants while ranking and to decrease the tendency of the participants to rank the mats in "order" either alphabetically or numerically. The names, types, and product names are shown in Table 6. Additional pictures of the mats can be seen in Appendix C where photos of the mats packed can be seen, as well as details to better understand the types.

Table 6: Sleeping Mat Labeling

Name	Label	Mattress Type
Intex Recreation 6879E Vinyl Air Mattress	Brown	Air Mattress
Intex Twin Downy Air Mattress with Mini Hand Pump	Blue	Air Mattress
MEC Reactor 3.8- Women's	Green	Open-cell foam
MEC Reactor 5.0 Sleeping Pad	Orange	Open-cell foam

Name	Label	Mattress Type
Therm-a-rest Z lite Sol Sleeping Pad	Silver	Closed-cell foam
Zotefoams Blue Foam	Foam	Closed-Cell Foam
Klymit Inertia X Frame Sleeping Pad	Yellow	UltraLite
Therm-a-rest Luxurylite cot	Cot	UltraLite

3.2.2. Participants

The instrument was approved through the Dalhousie Social Sciences & Humanities Research Ethics Board for research involving human participants. The study was administered at Dalhousie University, where posters advertising the study were hung to attract participants. Participants were selected using a variety of methods, including purposive, and convenience.

Some participants saw posters and contacted me directly to set up a time to perform the survey. However, most of the participants were asked to participate due to the knowledge that they had varying camping expertise levels to help ensure there would be participants in every level of the expertise groupings. Several of the participants heard about it from those who had participated in the survey previously. A primarily convenience sample was done as the first round of the test, but a more random sample would be taken in further iterations to obtain more variance in response.

The sample was comprised of a total of 31 participants. Height of the participants was recorded and three equal groups of equal height differences were created. These groups were labeled as short (62"-66"), average (67"-71"), and tall (72"-76"). Gender, height, and sleeping preferences were all considered. The group consisted of 17 females and 14 males. Even though there were a small number of participants, the experiment was still useful for due to the meaningful indications that were learned.

To determine their level of expertise, participants were asked how many times a year they participate in camping activities, how many of those trips are multi-day, in which months of the year they camp, what means of transportation they use to arrive at the camp place, and the location where they normally stay. Additional descriptive information was collected which asked the participants how comfortable of a sleeping surface they need on a regular basis, which was a rated question out of 5, with 1 requiring a specified sleeping surface and 5 was the ability to fall asleep anywhere. Answers to the descriptive items were categorized into scores as shown below in

Table 7.

Table 7: Groupings of Descriptive Items

	Group 1	Group 2	Group 3
Comfort Required	1-2	3	4-5
Frequency of Camping per Year	0-2	3-4	5+
Multi-Day Frequency	0-2	3-4	5+
Months of the Year	0-2	3-4	5+
Transportation	Car	Hike	
Location of Camp	Cabin	Tent Trailer	Tent

Assigning a value of 1 for Group 1, 2 for Group 2, and 3 for Group 3, the total expertise of each participant was calculated from an average of the scores for Frequency of Camping, Months of the Year, Transportation, and Location, rounded to the nearest integer. Based on the calculated average of the scoring of the demographic questions, the participants were considered Novice, Average, or Expert as seen in Table 8. 23% of participants were in Group 1, 55% were in Group 2, and 23% were in Group 3, labeled as Novices, Average, and Experts respectively.

Table 8: Expertise Classification Groups

Classification	Rounded Average	Number of Participants
Novice	1	7
Average	2	17
Expert	3	7

These groups were made up of both genders and a representation from all height groups, as seen in Figure 9: Gender Distributions among Expertise Groups and Figure 10.
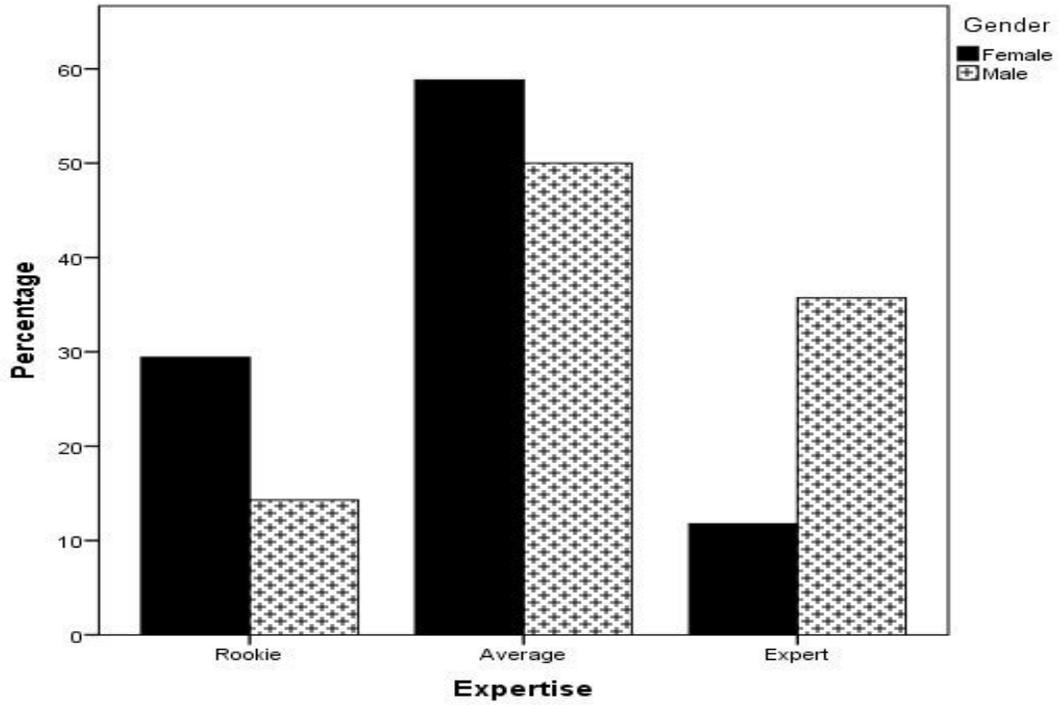
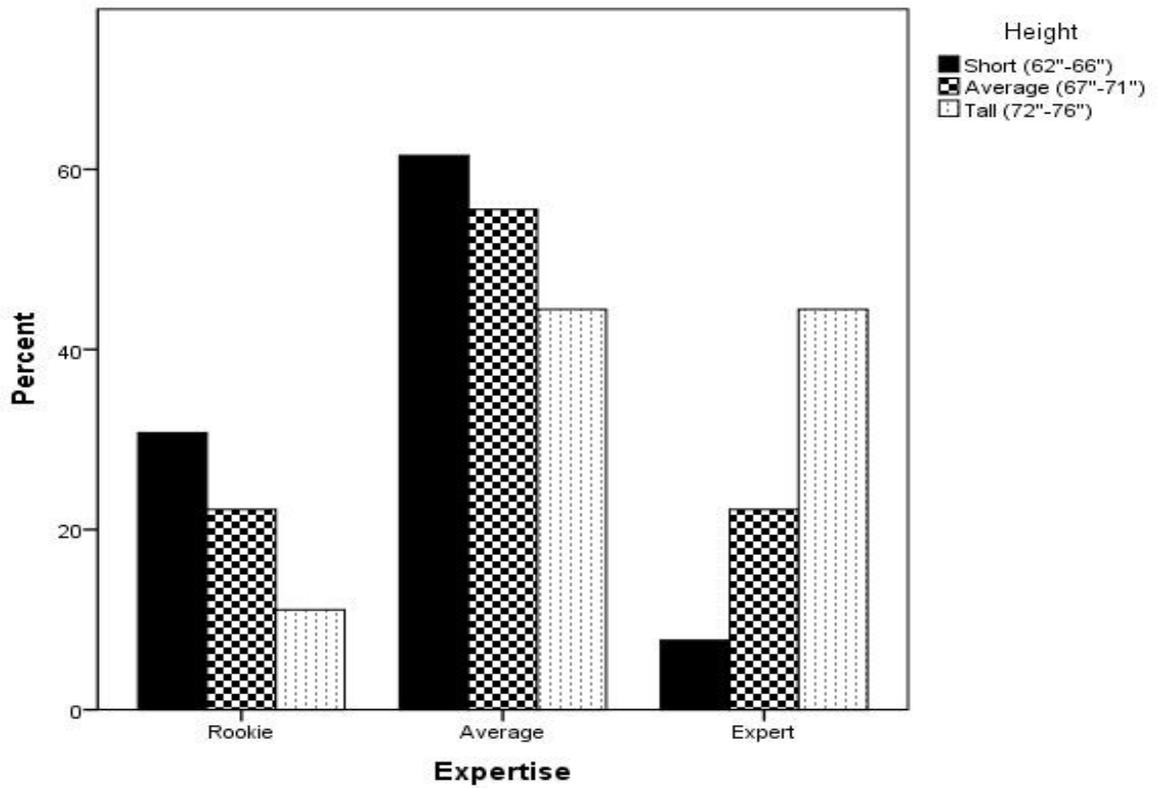*Figure 9: Gender Distributions among Expertise Groups*

Figure 10: Height Distributions among Expertise Groups

3.2.3. Testing Procedure

Each of the participants came to the testing location and signed a waiver disclosing their agreement to the test. Participation in the study was voluntary. All participants were advised that they could leave the survey at any time with no adverse effects. They were asked to fill out the demographic items which included gender, height, and questions to indicate their camping experience. They were then shown to the sleeping mats which were set up on a concrete floor inside. The products were already completely assembled as it was thought that, in addition to health concerns, the test would be too time consuming if it included assembly and disassembly. Participants ranked the eight mats three times in terms of comfort, perceived durability, and their favorite, respectively. Participants were then shown the price of each of the mats and asked to rank the mats from most likely to purchase to the least. The mats were available for picking up, laying on, and the packaging was available for inspection of packed size. Insulating values were written on several of the mats, and were available to any of the participants who asked.

3.2.4. Instrument

The instrument that was developed to assess the correlation between experience and product selection can be seen in full in Appendix A. Ranking questions were utilized to force participants to choose extremes, which are uncommon answers.

3.2.5. Data Procedure

The data were entered into IBMs Statistical Package for Social Sciences (SPSS) and required no cleaning as there were no discrepant values, data entry errors, or missing data. As this was an exploratory study with categorical variables, the data cannot be analyzed using ANOVA. Therefore, a cross-tab analysis was used to find patterns in the data. In the future, a literature review to define the scale should be performed to ensure construct validity to better

define expertise. Randomly dispersed positively- and negatively-worded items should also be interspersed within the instrument to also increase the construct validity. There was no communication between participants until after they had completed the tasks prescribed by the instrument.

3.3. Results

Patterns were analyzed between each of the dependant variables (Gender, Height, Comfort required, and Expertise Level) and the ranking of each of the mats in the different characteristic groupings (Comfort, Durability, Favored, and Purchase).

In addition to assumptions of normality and homogeneity of means and variances, an analysis of variance (ANOVA) requires a random sample of participants and equal intervals within items (Cohen, Manion, & Morrison, 2011). These two assumptions cannot be met with the data in this pilot study. However, ANOVA is a robust technique that could determine whether there is a statistically significant difference in means between dependant and independent variables with a different data type (Cohen, Manion, & Morrison, 2011). Patterns which occurred more than once per color are presented.

Table 9: Patterns between Dependant and Independent Variables

Variable	
Dependent	**Independent**
Gender	Comfort Ranking of Green
	Purchase Ranking of Green
Comfort Required	Comfort Ranking of Silver
	Purchase Ranking of Silver
Expertise	Comfort Ranking of Foam
	Purchase Ranking of Foam
	Comfort Ranking of Silver
	Purchase Ranking of Silver

Variable	
Dependent	**Independent**
Expertise	Comfort Ranking of Cot
	Durability Ranking of Cot

3.3.1. Gender Correlations

There is a correlation between Gender and the Comfort and the Purchase ranking of the Green Mat, which can be seen in Figure 11 and Figure 12. Women typically chose the green to be in the top three in regards to comfort, where the majority of the men ranked it in the middle. No women chose it as the bottom three in their final, purchase rankings, even though 12% selected it as in the bottom three in terms of comfort. In comparison, the same percentage (21%) of males
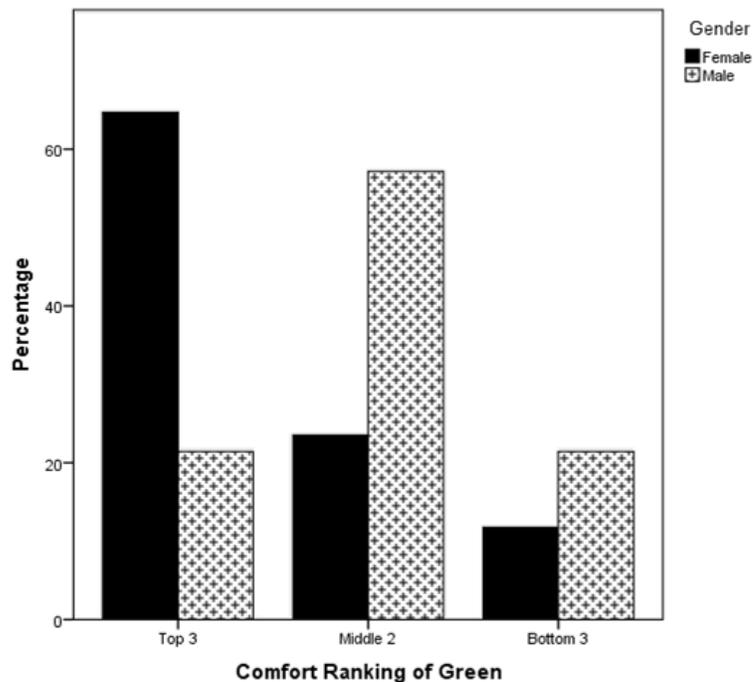
Figure 11: Frequency of Comfort Ranking based on Gender
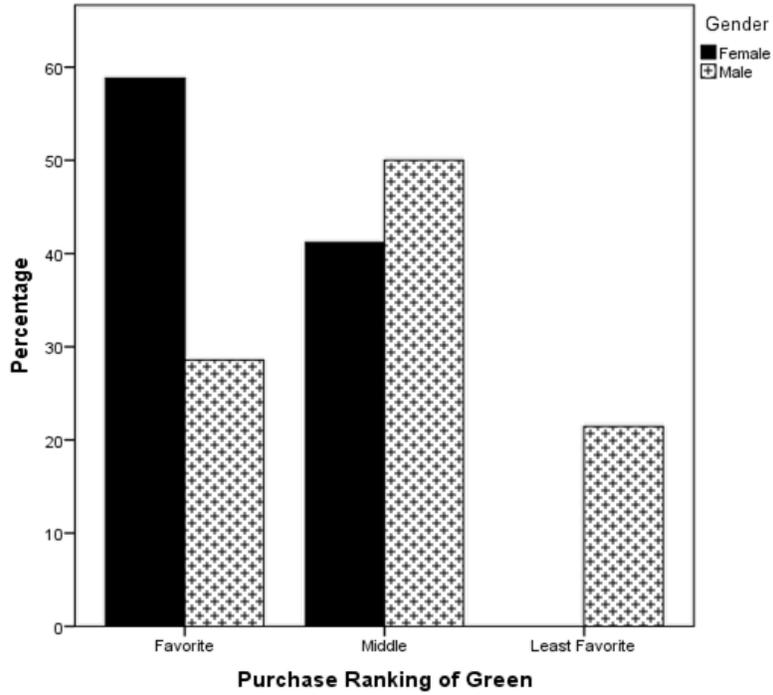
Figure 12: Frequency of Purchase Rating based on Gender

who placed the green mat in the bottom three for comfort did so for their final ranking as well. It was not calculated whether gender and camping expertise had a combined effect on the mat chosen.
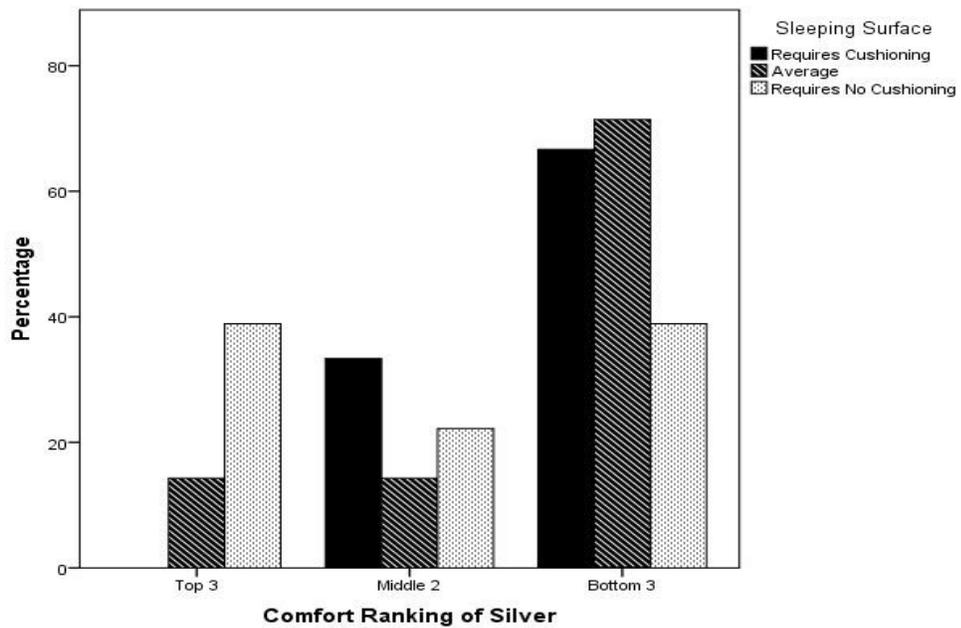
Figure 13: Comfort Rankings based on Comfort Requirements

3.3.2. Ease of Sleeping Correlations

The significant correlations resulting from the different levels required for normal sleeping can be seen in the silver sleeping mat ranking comfort and the final purchase ranking. As seen in Figure 13, those who identified as normally requiring substantial comfort to sleep, 67% ranked the silver in the bottom 3. In the purchase rankings, 83% of that same group ranked the silver in the top three, as seen in Figure 14. Even when taken as a whole, with no separation of comfort groups, the majority of participants chose the silver in the bottom three for comfort (52%), but the majority chose it in the top three for final ranking (68%).
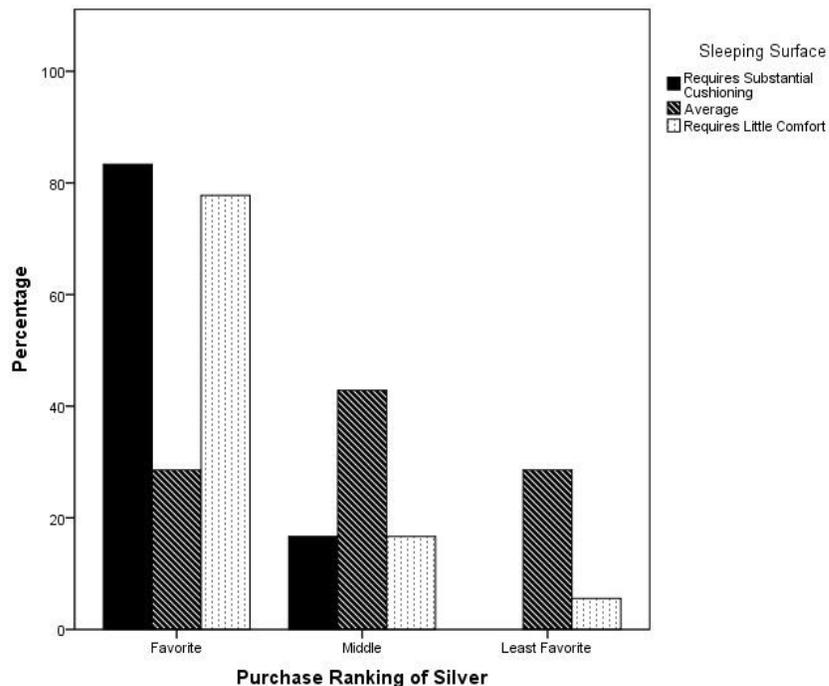
Figure 14: Purchase Rankings based on Comfort Requirements

3.3.3. Expertise Correlations- Blue Foam

The greatest number of patterns were seen when comparing expertise groups, which was what the study hypothisized. These were seen in the rankings of comfort and purchasing for the Foam Mat, in the comfort and purchase rankings of the Silver mat, the comfort and durability rankings of the Yellow mat, and the durabilty and comfort rankings of the Cot. Distribution of the

Foam responses can be seen in Figure 15 and Figure 16. 100% of the Novice group ranked the foam mat in the bottom three regarding both comfort and purchase. 42% of the Expert group ranked it in the top three for purchasing, even though there were only 14% who ranked it in the top 3 for comfort.
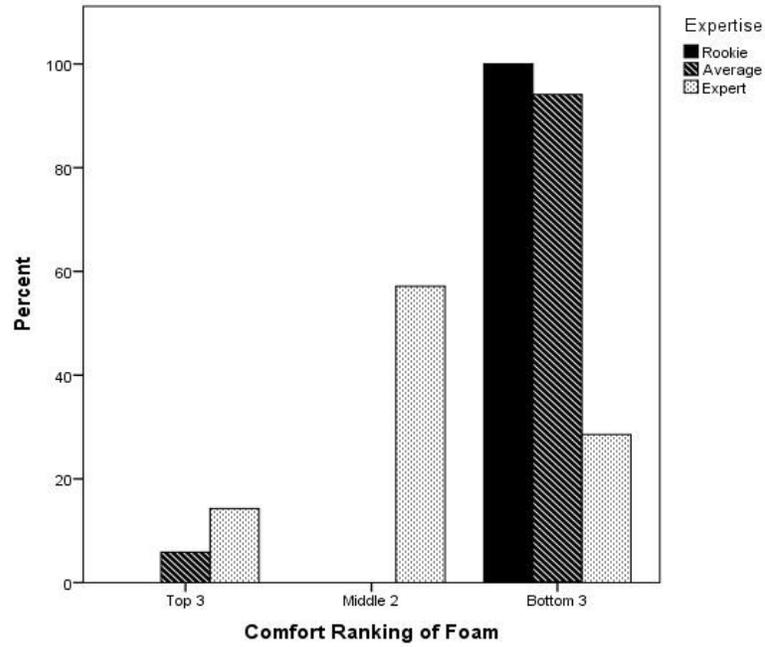
Figure 15: Foam Comfort Rankings and Expertise
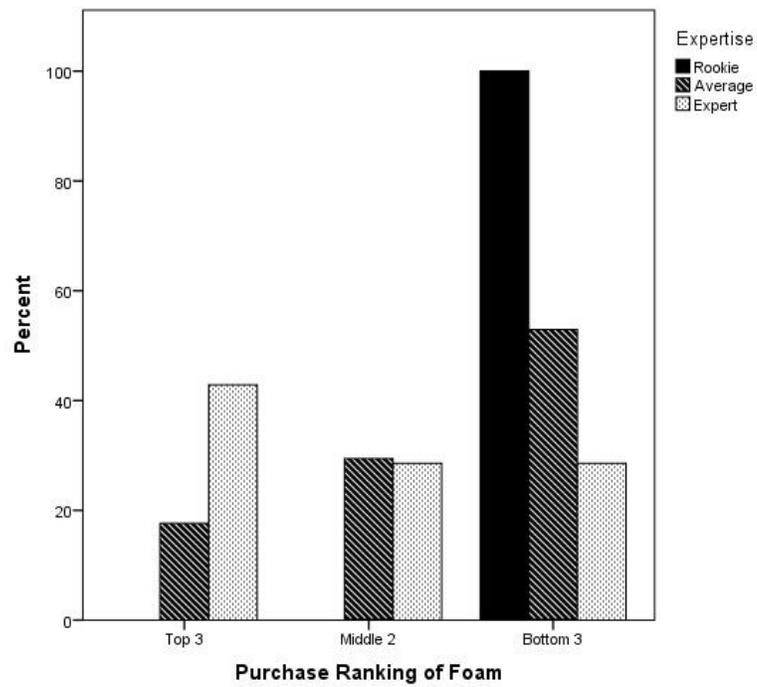
Figure 16: Foam Purchase Rankings and Expertise

3.3.4. Expertise Correlations – Silver Mat

The majority of both the Rookies and Average expertise groups ranked the comfort of the silver mat in the bottom 3, as seen in Figure 17. However, a strong majority of those in the average (71%) and expert (86%) categories ranked it in the top 3 in purchase rankings, as seen in Figure 18.
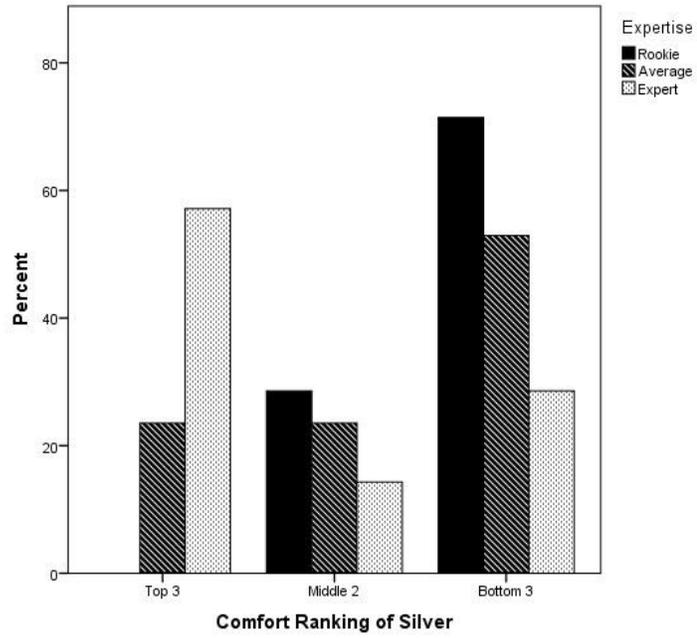
Figure 17: Silver Comfort Rankings and Expertise
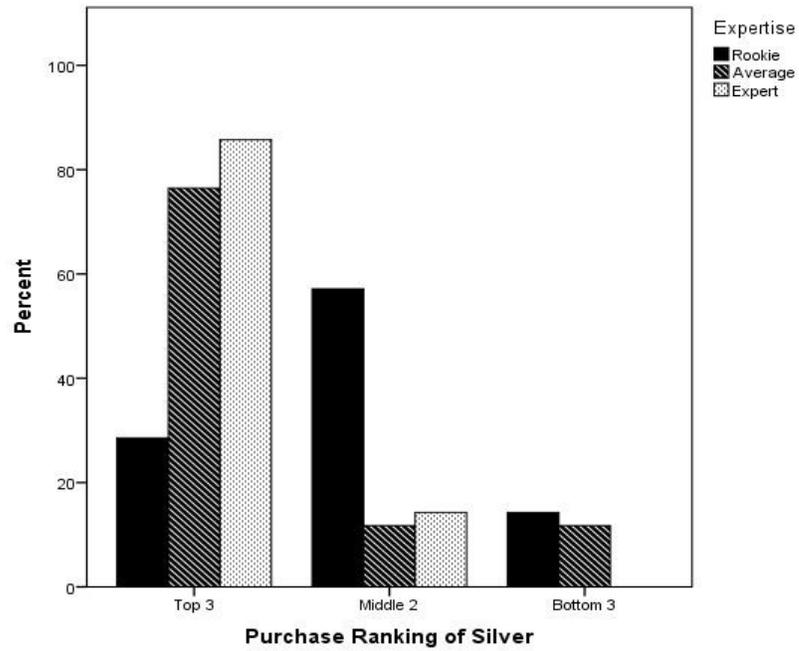
Figure 18: Silver Purchase Rankings and Expertise

3.2.5. Expertise Correlations - Cot

Novices were more apt to rank the cot as both more comfortable and more durable. Both the perceived durability and comfort of the cot, seen in Figure 19 and Figure 20 show significant differences in how the different expertise levels veiw the cot. There are similarities between the distribution between the durability and comfort among the expertise groups.
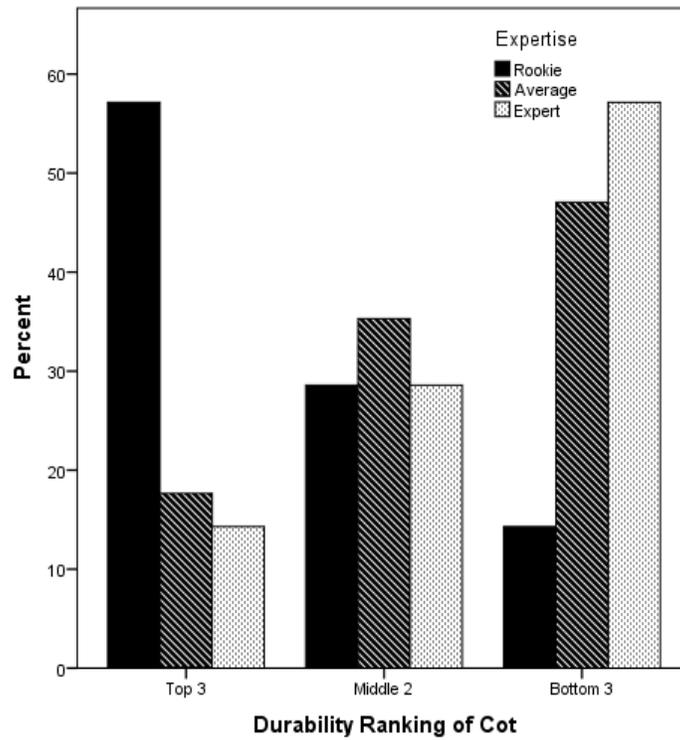
Figure 19: Cot Durability Rankings and Expertise
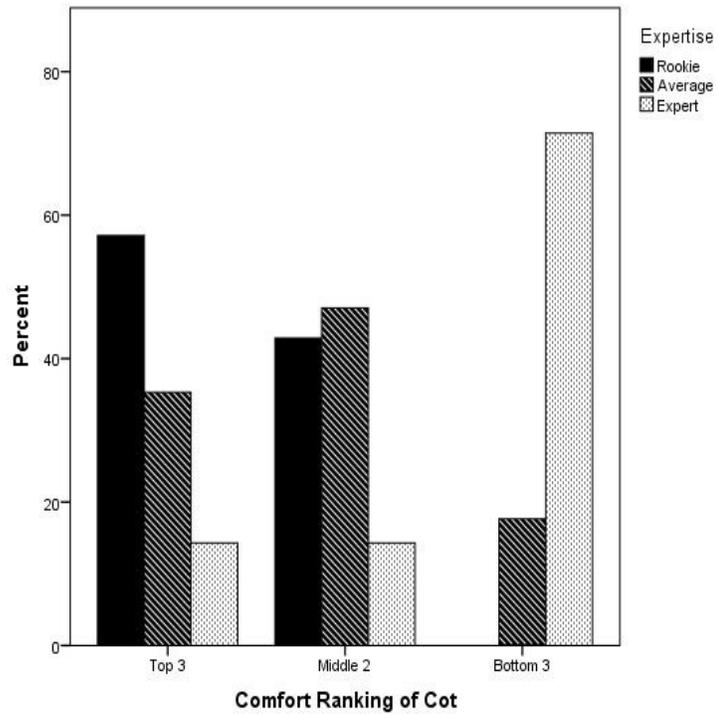
Figure 20: Cot Comfort and Expertise Rankings

3.3.5. Results – Top Ranked

Due to the fact that most people only purchase one sleeping mat, with the exception of those purchasing for an organization like a summer camp or for a family, the figure that holds particular interest is which mat the participants chose as their number one choice, which can be seen in Figure 21: Number 1 Rankings. These rankings were done after the participants had ranked comfort, durability, their favorite, and had seen the price for each of the sleeping mats.
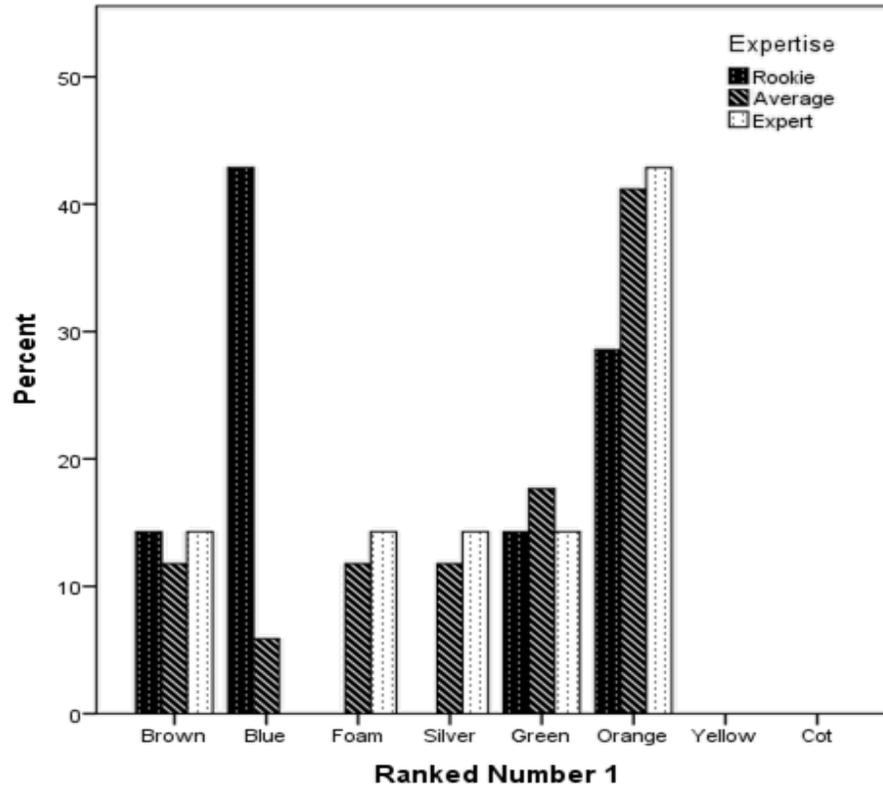
Figure 21: Number 1 Rankings

3.4. Discussion

3.4.1. Gender Correlations

The green open-foam mat was the only product in which there were significant differences between the male and female groups of participants. The green mat was also the only gender-specific mat of the test, as it is sold as a women's sleeping mat. While the participants were not informed that it was a Women's Sleeping Mat, there was a small indication, approximately 1 cm^2, on the mat which they may have noticed. This indication can be seen in Figure 22. There is also a small mark on the carrying bag as seen in Figure 23, however, many participants did not look at the carrying bags.

Figure 22: Gender Indication on Green Mat

Figure 23: Gender Indication on Green Carrying Bag

This may have biased the male participants against ranking it as highly as their female counterparts. Due to the fact that the green mat was the only mat with a significant difference in the gender choices of mats, this could also be the very subtle indication of a good design feature in that it was intuitively more attractive to the audience for which it was designed, in this case, females.

3.4.2. Significant Correlations

For those who were in different ease of sleeping levels, though participants did not think that the silver mat was as comfortable as others, the fact that many picked it in the top 3 of the purchase ranking indicates that many thought that the silver was a good compromise between other attributes. This could also indicate that comfort was not the highest priority of attribute. This is also seen in the silver mat between the expertise levels. In this case the average group demonstrated that comfort was not the main attribute used to rank the silver mat. The novices also shifted the silver higher when it came to purchase rankings, despite it being in the bottom 3 when ranked for comfort.

3.4.3. Blue Foam

The generic foam roll mat was described as the best basic camping pad due to the fact that they are cheap and very durable by an extensive list of sleeping pads (Moss, 2013). I have also found that these are the sleeping mats most often found at summer camps due to their combination of durability, functionality, and price (Ryckman, 2013). It was also mentioned that they are still functional when damaged, unlike air mattresses or open-foam mattresses, which make them a reliable choice for children and the outdoors.

Perhaps those in the expert group also realize this benefit, and this explains why comfort is not the determining factor for participants choosing their favorite as indicated by their most likely to purchase rankings. This does not indicate that the experts did not use comfort as a deciding attribute, but that, regarding the foam, there appeared to be other factors which were deemed important. The fact that there are factors beyond comfort impacting the choice of the experts regarding the blue foam indicates that factors only understood through experience may

be present in some designs. This is further seen by the fact that the majority of those with average expertise ranked the foam mat in the bottom three for both comfort and purchase.

3.4.3. Cot

The limits of the testing scenario were pointed out during the testing of the cot in particular. One of the advantages listed by the manufacturer is that it is able to lift the user off of the ground, and this was also mentioned by one of the participants. "This would be more comfortable than any of the other ones if I was trying it on pinecones or roots (Participants, 2015)." The price of the cot was remarked to be a dissuading factor for many participants in all expertise levels. There was feedback from a participant who was ranked as an expert, who remarked they would rather go without a sleeping mat than pay for the cot or the yellow x-frame. Both options were personally recommended to me and have received good product reviews from those who are trained and experienced in camping.

3.4.4. Orange Mat

It was thought that the high price of the orange mat would decrease its popularity, however the highest percentage of participants in both the average and expert categories chose the orange as the favourite, despite the price. If the orange mat was considered significantly more comfortable than the others, there is no way to determine the gap between first and second place. This then, may have been the determining factor, but it may not have come up as significant because of the similarities in ranking from the different expertise groups, as can be seen in Figure 24. It was chosen as favorite 2.4 times compared to the next closest mat. It was also interesting that the second top ranked choice was also an open-foam mat. Even though there were a variety of types of mats, the two self-inflating, closed-foam mats were represented by over 54% of all top ranked choices.
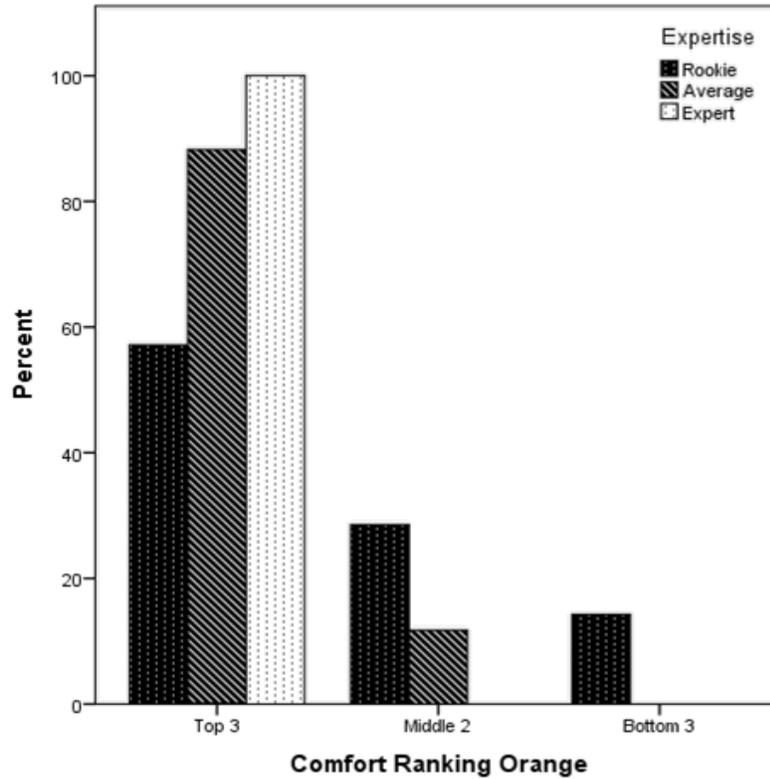
Figure 24: Orange Comfort Ranking and Expertise

3.4.5. Hypothesis

The hypothesis that there would be a significant difference between the selections of participants with different experience levels was supported, however it was determined that expertise is not the sole indicator to dictate which sleeping mat was preferred. Significance was found which suggests a correlation between expertise level and the following ranking choices: purchase ranking of the blue and foam mats, the comfort rankings of the foam, orange, yellow, and cot mats. Significance was also found between other descriptive variables gender and comfort required and ranking choices such as the purchase and comfort ranking of silver. It was indicated that participants with different experiences do have different preferences for products, placing certain attributes above others when deciding their favorites. However, this was not seen to be correlated solely to their camping expertise level. This leads to the supposition that while product

selection is impacted by factors, including gender and expertise level, that there are many more factors which were not able to be studied in this survey. Based on the variability observed between what was chosen for comfort or durability versus the final ranking, the situation was determined to be too complex to identify a singular factor which determines the favorite product of an entire grouping. The sample size was, however, too small to definitively support these assertions. Examples of other factors that may be considered in future studies are:

- Packed Volume
- Weight
- Appearance
- Perceived Assembly and Disassembly Time and Difficulty
- Order the mats were presented to participants
- Brand Loyalty
- Insulating Value
- Length and Width of the Mat
- Fitness levels of the participants
- Weight of the participants

Usability studies have been shown to be reliable even with a participant number of as low as two (Bangor, Kortum, & Miller, 2008). While this is a pilot exploratory study, this study does have value as a test for usability.

3.4.6. Usability

The findings from this study confirm that people do place different importance on product attributes which will affect their purchasing decisions. However, these differences are not due only to their difference in camping expertise, but also to more complex combinations of individual priorities. I believed that, through reverse engineering the participant's experience with the products, I could identify which of the attributes were most important to different users.

However, due to the complex nature of human behaviour, I have found that this is much more difficult than originally thought. Designers should use the attributes present in existing, competing products as a launch pad to start with what attributes may be useful to include. This, however, does not allow the designer to omit the investigation into the target users, but only as a place to start. Once a project area is decided, attributes must be collected and analyzed with the people involved, not simply those identified by competitors.

3.4.7. Future Steps

In the future, I believe that an instrument with rating items would give fuller data as it could be validated with items that would be reversely scored. In addition, more items should be added to the instrument with which to better determine the validity of any findings. I would also advise that the instrument include items about sleeping patterns, including rating statements such as: "I often feel cold while camping" and "I often am uncomfortable when camping". One facet the study did not measure was whether there was prejudice against any of the selections. For instance, one participant responded to the Blue Foam as "those old things that [the camp] gave us when we forgot our real [sleeping mat]". People are very diverse in their decision making, but as this study shows, it is not something that can be reduced to a single, communicable variable. Kolko (2014) notes that people do not purchase items simply because of the functionality, but also because of the way that the product makes them feel.

Analyst errors may exist where my personal bias impacted the instrument creation to a point where I was finding ways to divide the experts into groups. I created an instrument with items that would classify the participants into separate groups, but because of the small number of participants, it is possible that the range of expertise within the participants was not representative of the entire range of users. In particular, I believe that the expert group was not

as full of a profile as could have been surveyed, although the participants identified as expert were more experienced compared to the other participants. Future work should include a higher number of participants with a focus on increasing the number and intensity of expert participants. The high level of expertise considered when purchasing the mats, where multiday trips are undertaken carrying in all necessary equipment and supplies, was not represented in the expert grouping of the participants. I believe that this would put a different priority on attributes which did not appear to be of great concern in this study, such as packed weight and packed size. As these were inherently present for the participants to observe, they were not explicitly pointed out or measured.

This, I believe, explains why both the cot and yellow mat were ranked so poorly. Due to the relative categorization of the expert groups, the relative expert opinion of these participants may not be at the same intensity as those who are more extreme in their expertise. In further studies, I would recommend an inclusion of a higher number of participants, especially of those who are more avid in their camping participation. In order to determine the specific attributes that are important to each group, the hypothesis could also be refined to reveal more specific data. While it was shown that people made different choices for different reasons, deeper knowledge about product selection motivation may be gleaned by phrasing the hypothesis in one of the following ways:

- People who are ranked as expert campers consider [a product attribute] as a more important attribute than [another product attribute]
- Participants who are ranked as expert campers have a smaller range of acceptable products compared to novice or average campers

3.4.8. Inclusive Design

Inclusive design attempts to design products for the widest range of users possible. If this study had shown that different expertise levels were vastly different in their choices, it would make sense to design specific, separate products for each subsection. However, as there was a trend on which mat, or type of mats, the majority of participants ranked as number one, this indicates that a single product could satisfy a larger subset of the user population than originally thought. Clearly, there are limitations to this, where extreme sides of the spectrum, either on the novice or the experienced side, will not be included. It was seen that the orange mat was seen as the favorite mat for many of the participants. This indicates that while campers may have different choices, there are some similarities to what is considered most important. I believe that this results from overlapping acceptable attribute ranges among the different groups. Each of the participants chooses their favorites from acceptable ranges of different mats. While it is thought that some attributes are more important than others, there is also a range of acceptable values for any of these attributes. For example, if the cost and comfort and durability are all acceptable but the weight is 50% of the participant's body weight, that mat may be an unacceptable option. This was mentioned by some of the participants once they found out the high cost of the cot, and is most likely the reason that it was consistently ranked as the bottom choice.

It is likely then, that the top ranked choices made by the participants are representative of the compromise between acceptable attribute values. If an important attribute, such as comfort, is significantly better or more desirable in one product, the superiority of the attribute can increase the acceptable range of another attribute such as cost. This is what was observed in the top selection of the orange mat. Even though it was the second most expensive, it was consistently chosen as people's top choice in sleeping mat because it was overwhelmingly top ranked in comfort. I believe that the functionality of the orange mat, which includes its insulating

value, design for outdoor and backpacking situations, ease of disassembly and assembly, and compact packed size made it a desirable choice for the variety of participants present.

3.4.9. Limitations of Testing

Setting up many of the sleeping mats required that additional air be added to fully inflate them. Because it was unacceptable to have each participant blow up the mats using their mouths, and it was unpractical from a timing standpoint to have the administrator set up and take down each mat, the set up and take down of the sleeping mats was eliminated from the survey. This meant that, while the packed size was present for observation and the participants could feel how heavy each of the mats were, very few participants interacted with the product in that way. It is possible that this was taken into account, but no participants mentioned that as a deciding factor when asked.

3.4.10. Instrument Suggestions

The instrument asked the participants to interact with real products and comment on them immediately, which means that any comments or opinions are not retrospective. This was done because this is said to give a more cohesive, detailed viewpoint (Kolko, 2014). However, the survey was not performed in the actual context of use, which may prevent people from having a correct opinion about how they use it, or the preferences they hold. Some of these may be eliminated due to the fact that we are asking them to rank them, which means that certain situational biases would be eliminated. The participants may not to be able to understand or convey their preferences if they do not understand the situation in which they would be using them. Based on assessment, I observed the participants trying the mats out, which is similar to how the item would be purchased in a store.

The study has some bias towards those with experience as they would be able to intuit which attributes are important to the actual situation where novices would not have a context from which to draw their conclusions. However, this discrepancy is also very closely linked to the point of the study- to determine, if any, the difference in preference between those with and without camping experience. As well, while the study may not be conducted in an environment mimicking that of actual use, it is mimicking the purchasing situation in which the consumer would be deciding between products.

Hypothetical behavior is not a substitution for actual, observed behavior as it does not take into account many of the issues that influence the decision (Kolko, 2014). This is why we used real products, as opposed to hypothetical situations and products, which were then ranked in relation to one another to determine their level of interest comparatively. While timing or circumstances may influence purchasing potential, because all of them are subject to the same circumstances, and because the mats can be effectively judged against one another, the rank of preference can be determined. This is not a yes or no, "will you buy this or will you not", but a "would you buy product A over product B"? This study is based on observations and rankings as provided by the participants. It was noted that users may unconsciously report different results than what is actually being observed, or differently than what they actually would do. This study also has to rely on what people say and report rather than observing their actual behaviour (van Kuijk, Kanis, Christiaans, & van Eijk, 2007). Participants may have stated one thing but their actual practices or preferences may be very different than what they recorded. In future studies, it may be beneficial to request descriptive information after observing actual purchase behavior.

The hypothesis should be refined to give more specific details into the desires and motivations of participant's product selection. While it showed that people have different motivations, the range in which certain groups, either split by expertise or gender or other

descriptors, consider attributes to be acceptable would be more useful for developing design requirements. Through this study, it has been shown that people have different priorities differing levels of importance for certain attributes, which in turn affect their decision of choosing products over others. This information leads to emphasize the point of usability and understanding the humans and human factors that need to permeate the design process.

3.5. Conclusion

The hypothesis that people would have different priorities for choosing sleeping mats based mainly on their camping expertise level was supported by the statistically significant difference rankings of the blue foam mat, the silver mat, and the cot. It was also seen that people have different priorities and contributing factors other than simply expertise level to make decisions while selecting their favorite products. I conclude that decision making processes and influences are much more complex than the descriptors we collected about each participant.

It was also seen that, while the attribute priorities may be different between subsets of the user population, there may also exist a single product that appeals to a larger percentage of users. This shows the importance of understanding the variety of user profiles present and the benefits of applying inclusive design principles. This affects usability in the sense that, while a certain profile of user may have very specific needs, it may be that a broader application of those needs can be found which will appeal to a wider user audience. In this way, one product may have a wider appeal than a number of more specified, niche products. Understanding the users who not only fall into your targeted audience, but those who exist outside of your intended range can help to understand the priorities and motivations of the target users better. This understanding may also increase appeal to a larger audience who would never have looked at the product.

Due to the complexity of user behaviour, it is imperative that designers understand the user from more than a superficial, demographic perspective. Because users are so varied, it is important not to categorize them into a single metric on which the designer assumes is the most important attribute. One underlying assumption is that the products were successful because they were commercially available. However, this does not mean that the designers considered the human factors in their design process. By only looking at the final product and not the process by which the different attributes were decided upon, the motivations and decisions behind the design are not made obvious. As a starting point, the usability of current solutions can be measured and built upon in future designs.

The variety of answers seen by the participants underscores the need for prototyping and iterative designs. Many students, while progressing through their design projects, have very short timelines and do not often have the luxury of first developing an unusable design and fixing it later. It is also seen as common sense to include human factors when it is approached retroactively. It is important, therefore, to understand the mechanism by which human factors are included in design. A well-documented design process may provide insight into the design process and provide a framework by which we can guide students to include usability successfully in their own designs.

Chapter 4 – Case Study on Crash Simulation

4.1. Introduction

Design, and the process of designing, has said to be above all else, the difference between an engineering education and a science education (Hodge & Steele, 1995). While a consensus across all areas on the definition of design has yet to be reached (Self, To Design Is to Understand Uncertainty, 2012), Armstrong describes it as identifying the needs that a new project requires, creating solutions that meet those needs, and delivering the solutions (Armstrong, 2002). It has been defined as the imaginative jump from present facts to future possibilities (Page, 1966), and yet others describe it as the step in the development of products that takes the goals and reduces these to specific inputs for others to manufacture, the step that determines the quality of the product (Adams, 2012, p. 37). Everything in use has been designed in the sense that it has been created or used deliberately to solve specific problems. It is through design that desired outcomes are achieved (Petroski, 2006). The Canadian (CEAB) and American (ABET) Engineering Accreditation Boards both hold minimum standards for design within accredited undergraduate programs (ABET Engineering Accreditation Commission, 2011) (Engineers Canada Accreditation Board, 2015). The CEAB in particular, defines design as the solution to a set of needs in open-ended and complex problems with appropriate considerations for health and safety, applicable standards, and economic, environmental, cultural and societal considerations (Engineers Canada Accreditation Board, 2015). Arvola (2002) states that other design goals include the ability to approach ill-defined, uncertain, possibly incomplete problems to produce novel solutions. While the CEAB has specifically defined their goals for design in the above point, other areas, such as communication skills, professionalism, understanding the impact of engineering on society, team

skills, and ethics can also benefit from educating engineers in design (Engineers Canada Accreditation Board, 2015).

Teaching design increases students' ability to learn, gives them opportunities to respond uniquely to challenges, and highlights opportunities for them to participate in society (Miller & McGimpsey, 2011). Engineering itself is typically characterized by solving problems, but more than simply changing one's surroundings, engineering design is realising new possibilities by determining desirable compromises where resources are limited and needs are diverse (Jones, 1992) (Lima & Oakes, 2006). Through design projects, students increase their understanding of engineering and their technological skills, and better understand the integration and application of the theoretical analysis tools they learn in their classes (The Royal Academy of Engineering, 2005).

While design has sometimes been viewed as outside the realm of what typically belongs in the core of an engineering curriculum, namely natural sciences and mathematics (Muster & Mistree, 1989), it is in a unique position that bridges both art and sciences (Simon, 1982). Design education is of great importance to all engineering students, even those who do not go on to careers in design (The Royal Academy of Engineering, 2005). The task of how to incorporate design into engineering education, how best to teach it, continues to be a challenge, as shown by the large scope of literature describing the best pedagogical method (Collin, 2006) (Kumar & Hsiao, 2007) (Lemons, Carberry, Swan, & Rogers, 2010) (Wood, Jensen, Bezdek, & Otto, 2001). This is further complicated by the idea that, unlike natural sciences and theories, design cannot be solely taught, but must be learned through the experience-based process which requires that students move out of a conventional lecture setting (Muster & Mistree, 1989).

Teaching engineers how best to identify needs and how to understand the complicated nature of problems outside of textbooks has resulted in a shift to include real life problems, often accomplished through increased industry participation. By exposing students to real needs, users, and clients, the students are able to be directly involved with 'messy', open-ended problems. Students are unlikely to willingly approach complex and uncertain problems as most of their education has centered around known and defined problems (Self, 2012). It is, therefore, imperative that engineering education involve situations in which students can engage and use uncertainty to approach ill-defined problems such as those which typically characterize design problems (Self, 2012). These projects allow students to increase technical skills, and to understand the context and process of design. The educator is able to act as a guide through the design process without the simplified and caricatured solutions of contrived problems (Zlotkowski & Longo, 2006) (Hall & Childs, 2009). Through the responsibility given to the students in a real-world design project, they move from being passive recipients of knowledge to active participants in their own education (Muster & Mistree, 1989). This forces problem solving skills to be developed within the real environment of uncertainty, and forces students to consider the messiness that accompanies any problem that involves people. When engineers first encounter problems such as this- open problems with no single, specified answer- they are often bothered by solutions that are compromises as opposed to 'right' (Muster & Mistree, 1989). Their engineering education, therefore, should help these students by exposing them to design early, helping them learn the process by which they are to approach the types of problems that they will inevitably encounter after they leave university. Design education is tasked with the difficult task of increasing abilities and confidence in engineering students so that they can apply these skills to the design of new systems and products (The Royal Academy of Engineering, 2005). Each design project should be shaped by the problem it is attempting to solve, so it is important that students receive a

framework which guides them through principles rather than given specific steps to use identically in every problem (Devon & Jablokow, 2010).

However, though the students are involved with real projects, this does not mean that they take into account the users or the human factors involved beyond the technical aspects of the design project. The reasons for this are often attributed to their increased focus on technology, specifications, and engineering sciences such as material properties over the more subjective field of usability. This is not only a student bias, but also related to their education as engineering school generally focus on sciences and engineering analytical techniques (Adams, 2012). The consequences of this tendency towards formulaic and analytical thinking become especially apparent in capstone design projects, when engineering students in their final year of undergraduate study are given year-long projects often with industry clients and real life problems that demand a working solution. Many teams will end up with a product that meets the technical requirements, but the solution often is unusable, undesirable, or inappropriate for the application, never to be picked up or explored further.

This is not a problem isolated only to novice product and process designers. If it is not addressed or considered, a lack of human factors can continue to affect the success of products that end up in market. A majority of medical errors are often attributed, not to carelessness in an individual, but to processes, systems, products and conditions that either lead people to make errors or fail to avoid them (Institute of Medicine, 2000). The products in these circumstances are not made by novice designers, but have passed thorough regulatory and vetting processes. Therefore, it is important that students are educated with the knowledge and understanding to make designs that are usable and desirable.

I believe that many of these technically competent but otherwise unusable designs are due to a lack of human factor considerations within the design process. Many engineers do not see abstract concepts of usability, desirability, cognitive limitations and other human factors as having an impact on the design of technology. However intangible they are, Vincente (2003) argues that not only are they real, but they still have an important impact on the success of functioning technological systems. Through a crash course in design, Stanford's design school participants are encouraged understanding the user's motivations is the most important part of the design background knowledge (Hasso Plattner Institute of Design, 2015). Designers who make completely false assumptions about the natural world would not be seen as technically competent, but when they make unrealistic assumptions about human nature, users are often blamed for errors or failures encountered when interacting with the design (Vincente, 2003). While it may have been once accepted that technically superior products were innately complicated and usability was simply a bonus, lack of user considerations is now seen as a major source of discontent among consumers who use and purchase products (Jordan P. W., 1998).

Although there are equal minimum requirements for engineering science and engineering design (Engineers Canada Accreditation Board, 2015), higher education institutes are more likely to be near the minimum of design requirements rather than the engineering science. Engineering design is where complex, open-ended problems are addressed, and where ergonomics naturally fit into engineering education. However, human factors are not typically addressed in engineering education, and as a result, students often either overlook them in their design processes or attempt to add them on as a last minute afterthought to increase desirability. Through the emergence of computers, engineers have gotten stronger at technical problem solving, but have not increased the focus on how to make products that increase the quality of life through the use of human-centred designs (Adams, 2012). Engineers have been trained and encouraged to focus

on the technological aspects of design, so the 'softer', non-analytical aspects of technology fade from the focus, attention, and expertise (Vincente, 2003). This is mirrored in the treatment of appearance of many engineering designs. Although engineers may appreciate the elegance of aesthetics, this facet is often overlooked in the excitement to add a new feature, solve a problem in a unique manner, or implement cheaper solutions (Adams, 2012). While the design process will vary significantly between industries, with different values placed on certain aspects, the integration of humans, whether as users, operators, or manufacturers, must be considered. Human factors are an important aspect of engineering design that must be introduced and nurtured in all designers, including engineers.

How to best approach developing human factor skills in engineering students is a particularly challenging problem for engineering educators. As I saw in chapter 2, it is difficult to successfully incorporate human factors within a design project, even when the intention is there. In chapter 3, products available on the market were investigated, but analyzing a product already through the design process does not give insight into the reasoning behind its success. For this reason, I wanted to investigate the process by which a project incorporated human factors to make a successful design. This was decided to be done through a case study.

4.2. Case Study

The focus of this case study is a capstone design project from the Department of Mechanical Engineering at Dalhousie University. The project was sponsored by a company which asked the students to create a system that would mimic the inside of a seaplane for crash simulation purposes. The company currently offers training of helicopter evacuation techniques, modeling and simulating aircraft being submerged in water for more thorough and realistic safety

training. As there are also seaplanes which crash over water, the client wished to expand into the evacuation training required for seaplanes.

The group writes in their final report that the project was considered a success as they both achieved and surpassed the design criteria. Others also agreed on the success as their client was satisfied with the results, and their project was ranked the top among their class by both professors and fellow students. This also serves to demonstrate that human factors can make a project more usable without sacrificing the traditional views of a successful project in terms of budget or timeline. This final assembled project, as well as an exploded view of the pieces can be seen in Figure 26: Assembled Project and Figure 25, respectively, both taken from the group's final report.

Figure 26: Assembled Project (Maddalena, Felling, Lord, & Marin, 2013)

Figure 25: Major Part Assemblies, Exploded View (Maddalena, Felling, Lord, & Marin, 2013)

4.2.1. Reasons for Choice of Project

At their final presentation, the team mentioned the human factors present in their design. Due to the inclusion by novice designers of these rarely considered aspects within the project, it was thought that this would be an interesting design process to evaluate and analyze. I wished to identify the methods used to integrate the human factors in the project and understand how the mechanisms could be replicated in the future as a way to inspire similar considerations in future projects. This work hopes to identify what factors influenced an increased consideration of human factors, of use environment, of installation procedures - factors that are often overlooked by engineering designers, and which led to the success of this project. This project began at the final design presentation, and continued by reading through the team's final report. Other submitted work, such as the testing summary, the project inspection report, and the fall term reports were also examined. I also was given and examined three of the four team members' logbooks, and spoke with one of the team members regarding their inclusion of human factors. A meeting with the client was also set up to determine the success of the project after it was delivered to the customer.

From the documentation, it was said that the client provided a clear description of what they required, which the team disseminated into a list of quantifiable requirements (Maddalena, Felling, Lord, & Marin, 2013). They are as follows:

1. Must integrate into the existing Modular Egress Training Simulator (METS). Specifically, it can be contained within the 1.65 m wide x 1.78 m high x 4.26 m long frame and it will work with the existing metal grating.

2. Must accommodate at least two people at a time for training.

3. The seat orientation must be adjustable to three different positions: 0°, 45°, and 90°.

4. Must meet or exceed the anti-corrosion characteristics of the current METS module.

5. Must meet or exceed the loading characteristics of the current METS module.

6. Must facilitate flexibility for simulation parameters (eg. door or window release)

7. Must be able to be installed into a METS from storage by a two-person crew in two hours or less.

8. The seating must be able to re-orient in 30 minutes or less during a training session.

In addition, some desirable but not required qualities were indicated, including matching the egress path to an existing METS egress path, using either a single or no tool for installation, and minimal part failure risks while in operation (Maddalena, Felling, Lord, & Marin, 2013). At least three of the requirements (2, 7, and 8) as well as the desires for limited tooling and matching egress paths are directly related to usability, which I will expound on further in the sections following.

4.3. Identified Considerations of Human Factors

There are several user considerations present in the project that I felt were indicative of good human factors throughout the design process. The elements were identified in several different sources, including the final design presentation, three of the four team members' logbooks, an interview with the client, and the official documentation found on the team's website such as their final, build, and term reports. By identifying these factors, explaining why they are useful, and in what way the team indicated they were included, I will demonstrate why

they are important and how I believe they impacted the success of this project.

Gloved Hand

One of the human factors that was felt to be particularly insightful was the realization that the product was likely to be used and assembled by users who would be wearing gloves. This factor was mentioned solely in the final presentation; it was absent in the final report, the other documentation, and the three logbooks I examined. This environmental consideration showed keen attention to the usage situation, but as I could not find any basis for these decisions, it was unsure where it originated. After speaking with the client, he mentioned that, while he could not remember whether he or the team had specifically come up with that facet of the design, he had encouraged them to sit in the apparatus and they asked many questions about who would be operating it, what they would be doing, what equipment they would be wearing (Swain, 2015). He believed that it was likely during this time of inquiry that they were told that the user would be wearing gloved hands. When they came to design the size specifications of the handle, this was evidently remembered and considered, even though it was not documented.

Limited Required Tools

Human considerations in design do not come only in the consideration of the end user, although that is a huge consideration. It also comes in the form of who, where, and how the product or service will be installed, manufactured, and repaired. By including a requirement limiting the tooling, it is shown that the understanding of increased confusion with increased numbers of different tools has been incorporated. Ease of assembly has been shown to increase with limited or no required tooling (Selvaraj, Radhakrishnan, & Adithan, 2009), so making this an integral requirement in the project definition is helpful to keep the team focused on this part of the design.

Limited tooling was mentioned in their final presentation, as well as in their logbooks, their reports, and by the client in my interview with him. Changing the walls from one type of plane to another requires no tooling, the installation of the simulator requires three tools – a socket head and wrench, a spacing tool which the team created, and a plumb line (Maddalena, Felling, Lord, & Marin, 2013). While it would have been ideal to either require no tooling, or to use a tool that the client already had for their other products, with which the other employees were familiar, the spacing tool that the team created was simple and intuitive. This demonstrated that they considered this aspect of the design from the beginning of their process. This was seen as originating from the first meeting with the client, the notes of which were transcribed into one of the logbooks.

Limited Assembly and Reconfiguration time

In their presentation, reports, and logbooks, the team emphasized the importance of assembling and reconfiguring the design in a specified amount of time. One of the project requirements, the assembly time is closely related to the limited tooling in the sense that, while it does not affect the end user of the product, the participants in the training courses, it does affect the employees at the company. By creating a design that required a limited amount of time to either install or rearrange to another configuration, the importance of the intuitive nature of the design was enforced. This was also first seen in the project requirements given to the team in the first meeting with the client. During our interview, he mentioned how important it is to consider the limited cognitive and physical limitations to which humans are subject. He mentioned it was because he wanted the team to keep these limitations in mind that he required them to put a limit on the time required for the design (Swain, 2015). The client incorporated the user requirement into his definition of the project.

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Passively Locked

The aspect that was brought up most consistently among all the sources was the fact that the primary locking pin would be passively locked. This was mentioned in all three logbooks, in the presentation, final design report, and by the client. By designing for the inevitable forgetfulness of humans, this team showed insight into how design for users should look like. By eliminating the need for humans to be constantly diligent in order to be safe, they have tapped into the understanding that human error can more often be attributed to design error.

Focus Group

The team created a focus group held at the SSTL to get more opinions on their design. While this was not found in any official documentation, or discussed in their final presentation, it was found in one of the logbooks. The focus group took place in October, which means that while the team did come to the meeting with some ideas for solutions, the timing allowed the students to work this into the design planning. This focus group, whose participants appear to be employees at the client company, presented the group with important, insider information into what it was like to interact with these products. One of the more prominent concepts, the idea that there must always be an alternate exit strategy to ensure the safety of the staff and participants, was similar to what I had also heard from my own interviews of safety professionals (Messenger, 2015) (Swain, 2015).

System Power

Two of the logbooks showed evidence that they considered how the entire training system was to be powered. They considered human, gravity, and pneumatic power sources, although the system was already powered and it was not within the scope of their task to change it. Several considerations that they made included an understanding of the limited force able to

be exerted from humans, understanding that human actuation would result in human error, and require training of the humans tasked with operating it. They also included the realization that humans require to have spaces to work in, which increases the size of any solution. There were also worries about the safety requirements resulting from human power, but not in any of the other forms of power. This human factor consideration is fairly shallow as they did not investigate the human power needed for their specific design, and it did not ultimately change their design course.

Mimicking the inside of the seaplane

Because people need to respond instinctively, the situations in which they practice must be as similar as possible to what they will experience in case of an emergency. In an industry of safety, it is important to realize that in an emergency, the participants will be under a great deal of stress. It is, therefore, crucial, that the actions they must perform to bring themselves to safety are mimicked as closely as they can during the safety exercises. The benefit of the training is not only the knowledge of what they must do, but muscle memory through the physical experience of going through the actions. This requires that the safety training as closely mimic the actual emergency as possible, and means that environmental factors need to be accounted for. The ability to get people out safely in case of panic while training is also very important as people will not do this naturally on the first try (Messenger, 2015). Training must include the recreation of the type of aircraft in which the users will be flying, including such details as identical seatbelts and clothing worn by the participants. Environmental factors such as ambient noises, weather conditions, and the disorientating effect of falling into water are also accounted for by the company in an attempt to better train its participants.

The client mentioned that he had already determined that he wanted a certain type of airplane, specifically seaplanes, simulated due to the number of accidents experienced over water (Swain, 2015). This, then, is the reasoning behind the project requirement of two people being able to fit in the design, as this is reflective of the types of planes in which they wished to model. There was mention of specific plane selection in two of the logbooks, with their choice justified due to the prevalent use of that model. The final design allowed for switching between different planes, due to the team's design of a reconfigurable frame which could afford many different types of planes. The company now advertises that it can mimic six different fixed-wing aircraft for safety training, all designed so the trainee has to operate and exit just as if they would on the aircraft that they fly in (Survival Systems Training Ltd, 2014).

Fit into existing system

One of the strengths of this design was its incorporation into the company's current operations, including being integrated into one of the two current training modules. It is important to understand that designs do not exist in a vacuum, but need to function in context (Löwgren & Stolterman, 1998). By expanding on the current functionality of the broader system, the team was able to use the current design for the design fixture. This allowed the team to avoid drilling new holes into the existing structure, and showed that they were aware of more than only their project.

Default locked pin position

An additional consideration that was noted in their final presentation and throughout the report was the safety feature of a passively locked pin, which implies that the team took time to think through typical use scenarios. In the health care system, it is understood that errors are most easily prevented by making it harder for people to do the wrong thing, with the default being

the safe or 'right' thing (Institute of Medicine, 2000). While this is not meant to promote careless and inattentive users, it does attempt to prevent errors made through inevitable forgetfulness and human error.

4.3.1. Sources of Human Considerations

While the available documentation in the form of their first term and final reports did mention some of the human factors discussed above, it was not clear from these reports what the justification was behind these considerations. As I looked through the logbooks, I had hoped to better understand where these human factors were originating, in what capacity they were first brought to the team's attention. Looking through three of the team members' logbooks also did not clearly identify the source of the human considerations. There were a couple of notes to indicate the member in charge of construction was aware of some human challenges- phrases such as "hard to locate", "rounded corners to prevent jamming", and "installed in under 1 minute" were used to describe and justify design decisions (Maddalena, MECH 4010 - Design Project, 2013).

Initial research identified this team as being formed from diverse students including mature students with previous degrees and varying personal interests, such as performing arts, theatre construction, construction, the outdoors, and previous work experience in the field of Maritime risk. This combination of diversified backgrounds may have played a factor in the design process, and a diversified composition has been observed to be linked to innovation within organizations (O'Reilly & Flatt, 1989). The team also seemed to effectively work together, a trait that must be present for diverse teams to perform well (Ancona & Caldwell, 1992). There were, however, other factors that likely impacted the team's performance. An examination of their final report indicated that many of the human factor requirements and suggestions originated from

the client, who insisted on many of the considerations based on the existing platforms that exist for helicopter training.

Considerations made by the team also seemed to be very indicative of the fact that they considered themselves to be typical users. The team, who knew the design and setup quite intimately, performed all assembly tests, and Requirement 2 (Must seat 2 people) was considered complete because two of the team members were able to fit in the completed design. Whether the team considered anthropometrics to determine that they were representative of typical users is unclear. The documentation showed no consideration of anthropometrics or biomechanics in any of the sizing or the physical installation requirements. After speaking with a team member, she also confirmed that they did not consider the anthropometrics of a typical user to determine if they were served by the design presented.

The third, and final, logbook I read was the most thorough, and of the team member's I believe was the secretary or note taker of the group. It was in this logbook that the similarity was observed between what the client required of the team and what appeared in the final requirement list. From the first meeting with the client, there is a list indicating the design requirements given to them. These include fitting the existing ring, interacting with decking, orientable to 0°, 45°, and 90°, swappable paneling, a level of refinement similar to their manual one, two (2) seats being required (although 4 was indicated to be preferable), installed by 2 people in 1-2 hours using only hand tools, and that the configuration needed to be able to be changed in approximately 10 minutes. They were also given three possible types of seaplanes from which they were to pick the most general. Human factors were also mentioned as the smallest opening would be the worst case scenario (Felling, 2013).

It is possible that the human factor considerations were brought up in a discussion among the group members as opposed to individual brainstorming and was thus not recorded in any of the documentation. However, this is thought to be unlikely considering how the team went about testing those human-biased requirements. This is also negated by the fact that most of the human factor elements mentioned in the logbooks are done so in the context of client meetings. One of the team members also noted that they did not investigate different areas of human factors beyond those which were given by the client.

4.3.2. Client-originated considerations

The company, whose CEO has a master's of education and a background in teaching, has a rigorous devotion to usability, with the reputation of the company built on safety training through experiential learning. Blind trust in the client's understanding of the problem can be major pitfall to design, leading to failure and a misallocation of valuable resources (Keech, 2006). Part of the skill of engineers is to recognize the difference between and reconcile the perceived requirements of clients and what they need in reality (The Royal Academy of Engineering, 2005). However, when the client has a clear understanding of human factors and how best to incorporate them into the design, it is possible that following their direction is the most beneficial to the design process. In general, designers cannot rely on the client to properly articulate the human factor components and how to best incorporate it into the design requirements.

4.4. Discussion

I want to understand the mechanism which made this design so successful. By doing a case study of a process where ergonomics was integrated into a successful project, I hope to be able to use the methodology to help guide other students to likewise incorporate them. There were several factors attributing to the success of the project, including a hardworking, motivated

team of intelligent, diverse students. Additionally, the clear vision and the specific problem definition from the client created an environment in which the team's efforts could be directed to a well-executed solution. Although the client pushed the team to ensure they incorporated human factors, a less capable team may not have been able to accomplish the same outcome, even if similarly pointed. A combination of the team's effectiveness and the client's guidance came together to create a successful solution.

4.4.1. Steps in the Design Process

These students took the problem given to them by the client and created a solution which followed the client's direction and matched the embodiment envisioned by the client. Stanford's design school, also known as d.school, encourages the use of five steps or mindsets which they believe every design should incorporate. These steps include empathizing, defining, ideating, prototyping, and testing (Hasso Plattner Institute of Design). I believe that this team started their design process at the third step of ideation or brainstorming, with the project landscape already scoped out for them and the project definition handed to the team. Engineers often start with the problem already defined, where they are expected to simply build what others have designed (Hasso Plattner Institute of Design, 2015) (Monteiro, 2012). In order to design the right solution, research into the problem and the problem landscape is needed. Understanding and outlining the correct problem is the only way that the correct solution can be found (Hasso Plattner Institute of Design) (Monteiro, 2012). The first step in a design process, where the definition of the problem is done, is said to be the most difficult part of the entire process (Caswell, Johnston, Fauvel, Douglas, & Eggermont, 2004). This is reflected too, by the design project described in an earlier chapter. As there was little specific project description and requirements, the project had no direction, and no final measure of success.

4.4.2. Problem Definition

As I looked through their documentation, I saw little evidence that the team was forced to empathize or understand the problem landscape, or justify why the project tasked to them was the right problem to be solving. While they did generate several potential solutions, the course of action was more implemented than generated. The "what' was already decided, the why was determined, and they needed to figure out the how. The d.school highlights the transition between define and ideate as the difference between determining the challenge and focusing on generating solutions to address the identified challenge (Hasso Plattner Institute of Design). While design is iterative, and the specific chronology of steps is not linear or even sequential, the following steps are often seen within some part of the design process: Define the Problems, Generate Potential Solutions, Decide a Course of Action, Implement Chosen Solution, Evaluation (McQuain, 2012). These students were able to skip or eliminate the first two steps entirely and decide on a course of action to solve the given problem based on a trust in an explicitly clear client.

While interviewing the client I asked how much pushback he had received from the team in the areas of problem definition and justification for solving the problem he had presented to them. He explained to me that, in this project, before giving the idea to the team, he had researched the area thoroughly and had justifications behind it which he presented to the team. He mentioned that it was important to him to get the team to buy into the idea, and was intentional about "selling" his idea to the team (Swain, 2015). He brought them to the implementation site and explained to them the importance of and justification for what he wanted to do. He also explained why he had chosen what he did and made sure that they were on the same page before allowing them to go and brainstorm solutions. In this case, the reasons for the project had already been justified to the team before they began, which does not mean

that they blindly believed the client, but that they had received sufficient reason to believe that the problem the project was addressing was indeed the one that should be solved. If we have determined that problem definition is the hardest part of the design process, and that human factors need to be incorporated into the problem definition, we need students to be able to both question the problems definitions given to them by their clients and provide justification for their problem framing to better communicate with clients.

Many design models start with project definition, or problem finding as the beginning step of the design process. Jones (1992) suggests that, depending on the project, you can start at different steps in the design process. While a socio-technological design may require intensive empathetic understanding of the project landscape and a more detailed exploration of the project scope, a simpler project may allow the designer to start further down the process. Perhaps in the case of a simpler project, it would be enough to simply evaluate the alternative designs and choose to implement the one most appropriate for the project. He argues that as designers move further along the process, they move away from a vagueness and generality towards steps which are more concrete and certain (Jones, 1992). However, if the students are conditioned to expect these simple projects even in their design projects, which are to be their exposure to the world of messy, open-ended problems, it is no wonder that they are hesitant to engage in situations of uncertainty. Explicitly defined problems with solutions that exist and only need to be discovered through facts or truths already dominate the education of engineers (Self, To Design Is to Understand Uncertainty, 2012). Framing the problem correctly includes understanding the situation, describing the situation using known concepts, and using both patterns of reasoning and problem solving to find a way to act within that situation to find a solution (Dorst & Tomkin, 2011). One of the main benefits of incorporating real projects is the practice of defining the problem in the midst of ambiguity. Inexperienced designers, especially students, tend to rush

down a track that they perceive as defined, moving swiftly to define their solution (Self, To Design Is to Understand Uncertainty, 2012). While this may be appropriate for some problems, this is certainly not applicable to more open-ended problems. If they continue as if every problem is so easily approached, they can miss the innovation and creativity and fullness of project that may occur had they explored the project definition more fully (Self, To Design Is to Understand Uncertainty, 2012). While definition and convergence are necessary parts of the design process, it is important that the students first learn how to first explore and define the problem before converging on a single solution. This then is the reasoning behind putting novice designers on projects where there is not full problem definition, to allow the students to fully explore the project landscape and understand the problem's scope. Designers are required to produce unexpected solutions to problems, work with uncertainty and incomplete information, and imaginatively solve problems (Lawson & Dorst, 2009). If we give students problems which do not allow them to fully explore the ambiguity, they will be ill equipped for the projects and jobs that await them once their education is finished.

It has been shown that many problems occur from incorrect problem definition, and an inability to include human factor considerations in the design process from the beginning. If, as I believe, the likelihood of success for this project was increased because of the clear and purposeful project direction, this team was greatly helped by their thorough and descriptive client. They were able to avoid the most difficult obstacle, problem definition, and were guided towards solution formation. Jones comments that the complications of design arise from the fact that designers are forced to use what is currently seen to predict a future solution that only comes to pass if they are correct in their assumptions. Designers need to both predict what their effect their design will have on the problem as well as go through the actions to bring about this effect (Jones, 1992).

4.4.3. Depth of Human Factor Considerations

It should be emphasized that these students did do a good job; the project was a success, and the team did a commendable job of incorporating human factors into the final design. Successful design, however, is not simply about designing the technical requirements of the project, but about the required effects of that design for the client, users, and society (Leurs, 2014). I do not believe that the successfully considered human factors resulted primarily from the design process that they employed, but because many of the considerations originated from a client who was both clear and insistent on the inclusion of the human factors in the design requirements. It is impossible to know what process the team would have taken if the problem was not so thoroughly defined for them. The work of translating and meeting those requirements into a workable, accomplishable design is a comment on the engineering skills of this team. The team had a difficult task in front of them, but they had the advantage that a major hurdle had already been overcome. By providing a project definition riddled with human factors requirements, the team could focus on the technical implementation of those ideas. This analytical execution of solutions is typically where engineers succeed, which makes this project less enviable from a student design process standpoint.

Without a real understanding of the users, human factors can appear be present without a real consideration for the humans affected by the design. This lack of understanding can take the form of considering either the wrong users, or considering too narrow of a scope of users which includes assuming that the designers themselves are representative test subjects for the design. By creating an environment in which the team became the end users validating the human aspects of the end product, it is demonstrated that this team did not fully understand the purpose behind incorporating human factors into their product requirements. One of the key factors that human centered design principles stress is that the designer is not the end user; the designer is

not designing for themselves, but for an end user (Hasso Plattner Institute of Design, 2015) (Lund, 1997). Through their validation and testing methods it appears that this team did not understand why this human factor was included, unless they received confirmation from the client that as would have been clearer if they had developed and integrated the human factors into the design requirements themselves. Design, from a more holistic standpoint, is more than just the design of objects, but the creation of both physical and virtual objects that are good fits for humans in both the physical and psychological aspects (Vincente, 2003, p. 59).

4.4.4. Technical and Human Focus

The strength of engineers is also said to be one of their weaknesses- since they excel in their technical expertise, it is easy to forget that other people do not have similar technical backgrounds or familiarity with the design (Vincente, 2003). Many design exploration exercises would be helped by assuming that the designer's preconceived notions are likely to be wrong, and only to be trusted when confirmed by an outside source. It should be made known to students that it is more useful to acknowledge that they have a false picture of the aspect of life they are trying to design for than it is to assume they have unmerited insight into every aspect of the world (Jones, 1992).

The inclusion of human factors does not mean the exclusion of solid technical design principles. Instead, combining the technological with the human is an important aspect of design that, up to now, engineers are being criticised for missing. I think the separation of them into two different steps is part of the problem that exists currently. Both sections must be done if a successful project is to be designed. It may not be possible to do them simultaneously, but at the very minimum, they should be done alternatively through the iterations. Perhaps if we chose to keep them together as a symbiotic system, the missing connection between human and

technology would not be so pronounced (Vincente, 2003). Neither can be ignored or promoted to the exclusion to the other. Engineers typically are strong on the technical aspects of design, which they, understandably, know more about than the typical user. However, there is also a lack of understanding of how people actually interact with the designed technology (Vincente, 2003).

4.4.5. Guidelines for Students

Making students aware of the necessary presence of human factors is not enough, similar to how a simple willingness to be more creative does not equal the complicated reality of actually increasing the innovation and creativity in projects (Cohen R. , 2014). Helping students to increase the understanding and empathy they have for the end users will help them to recognize that the need for usability is present from the start of projects. The students also need to have a value attached to the inclusion of human factors; they need to know why they are included, and why they are important (Swain, 2015).

The problem definition this team utilized was one in which the human factors were laid out for them, and they fulfilled the requirements without the deeper indications representative of true understanding of the reasons behind the considerations. By demonstrating the value of usability, guiding students towards practices that make it possible, and requiring that it be integrated by the students into the project definition and requirements, it is hoped that more user-focused, human-friendly solutions will be created by engineering students. If we want to help students be able to create usable solutions to properly defined challenges, we need to both instill the value of why human factors are an important consideration. In addition to this, we must also give the students difficult and vague enough problems to allow them to try, and possibly fail within their attempts.

4.5. Conclusions

Design is becoming increasingly human-focused as clients and customers demand intuitive and creative projects. Designers who become aware of this, basing their focus and requirements not only on technical specifications, but who also move deeper into the problem definition to include those using, manufacturing, and repairing their products, will be more successful. This does not mean that process, rationality, and analysis are discarded (Cohen R. , 2014), but that tools are added to them to move design projects further into a realm where messy problems can be approached with innovative, human-focused, and creative solutions. There is no checklist to rigidly follow to attain a well-designed product. Kathleen McLean, an exhibit designer with the Exploratorium, states that there is no one key or tool which will fit for every circumstance. It is only when we have an arsenal of keys that we can properly decide which is useful for our specific purpose (McLean, 2004). Human factor considerations may not be the sole key on our key ring, but it is a key that opens doors to increase empathy and, therefore, the likelihood of a creative, innovative, and successful design.

Caswell (Caswell, Johnston, Fauvel, Douglas, & Eggermont, 2004) cautions that the retrospective view of a successful design breaks down when a novice attempts to apply the process to a real design project, as suggestion and portrayal of other design processes does not necessarily translate well to application. Perhaps the tool we need, then, is not to encourage students to simply think about human factors while doing their project, but to incorporate them so fully into the design requirements that a successful design cannot exist until the human factors are not only considered, but designed for and around.

How do you go into deeper need identification than what is explicitly spoken by the client? It means identifying what the real problem that the client wants solved. It may mean

solving exactly what the client has identified, as happened in this project. In this case, the underlying reasons and justifications were explicitly given to the team by the client. He purposefully included what he identified as a 'buy in' or 'so what' factor in the initial introduction of the project to the students. In any case, students assigned to these projects need to be able to pursue and question the underlying problem that is to be solved. This may come from a misidentification of the problem by the client, but also should purposely come from ambiguity in the problem definition as assigned in these projects. There is a balance that must be struck between confidence and arrogance. Students must be confident enough to delve into an ambiguous and messy problem and ask questions of why, to question the reasoning and justification of problems. The understanding that they are not the typical user or the client also needs to be understood so that the students do not solve a problem they perceive but is not actually there. I believe that there needs to be a way for students to express their queries, but also document them in such a way that prompts a discussion between the client and the student. By knowing what kinds of questions to ask, and having their findings to these questions available for discussion with their client, the students can have justifications for their answers as well as being able to have these justifications and processes open for discussion by the client. This finding led to the final project.

Chapter 5 – Educational Tool

5.1 Background

5.1.1. Applicable Literature

The purpose of design education is to increase the confidence of those less experienced with design (Self, 2012). This can be done through giving students the opportunities to practice design and build this confidence through practice, combined with introducing the students to the various design tools available to them. This combination of experience and knowledge of available tools must also be accompanied with an understanding of the tools' strengths, limitations, and the context in which it is to be used (Self, 2012). Giving students and novice designers tools without explaining reasons behind using them, without demonstrating their value, is not enough. Justifications must be provided for the use of tools, in the same way that communication of the design decision justifications are required. Students may be able to understand the process someone else is using without being able to mimic it within their own design processes. Without prescribing exact steps, a framework can be created to guide and encourage the students to follow design principles. Design frameworks are an overarching concept in which we should educate novice designers, specifically how to incorporate human factors into that design process. Through the use of effective tools, these methodologies can be better ingrained into the novice designer's own design process.

Methodologies for design were once shunned by designers, and subsequently educational institutions, as they are believed to stifle creativity and the freedom needed to tackle messy problems (Green & Bonollo, 2004). However, whether they realized it or not, a process is always used while designing. There is, at least, a rule of thumb, a method, or an approach, even if it is not effective, realized, or used exactly the same from project to project (Stillman, 2012).

While experienced designers may not use a single, structured design method for every project they undertake, many of the steps used in their projects reflect those points which are explained in many of the formal processes. The ability to decide and apply which phases and points are useful to specific projects is a skill that comes with experience, after the designer has determined which of the methods is most effective for them. However, when design methods and processes are not taught in school, students do not include them in their work post-graduation and must learn the skills over time (Gill, 1990).

Though there are differences in processes, styles, or implied meanings of the maxims, a high correlation was found between two separate sets of expert designers evaluated which design tools or maxims they reported using (Lund, 1997). Some of the principles are specifically targeted towards computer applications, but many transcend specific application boundaries. These range from the need for designers to consider the user as separate and different than themselves (1. Know thy user, and YOU are not thy user), the importance of cognitive considerations (7. Don't overload the user and 9. Minimize the need for a mighty memory), and consistency (2. Things that look the same should act the same and 8. Consistency, consistency, consistency) (Lund, 1997). This highlights the fact that, though designers may have different specific processes that they individually adhere to, there are principles and overarching themes that they use in their own processes. Engineers working on design projects need to realize that established, structured techniques will help create more successful projects (Kurowski & Knopf, 2011). Even if tools and techniques cannot be applied to every design project, the overarching processes, and principles of more experienced designers should be used as a guide until the novice designer develops their own alterations to the processes through experience (Kurowski & Knopf, 2011).

Having a framework to follow during the process helps the designer to design better, giving the ability to look back and understand the steps. This presence and adherence to a

framework allows for the designer to better communicate what has occurred, both for their own benefit and for the benefit of those for whom the design is intended (Stillman, 2012). While it cannot prescribe the exact form that the project will take, the consideration of human can provide a framework by which designs which are both useful and usable can be created (Gould & Lewis, 1985). If there are methods and tools that expert designers use, novice designers can be mentored to include them with the goal of making them better designers faster than if they go through the process of trial and error. By creating experiences in which the student can go through the design process many times before they leave school, they can be trained in successful methods before entering the workplace.

As I looked into the literature surrounding engineering education, I was surprised by the number of how many different methods there were for design, even how many related specifically to engineers. Though I have studied design, designed several projects, and taught classes on design, I cannot easily and immediately interpret which were useful. Students, as novice designers, would likewise find it difficult to determine which would be helpful to them and which not. By looking at several of these models and seeing where they overlap as well as collecting and combining methods and tips from designers and design firms, I posit that it is possible to create a basis for students from which to gather information on how to design without being completely overwhelmed by the large amount of data that is available to them.

This work is not focused on deciding which of the variabilities of the design process is the most useful, but we will look at which broad categories are present in most of the design processes. A typical engineering process is seen below (Ullman, 1997):

1. Identify Needs
2. Plan for the design process
3. Develop engineering specifications
4. Develop concepts

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5. Develop products

By looking at other design processes, we see that there is a move from a region of uncertainty in research through concepts and clarification through to a final design (Newman, 2006). Others include preliminary design, preliminary component design, detailed design, analysis and optimization, finishing with Documentation and detailed project planning (Rychener, 1985). Others, specifically targeted towards those learning the design process in an engineering program state that the five main steps are Idea Generation, Conceptual Design, Detailed Design, Prototyping, and finally Refinement and Ramp-Up (Gregson, 2009).

This is not to say that there is not room to be human focused in the non-specifically human centred design processes. However, as shown in the first chapter, even if the designer has an intention to be user focused, the engineer tends towards the technology and not towards the human aspects without specific steps outlining how that should transpire. By incorporating humans directly into the process from the beginning, I believe the design process will be more calibrated to include human as the success of the entire project.

5.1.2 Different Methods currently in Use for Increased Usability

There are processes which have tried to be more human focused in their design processes. The Design Gym (2016) has distilled their design process down to 5 steps, which are: Examine, Understand, Ideate, Experiment, Distill. From the first step, they encourage a deeper look into the problem, into the context and objects involved. However, the greatest emphasis is placed on understanding the people who are involved in the problem (The Design Gym LLC, 2016). d.school, the design school at the Hasso Plattner Institute of Design at Stanford University, have labeled the steps as: Empathize, Ideate, Define, Prototyping, and Test (d.school, 2010). While others may not prescribe a different process, there are principles they recommend to include in

design- early focus on understanding users and task, empirical measurement of the tasks being performed, and iterative design which cycles through testing and redesign (Gould & Lewis, 1985).

Since there are similar steps required for most design processes, it should be possible to incorporate human factor requirements into the design process as the students are guided through the engineering design steps. The pursuit of empathy should be taught and learned as a methodology for the inclusion of human factors. The closer the design can come to empathizing with the intended user, the more likely the project will be usable and desirable (Kolko, 2014).

When they approach designers, clients often have an idea of the solution they believe will solve their problem. Instead of going through the design process to properly define the problem and evaluate different solutions, engineering designers are asked to implement the preconceived solution (Design Industry Advisory Committee, 2004). As a result, many engineers are not involved in the decision making and problem defining processes and are not required to consider the broader impact of what of for whom they are designing. Kolko (2014) suggests that empathy, which he believes can be both taught and learned, is imperative for the creation of user-friendly products, and that successful design requires the integration of human factors and an empathy with the users.

True empathy requires the designer to give up preconceived ideas in order to truly immerse themselves in the user's world. I have been exploring potential approaches that could encourage human factors and technical engineering to come together. This work is based on the research behind the conceptualization of a tool to increase the ability of engineering students to observe and empathize with those for whom they will be designing, and by doing so, increase the human factors incorporated in their design projects.

There are currently prompts and checklists to help the designer work incorporate usability considerations into their design. One is the IDEO methodology cards to help designers understand the people for whom the design is intended (IDEO, 2002). They have both a physical model of 51 cards and a virtual app which allows the user to take voice memos as they scroll virtually through the cards. These cards offer a suggestion, as well as a "HOW" and "WHY" for each section, followed by an example of this as experienced by the IDEO design team. An example of these can be seen from their website, recreated in Figure 27 (IDEO, 2002).
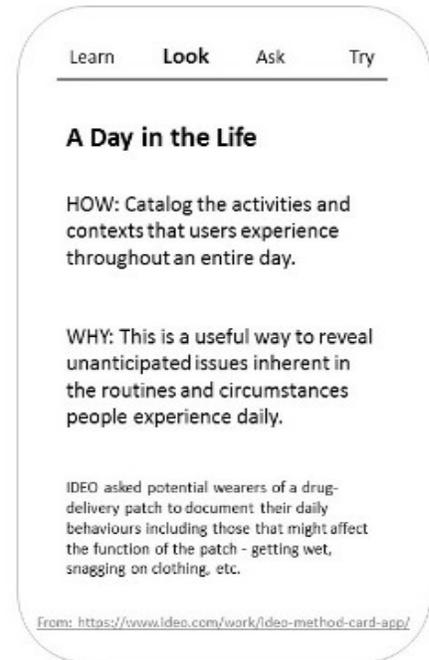
Figure 27: IDEO Method Card example

With the exception of 5 preliminary research steps, each of the suggestion cards involves users, participants, and input from people involved in the design (IDEO, 2002). It is clear that IDEO does not believe that user and human input should be saved until the last step.

Another resource is a set of 25 recommendations for incorporating usability in practice, ranging from easily applicable to reimagining the corporate structure of the project being designed (van Kuijk, 2010). Each suggestion gives both the justification explaining why it is important and what is required to implement the suggestion (van Kuijk, 2010).

However, without an example or plan for how to integrate these design processes into the actual practice of engineers, they will, as I did, think they are including them while in actuality miss the mark. Gould and Lewis (1985) also observed that, as they recommended the use of usability principles, the reaction by designers was that they were obvious. However, when later

asked about their processes, it was found that the human factors which were considered so common sense were not used or employed in the design process. This implies that ergonomics, although they may seem obvious when presented, are not automatically included in the design process, even if people may be aware of them. We therefore need a way to guide and encourage students to include the considerations into their designs so that it becomes part of their design process as practicing designers.

5.2. Project Conception

5.2.1. Client

The goal of education is to have the students begin to think like professionals, which can be best accomplished through the integration of reflective practicums into the education (Schoen D. , 1987). Many of the design skills that will help make the students successful, such as how to best integrate human factors into their design process, cannot be taught through lectures but can be learned through monitored, controlled practice (Schoen D. , 1987).

5.2.2. Initial Idea

It was through in this consideration of different platforms that could influence and help novice designers that the idea of a mobile application, or app, was created. This led to the searching out of people who were experts in different facets of the design. Because I am envisioning creating an app for educational purposes specifically targeting engineers, I contacted several people for their specific input on the app. Those I contacted and specifically interviewed were an engineering design professor from the University of Prince Edward Island, a telecommunications analyst from Telus Ltd., human factor professors from Dalhousie University, as well as observations made about first year engineering students during their first semester design class.

5.3. User Input

5.3.1 PhD candidate focused on Engineering Education

The PhD candidate I consulted is doing her research in the area of engineering education, specifically in comparing the processes of novice designers compared to expert designers. One suggestion was that specific answers given in the app are then used in future questions. For instance, the students will be asked to identify the stakeholders, or those involved in the design, in the first stage of questions. In subsequent stages, another question will be directly aimed at those identified stakeholders, with the question field populated with their previously entered data. By including their data in subsequent answers, and prompting for specifics to do with previously identified users, I believe they will be able to think clearer about which humans they are considering in their design.

5.3.2 Telecommunications Expert

I spoke with a telecommunications expert regarding the technology surrounding mobile apps and what makes them either good or bad to use. He recommended making sure that the app was ubiquitous, with both Apple and Android platforms supported, and the ability to access all the information on a personal computer. It is required that, if the use of this app will be contributing to their justification grade, that they are able to perform the assignments without being hindered by a mismatch of technological platform. From this meeting, it was also suggested that a parallel website be set up with the same questions and output capabilities. In this way, more complicated answers and outputs can be entered through the use of a keyboard as opposed to simply typing on a phone or tablet, which can be tedious. When asked why an app would not be applicable to this process, the fact that the flow of an app can be too linear or rigid for a creative, iterative process like design. It was from this meeting that the option to skip to a separate

section was created, along with the option of designating something as not applicable (N/A). However, it is concerning that the students would not see important facets as applicable to their design. For this reason, if they choose to mark a question or prompt as N/A, they will have to justify why this is so. In this way, the reasoning behind the inclusion or exclusion of certain factors can be monitored through documentation.

Certain aspects of apps can be quite frustrating, such as when they crash and lose all the formerly input data, so a feature I believe would be beneficial for the developers to include is an auto-save version which would back up the answers of logged-in users. Another frustration of using the app format is when there is a lot of work, or a deletion of work, to go back to a step which was previously encountered. By creating tags, links, and saving automatically, the user should be able to move non-linearly through the app without a loss of previously entered data. It is also important that the user not get 'lost' in the design, and that the flow is intuitive.

The benefits of using an app were the obvious lack of physicality and ease of distribution, the familiar platform on which the user could interact, the availability of customization through tagging, the fact that it was easily distributable, that it was flexible yet still a guiding framework, and that the information would not be hidden behind academic walls but could be accessed by anyone who paid for the app.

5.3.3 Professors of Human Factors

I interviewed together a professor of ergonomics and human anthropometrics, Dr. John Kozey, and his colleague, Dr. Heather Neyedli, an assistant professor in kinesiology who teaches a course on cognitive human factors (Kozey, 2015). They both seemed skeptical of how the idea of an app could be used in conjunction with education to increase human factors in engineering design. They have observed through teaching that the biggest problem that they see in

engineering students specifically is an inability to understand where in the bigger system their design fits. There is no question as to their ability to create technically sound projects that work well in isolation. However, when they are asked to integrate with other parts of the system, especially when one of those parts are the unquantifiable actions of a human user, the design is ill-designed. One of the major concerns they had was that they felt it would be too shallow of an approach to human factors, without giving it the full advocacy needed. They suspected that an app would tend towards the side of a checklist which would allow the students to check off that "yes" they had considered things without having to incorporate those considerations into the design.

It was also noted that the app could not work unless there was an explanation that incorporating human factors is adding value to the design projects and that it is a method of failure avoidance. It was emphasized that there should not be an app simply for the sake of having an app, but that it should be for the enhancement of the human factors in design.

Through the conversation, and an explanation as to how the app would function in the classroom, and both of them agreed that, through the proper education and integration the app could be useful.

5.4. Project Description & Concept Generation

5.4.1 Tool Choice and Accessibility

Due to the prevalence of smart phones and personal computers, we believed that a mobile application would be a familiar way to reach designers, both students and professionals, on a platform in which they were comfortable interacting and to which they had high accessibility. Constructivist Theory of Learning suggests that learning is increased when the user is engaged, with relevant material, and a choice of interactivity (Wilson, 1996). Even in 2006, before the rise

of the prominence of smartphones and related apps, 97% of North American Medical schools using online course material (Kamin, Souza, Heestand, Moses, & O'Sullivan, 2006). Mobile applications have been used in a variety of industrial sectors and across other facets of society. The Braille Institute has created an app titled VisionSim to help experience how the world appears to someone with the symptoms of nine degenerative eye diseases through the use of filters on the camera (Braille Institute, 2013). The application was created to foster empathy for those affected with these eye conditions and is used by those with healthy levels of vision (Braille Institute, 2013).

Professionals such as veterinarians are also served by apps, as shown by a drug-index app that allows them to access information in a convenient way even during the rushed schedule found in a hospital (Innovation and Technology Association of Prince Edward Island, 2013). We believe that, by redesigning how content is used and delivered to students, we will change the way they approach and progress through their design projects. Like other educational apps, potential benefits of this platform include increased accessibility through the portability, which gives convenient access to relevant project processes.

The accessibility to the mobile application (app) is technically not different than the accessibility to any virtual document students would have access to on their smart phones. The accessibility is seen as a requirement if the students are expected to use it in different locations. If the tool was relegated to a physical tool, there would be obvious limitations to the contexts in which it could be used. Computers are often able to be modified for persons with disabilities, which would ensure that more people are able to use this tool.

The app would also need to be explained by the instructor, with the limitations and benefits clearly laid out. Without instruction, or necessary use, the students are likely to treat it as any other tool that is available to them but optional for their design processes.

5.4.2 Tool Format

From my experience, engineers are comfortable with the idea of questions and processes that they must work through, which led us to believe that prompting them with questions would be received well. Due to the volume of work which has been done on design processes, usability, and human factors, it is not possible to present students with all, or even most, of the research which has been done in this area without a cognitive overload and subsequent overlooking of the information present. By presenting specific, but open-ended questions for them to answer, with options to guide them towards the sources of more information, we hope to avoid the informational apathy that can result from an excess of information and having to sort through the information themselves.

This results in the possibility that the students will not delve into subjects not broached by the application, and any non-highlighted areas have the possibility of being completely ignored. To avoid this, we will include links to further information, as well as make the suggestions a combination of prompts towards deeper discovery and open-ended questions designed to encourage exploration as opposed to 'correct' or 'right' answers. We avoided making a checklist which could be completed with no real consideration for the user, as no understanding or confirmation of compliance would be necessary in a question statement that is able to be answered with either yes or no.

5.4.3. Tool Content

There is more than one facet of interaction between humans and the technology they use. These include physical, psychological, social, organizational, and political levels which are not independent of one another (Vincente, 2003). By providing a framework requiring students to consider and integrate these factors both at the beginning and throughout their design process, we believe that their designs will be more successful as they take these into account. The content of the app reflects these varying levels, as questions will be directed at each of these. One of the criticisms heard is that engineers often do not understand how to properly integrate their designed technology into the broader system which includes these levels of human interaction (Kozey, 2015).

The majority of questions and surveys that are currently available to students are based off of validated usability studies, which the students can use once they have a prototype. However, this does not allow them to design with human factors integrated from the beginning, but to only see retro-actively once there is already something designed. While validated, reliable usability surveys are available, such as the System Usability Scale (Brooke, 1996), these are often evaluated at the end of the process as opposed to an integration from the beginning of the human factors. We believe that incorporating these empathic considerations as requirements before there is a prototype or even a defined problem will allow the engineer to understand better the world of design from which they are stereotypically excluded.

There are validated models and surveys to assess usability and which can prompt designers to better incorporate human factors into their designs. If the principles and methods are proven to be validated models of human assessment, I do not see the benefit in redoing all of the material already in circulation rather than incorporating it. By using validated material and

content, we would be able to better understand if the way in which the material presented is beneficial to the students. By integrating the already validated material in with the class, using it to create documentation for design projects, the students will be able to see the benefit through the familiarity of using it in their design projects.

If this app can be used in subsequent years through the students engineering education, the similarity in design processes through the years would be beneficial for solidifying the process and the human factor considerations in the novice designer's own design process. The usability of the projects could also be evaluated between those years which have used the tool and those which have not. This would also require the education of the educators. It would not be enough for the app to be available for the students to use. The use and strengths must be explained each time the app is expected to be used, as there may be some confusion from the previous year, or some students who would not have seen it before due to transfers between universities.

Designers now must consider how their solutions can benefit and interact with the user, where humans are placed at the center of the design process and system (IDEO, 2009). We then, require the students to identify the major stakeholders- those involved in the use, benefit, manufacture, repair, disposal- of the design. By identifying how their design fits into the larger social and organizational levels, they are more aware of the different roles played by people throughout the life of their project. If purely physical or anthropometric research is performed, it may be that entire user populations will be missed, such as nurses when working on a medical device. The goal of human-centered and empathic design is that the goals and preferences of the

stakeholders will be considered and a solution will be found which benefits and aligns to these stakeholders (Battarbee, Suri, & Howard, 2014).
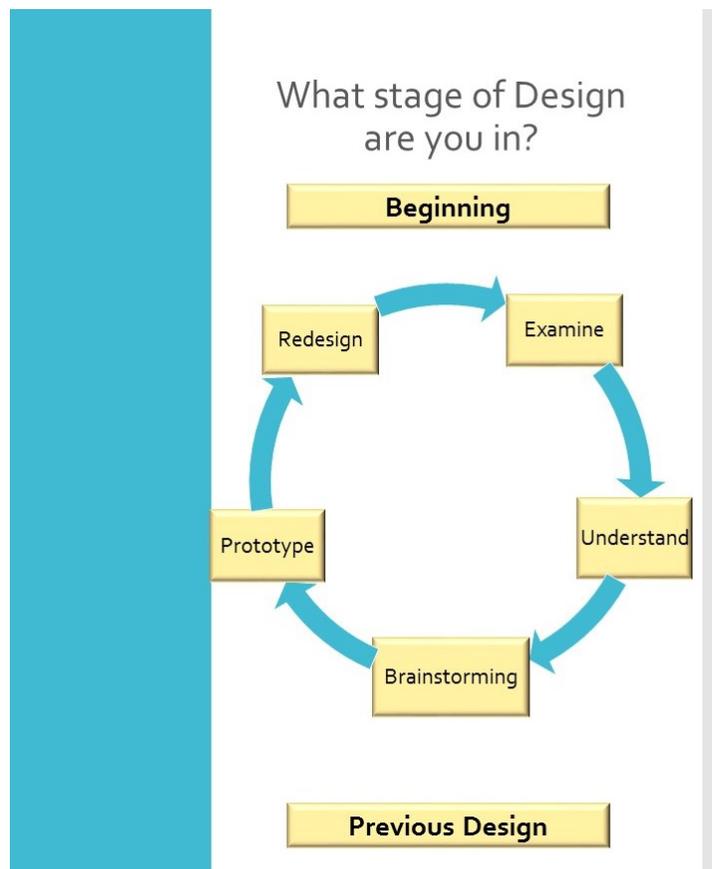
Figure 28: Start Menu for App

The app would begin by prompting the student to pick which stage of the design they believe they are in, as seen in Figure 28. This would allow them to work through the app from the very beginning, or advise them if they wish to start at another step. I think it would also be useful to have the possibility of having more than one design, which could be an advanced feature. This would also be available from the start menu so that information could be reviewed from other designs, or multiple designs could be supported simultaneously.

5.4.4 Questions

The app would primarily be a guide for the students rather than a prescribed route for them to take. Because of this, and the desire to be applicable to as many design projects as

possible, the students will be encouraged to answer questions as they go through their design. It was important that these questions could not be answered with a yes or no, but that the students would be required to think more deeply about the justifications behind their answers.

Below are several questions that would be presented to the student, although it is not a complete or final list.

Stakeholder Questions

- Who are the stakeholders in your design?

- Who will buy it?

- Who will use it?

- When and where will they use it?

- How often will they use it?

- Who will repair it?

- Who has to interact with it on a daily basis?

- What regulatory bodies and standard committees are going to regulate its use?

- Who will you have to convince to use this product?

- Assuming that it functions technologically, what facet of the design is most important to [the stakeholder]? *Where "stakeholder" is replaced with their previous answers*

- What is the design goal that [stakeholder] is hoping to accomplish?

- Who is someone in the role of [stakeholder] that you can contact with questions?

An example of how this could look is shown in Figure 29.

Figure 29: Sample Question regarding Stakeholders

Current Solutions & Competition

- How this problem is currently solved?

- What does [stakeholder] currently do to solve this problem?

- Who currently solves this problem?

- What is lacking in the current solutions?

Problem Definition

- What is the problem?

- Why do you think it is a problem?

- Why do you think you can solve it?

- What is the ideal outcome you would like to see from this design?

- What will be considered a success?

- What are the requirements that are in conflict with each other? (ie. Strength and weight, cost and high quality)

- Which of your requirements is focused on [stakeholder] specifically?

In addition to information gathering questions, there also needs to be questions that prompt the designers to talk to people to validate or negate the assumptions they have created during the initial information gathering stage. For this reason, there also needs to be prompts to physically communicate to users and people relevant to the design.

Interaction and Observation

- What environments have you experienced that are similar to where your design will be used?

- What differences do you see between what people say they do and what they do?

- How does [stakeholder] describe their interaction with the design? How is this different than other stakeholders?

5.4.5 Requirement Development

As seen in the case study presented in Chapter 4, the integration of human factors into the list of requirements ensured that the project continued to focus on human aspects throughout the design process. By requiring the inclusion of human factors into the list of project requirements, we ensure that they are ingrained into the success of the project.

If the students have specific and complete requirements to do with humans, it will give them a point that they are to aim towards. This may be a requirement of a minimum usability score within a later-stage usability test, or a specified time in which the user must comprehend and accomplish specific tasks.

The requirements that have shown to be most correlated to project success are those which are both specific and complete (Joshi, 2013). Ullman (1997) also stresses in his creation of requirements that the units be measurable or readdressed to have a specific unit. Certain users may need to be specified in the requirements to ensure that the target population is tested, but it must be stressed to novice designers that they or people close to the design process, should not be used for user testing. Joshi (2013) also suggests the use of a guideline to ensure that students are following a framework while they are novice designers.

5.4.6 Usability Tests

To gauge the usability of websites, several aspects are considered: whether the specified tasks are accomplished, how long it takes to accomplish the specified tasks, how satisfied with the design the participants are after trying to complete tasks, changes needed, and whether performance meets the project objectives (U.S. Department of Health and Human Services, 2016).

Once a design has reached the point where users can test it and give their feedback on it, usability tests can be performed. One test that has been developed is the System Usability Scale (Brooke, 1996). Introduced as a "quick and dirty" way to test the usability of user-computer interfaces, it has since been validated and deemed reliable when assessing significant changes, learnability, and is strongly correlated to other rating systems which assess the "user friendliness" (Lewis & Sauro, 2009). The ten questions for the SUS are given below in Table 10 where the odd-numbered items are positively worded, and even-numbered items are negatively worded

(Brooke, 1996). The instructional statement preceding the items is based on the modification made by Bangor, Kortum, and Miller (2009).

Table 10: System Usability Survey Questions

	Check your first instinct to each statement, and make sure all statements are checked. If you are unsure how to respond, please select "3".					
	Question:	**Strongly Disagree**				**Strongly Agree**
		1	**2**	**3**	**4**	**5**
1	I think that I would like to use this system frequently					
2	I found the system unnecessarily complex					
3	I thought the system was easy to use					
4	I think that I would need the support of a technical person to be able to use this system					
5	I found the various functions in this system were well integrated					
6	I thought there was too much inconsistency in this system					
7	I would imagine that most people would learn to use this system very quickly					
8	I found the system very cumbersome to use					
9	I felt very confident using the system					
10	I needed to learn a lot of things before I could get going with this system.					

This would be included into the app through an interactive page that the user could either fill out on the student's phone or through the parallel website. This information would then go into the appropriate algorithm to calculate the SUS score. I would like to update the questions

slightly to replace "system" with "product" to allow it to be applicable to more than computer based projects. This change has been implemented within the SUS and the test continued to be reliable (Bangor, Kortum, & Miller, 2008). The SUS has been tested on a variety of interfaces in hardware, software, and physical products and is, therefore, able to be applied to the variety of physical projects seen in engineering education (Bangor, Kortum, & Miller, 2009).

The test can provide useful information with as little as two users (Sauro, Measuring Usability with the System Usability Scale (SUS), 2011), which makes this a test that is beneficial for use in design projects which have very short timelines. The test section of the app can also have a section where the observer/administrator can make notes on the actions of the user, and take pictures of the interaction. It should be noted that a usability test will not identify for the designer which parts of the design are good or bad, which is why the details of the user interaction

Figure 30: System Usability Scale in App

will be included in the documentation. As the test is quite simple and does not require much time, it would be easy for them to make small changes in their design and reassess for quick, effective iterations. Demonstration of what this could look like in an app form can be seen in Figure 30.

5.4.7 Scoring

By including a section of the app where the students are able to can get quantified feedback on their design, they are able to self-identify when they have created a product that is usable or not. The projects could be independently assessed for a section of their grades, or the students could be rewarded with a prize for that project that is the most usable. The scoring of the SUS accounts for the negative and positively worded questions. The value of items 1,3,5,7, and 9 is their scale position minus 1. The value of items 2,4,6,8, and 10 is the score position subtracted from 5. The values are then summed and multiplied by 2.5 to obtain a value out of 100, which must not be interpreted as a percentage (Brooke, 1996). The scoring is presented in percentile ranking and anything below 68 is considered below average. Bangor, Kortum, and Miller (2009) suggests using a letter rating to distinguish between levels of usability, with scores as shown in the table below. Descriptive, adjective ratings are also recommended and are shown under the letter ranges in which they fall.

Table 11: SUS Scoring

SUS Score	Grade Scale	Adjective Ratings
0-60	F	Worst Imaginable, Poor, OK
60-70	D	
70-80	C	Good
80-90	B	Excellent
90-100	A	Best Imaginable

5.4.8 Accessibility

While this app seeks to promote the inclusion of human factors within the design processes of students, it is important that there are ergonomic considerations made in the design of the app itself. A significant percentage of the engineering student population are international students, a population that includes many non-native English speakers. The word cumbersome in question 8 has shown to be confusing to non-native English speakers. I recommend changing the word to awkward, as suggested by Finstad (Finstad, 2006) and Bangor (Bangor, Kortum, & Miller, 2008). By adapting the content to be inclusive to as broad of a population as possible, students will be more comfortable with the content, allowing for more effective learning (Variawa, 2014).

In the same theme, it is important that this app be functional for use by persons with disabilities. Ability level is not a dichotomy and is instead measured on a continuum; by designing for extraordinary cases, the applications often benefit the general population (Newell & Cairns, 1993). If the app is designed to accommodate users with a diverse range of abilities from the beginning, unusable and possibly disabling situations can be avoided rather than addressed with a fix later. One example of the need for this is highlighted by the clients for the first year final design project, as the clients were all selected based on an existing level of vision loss. If the students are expected to test out their design and have their clients give input, it is necessary that the app takes a variety of abilities into account. Shneiderman (1986) commented that designers need to be cognisant of how design decisions affect those with differing abilities, specifically those with physical or mental limitations and those from other cultures.

5.4.9 Tags for Sorting Questions

The card recommendations by van Kuijk are split into different categories to indicate the category of the recommendation- Usability 101, Process, Team, Project, Company, and Market

(van Kuijk, 2010). The IDEO design cards are also tagged according to the typical actions of the step in which they occur: Learn, Look, Ask, and Try (IDEO, 2002).

Within the steps and prompts within my tool, I would also like to include imbedded tags as well as the option for the students to insert their own. Sample tags would include Prototyping, Research, Users, Act, Make, and Watch. These would allow students to use the tags to identify what human factors to include in the steps of the process. They can also sort them using this, or add tags of their own if they believe that it would assist them in organizing their project. Tags can also be used as an assignment, as all the questions tagged "investigate" or "stakeholders" may be assigned to the teams to consider and answer. An example of how I envision the tags would be presented is seen in Figure 29.

By creating searchable tags, the iterative aspects of design can be integrated. The steps would have a sequential order to them, but at all times the previous questions and answers would be available and editable for continuous improvement.

5.4.10 Documentation of Work

In order to create a system of checks and points of discussion, the app is going to require that the students insert their answers, thought processes, and justifications for different points in their process. Because it has been observed that requiring aspects works better as a motivator than simply recommending them, by requiring the answers to the human factor promptings, the students will adopt the processes more readily than they would if the tool was only made available to them as an option. In order to see that it is being used, there needs to be a deliverable that can be handed in with other required documentation. For this reason, a method for the answers of the students to be saved, exported, and handed in as proof of compliance is included. Their

answers, research, and justifications can be reviewed and critiqued with the ability to check from the beginning of their design process which human aspects they have considered.

By creating similar prompts for the team which are applicable to the design process rather than to a specific design project, the app is able to reduce the administration time required for the instructor to spend with each team. By prompting them to enter their data, the information and individual prompts for the inclusion of human factors can be presented to the students both in class and while they are going through their design process. The introduction of the material through different platforms can help the students better understand the necessary process, as well as how to integrate it into their design process. This requires that the instructors explain and emphasize the importance of including human considerations into the design and show the benefit of using the tool. Although the students may not be convinced, by creating an environment in which it is required, they will have a process to follow by which they can include human factors into their design projects. By producing a similarly formatted output, the instructor can more quickly identify and decipher where teams are incorporating human factors and when they are not. This will require interaction from the instructor or design coaches as outputted answers as assignments will not inspire change in design processes unless there is also comment and correction. The design process often includes check points where designs are reviewed and terminated in the case of failure (Ullman, 1997). By requiring design reviews and input by instructors, novice designers have a chance to alter their designs towards more successful aims.

During the requirement creation of design projects, there is often a documentation of items that are considered and later removed. By creating lists which show items that have been

Figure 31: Sample Question to Delete Stakeholder

removed, the students can have a clearer picture of what their design thinking process has been during the project. For example, during initial brainstorming, the design team may have an idea of a stakeholder that would influence the design and later decide that that particular stakeholder would not be a part of the considerations. They could then delete the stakeholder from the current list but still see the fact that it was considered, as seen in Figure 31.

Report templates for usability testing can also be done. By inputting testing data for both usability and other functional tests, sample report templates can be partially filled in, saving the students work. Usability test templates are provided by Usability.gov which are able to be customized to the project's requirements (U.S. Department of Health & Human Services, 2016).

5.5. Future Steps

5.5.1 Functionality

Through the study of current engineering design methods for novices, I have researched the pedagogical method and content required to create a tool to help incorporate human factors into the design process. To bring this app to a functional tool, experts in areas of user interface and app development are required. Teams have shown to be more effective when made up of people with different perspectives and areas of expertise. Necessary abilities and expertise for a project will come together and the task will be accomplished through teamwork (Blackmon, LaMaster, Roberts, & Serrell, 1988). My area of expertise comes in the content, and I have researched thoroughly the content and presentation method that should be reflected in this app. I understand from the engineering side where, in my experience, there was a lack of understanding and transference of knowledge in the area of human factors. If this app was to move forward, as I hope it does, I would like to be able to work with those who have done app development before, those who understand it well, those who have an idea what makes a visually appealing and usable app. One of the main benefits of doing an app is that we can continually alter the information if needed. This does not give the permission to release a sub-quality product for the students to use, but that updates can be done after user testing reveals problems. No requirement of additional equipment to be purchased by the students.

From my research, I have seen that developing and designing something with only putting human factors in at the end as an afterthought creates unusable products that are often technically sound. Because of this, I would like to develop the app part of this project with people who are experienced in the area of app development, who understand the process of app creation and what user interaction in an app looks like, and integrate them into the development from the

beginning, just as I am encouraging the users of the app to do. To attempt to make a software usable only at the end or near the end of the project would be synonymous with requesting that a fully constructed building be made 'worker friendly' (Morrison, 1993).

5.5.2 Viability of Design

The proposed method of distribution would include requiring the students register for or purchase the app for the class. During the validation stages, I think it would be best to make it free for educators to try, given that they provide statistics on use and grades. Further on, there could also be a discounted price for those students who are in a class using the product, while it would also be available for the public. Another option would be that the material would be accessible for free in an app, but not the ability to export. That way, users would be able to access the information without paying for it, but would have to pay to take advantage of the ease of documentation functionality.

5.5.3 Validation

To move forward with this app would require that the efficacy of the delivery be tested and validated. I would propose to use this in a first year design class for both theoretical and hands-on projects that they are assigned. This could be accomplished by first walking them through how it should be used and the benefits of human centred design, then asking them to apply it to a theoretical design project exercise and finally requiring it on their final design project. If the students are broken into two sections, both of the classes should be introduced to the tool and to the importance of human centred design. One class should then be required to submit human centred considerations with every step while the other would be given the opportunity to use it but not required. My hypothesis is that the requirement of use will increase efficacy of

uptake and will increase the human consideration within designs. The designs would then have to be judged, showing how their design compares in usability and client desirability.

5.5.4. Tool Prototype

In order to allow the method of delivery to be tested, a prototype will need to be made in steps before the entire solution can be developed. I suggest that the first step is to create a way for instructors to prototype this system within the systems already available to them. This would require setting up similar questions and documentation to what would be in the software program inside the available software platforms already in place. This may include quizzes and documentation updates on blackboard or having a system in place to make teams check in on Brightspace. This would allow the content and delivery method to be tested before the technological back-end of the software need be developed. One of the first future steps, then, is to create a "How-To" package for instructors to implement within their own software systems. This documentation could therefore guide instructors into including usability factors from the beginning.

5.6. Conclusions

As we move forward, we wish to create a validated model of which questions and which prompts to give the students. As the problems they are working on are inherently messy and broad, we also will work on identifying areas where the questions can be informative and helpful without being too narrow in scope. This tool is meant to be a framework and a guide as opposed to a strict path for the designers to follow. Identifying how this required feedback changes the design process of students is also of interest for future iterations of the tool.

Design, and the process of designing, has said to be above all else, the difference between an engineering education and a science education (Hodge & Steele, 1995). By creating a tool

which fits into the engineering design process and pushes them to understand the human factors, we believe we will push the students beyond unusable and undesirable projects, and help guide them to successful, human-centered projects.

Chapter 6- Conclusion

6.1. Usability

Through this research, I have looked into usability and the effects it has on the success of projects. Usability has a long history of being applied in different aspects of design, which becomes increasingly important as consumers are demanding usability from the products that they purchase and must interact with. The importance of usability ranges from increases in safety as well as increases in efficiency through a decrease in frustration. It also been thought to be one of the last remaining ways to obtain a significant advantage over manufacturing competitors.

Engineers are not typically skilled at incorporating human factors into their designs, and are criticized for not understanding how the human user works into the system of use. Although there are prompts for the engineer to use within their design process, these are often used ineffectively if not given specific guidelines of use.

6.2. Discovery Centre Project

I undertook a design project for a local client who wished to create an experiential learning station in the form of a science centre exhibit. Through miscommunication regarding availability of resources and timing differences in the development process, there was no delivery of a full-sized model as the client had wished. There was a prototype which proved the functionality of the design, through which it was demonstrated that even designers who are thinking about and invested in incorporating human factors into their designs can fail to do so if not given specific guidelines on how to do that. This led to the idea that a more structured framework would be useful rather than only encouraging designers to incorporate human factors without a plan. For this reason, the engineering design process was more closely investigated to see where ergonomics could be inputted.

6.3. Product Analysis

Several off the shelf products were investigated to determine if there was a correlation between previous experiences and what type of product people would be interested in purchasing. These products were all considered to be successful due to the fact that they were all available from local chain stores. The results showed a preference of the gender specific product in females, as well as a high preference for one particular sleeping mat. It was from this pilot study that the ideas of ranges of acceptable values were demonstrated as users all rated one of the mats unfavorably when they found out the high cost. Our study hypothesized that one factor, the camping experience levels of users, would correlate to their product preference. However, partially due to the fact that the data did not mimic the expectations, it was thought that, due to the complexities of users, one factor alone would not be enough to fully explain the reasoning behind the product selection.

6.4. Case Study

After the complexities of human factors became apparent in the product selection study, it was decided that a closer investigation was required into a design project that successfully included human factors. Through a case study, I investigated the successful project of a capstone design project which mimicked the interior of a seaplane for emergency training simulations. The team included both user and environmental considerations and was deemed to have a successful project by both their peers, professors, and client. The source of their considerations was found to be mainly their client, whom I interviewed. His company is very conscientious of required user experiences and the ergonomic and user requirements were given from the beginning of the project. From this experience, it was thought that if the requirements of projects could from the beginning require the consideration of human users, the projects would have higher usability.

6.5. Creation of a Tool

This belief that a major increase in human considerations would come from using human considerations as project requirements led to the idea of creating a tool. This tool would allow engineering educators to guide and encourage students to include human factors in their design processes consistently. Due to the prevalence and wide acceptance of smartphone applications, it was thought that a combination of an app and a parallel website would be an effective method for utilizing this idea in the classroom. Through expert input, as well as observation of students doing a client design project with obvious human factor implications, several considerations were developed for app user experience. Content for the app was created, as were several features, such as the ability to tag questions, or to sort them for later consideration. I believe that, through a class that requires documentation of human consideration or lack thereof from the beginning of the engineer's design career, the design process of these novice designers will be guided towards one that includes usability.

6.6. Overall

The investigation into human centred design demonstrated how difficult it is to define usability and incorporate it in designs. This research analyzed usability through several aspects by tackling it from several facets. By looking at it from a design project perspective, it was understood how usability can be ignored, and how users and stakeholders can easily be forgotten. It was through this design project that the idea to create a framework for novice engineer designers began. If there was a tool to help students to better consider humans, the design projects would have more real world application, desirability, and ultimately success. By talking with people, many of my observations in the first project may have been corrected rather than propagated

through my designs. This underscores the need to not simply consider but communicate with those who are involved with design.

This assumption also carried through into the design of an instrument to design the usability of commercially available products. It was my hypothesis that experience would be the defining feature to distinguish participant's selections. While the data had trends that supported this simplistic model, it also supported the idea that human behaviour and motivation is a complex factor which must be considered more fully. It also underscored the idea that products cannot be created and then have human factors tacked onto the end. To have a usable product, human centred design must be incorporated into the design process from the beginning.

The case study analyzed a project which had a successful consideration and implementation of human factors and a client who deemed the project a success. Investigation into the source of these considerations revealed that many of the directions were given by the client. As it was noticed that these definitions for success were incorporated from the beginning of the project, the framework I hoped to build to help students became more defined into a guiding path through their design projects. It was not practical to assume all clients would have an understanding of human factors and be able to convey these to a novice engineering team. For this reason, I thought instead of how to make human factors embedded into the design, so that the success of the project would be tied to whether usability was considered.

Through the observation of first year students in their client based design projects, and discussions with experts in other areas related to education and information delivery, the framework for the tool was decided to be a mobile and computer application or app. While I originally wanted to stay away from an app, the accessibility, familiarity of platform, and the lack of physicality made it a good choice for information delivery to students. Through the use of an

app, they will be required to submit their consideration and design justifications for class-required design projects. By creating a pattern of including usability in their design processes, it is hoped that they will continue to do so as they move out of school and into professional practice. Once the engineer can start to appreciate the complexities surrounding usability, and have a framework for dealing with those uncertainties, I believe they will start to create more usable products. This in turn, will reveal solutions better fit to those who need to build, use, repair, and interact with them.

Appendix A –Catalog of Current Discovery Centre Exhibits, 2012

	Discovery Centre						
#	Name	Concept Taught	Text	Appear-ance	What to do	Concept	Inter-activity
1	Slap Organ	Sound and Music-Vibrations	2	1-(2)	1	2	3
2	Reaction Time	Timed Stimulus response	2F	2,3	1	2	3
3	Mirror Mirror	Reflections	1	2	2	2	1
4	Balance/Equilibrium	Balance	1F	2,3	2	1	3
5	Floating Body	Reflections	1	3	2	1	2
6	Floating Head	Reflections	3	3	1	2	2
7	Persistence of Vision	History of technology- movies	3F	3	2	1	2
8	Pupil Dilation	Anatomy- light control	3	1	1	1	1
9	Mirage (x2?)	Reflections- Virtual Images	3	3	1	2	1
10	Blood Pressure	Anatomy- blood pressure	3	2	1	2	1
11	Pumping	Anatomy- blood flow	2	1	2	2	1
12	Truss	Structures- strength of triangles	3	3	1	2	2
13	Lego Land	Creativity, Structure- building	1	1	1	1	4
14	Speed of Sound	Sound and Music-Speed of sound	2	2	1	1	2
15	Resonating Rings	Vibrations-resonant frequencies	3	3	1	3	2
16	Bernoulli Blower	Buoyancy	1	3	1	3	2
17	Farmer's Dilemma	Riddles and Logic	1	3	3	2	3
18	Hearing Test	Sound and Music-frequency	2	3	1	2	2

#	Name	Concept Taught	Text	Appear-ance	What to do	Concept	Inter-activity
19	Microscope	Optics	1	3	1	1	2
20	Million faces	Reflection	1	2	3	1	1
21	Water and our World	Water-Conservation	3	1	2	2	3
22	Bubble Room	Properties of Water and Soap	3	2	1	1	3
23	Elements	Chemistry-Elements	3	3	1	3	1
24	Tension on Suspension	Structures- Tension	3	2	2	2	2
25	Mirror Write	Reflections, Perceptions	3F	2,3	1	1	3
26	Talk Listen	Sound and Music-sound waves	1	2	1	1	2
27	Doppler Dog	Sound and Music-Doppler effect	3	3	2	3	2
28	Buttress	Structures-supports	3F	3	2	2	3
29	Magnets	Electricity-magnetic field	3	3	2	3	2
30	Coils	Electricity-transformers	3	3	2	3	2
31	Sandbox	Play	1	2	1	1	4
32	Pi Calculator	Mathematics-calculation of pi	3	3	2	1	2
33	Puzzle Table	Riddles and Logic	1	2	2	1	3
34	Safety Cord	Mobius Strip	3	3	1	3	1
35	Sand Pendulum	Lissajou Patterns	3	2	1	3	3
36	Play House	Imagination- play	1	2	1	1	3
37	Gyroscope	Angular Momentum	2	3	3	3	2
38	Look into the Eye	Anatomy- Retina Image Flipping	3	1,2	1	1	1
39	Power Output	Energy- convert human to hp	3	3	1	2	2
40	Arch Bridge	Structures- building	2	1	2	1	3
41	Skeleton Bike	Anatomy- Skeletal Structure	1	2,3	1	1	1
42	Are you a Battery?	Electricity-conductivity	3	2	1	2	2
43	Build the Arch	Structures- Arch	1	3	3	1	2

#	Name	Concept Taught	Text	Appear-ance	What to do	Concept	Inter-activity
44	Normal Distribution	Mathematics- Probability	1	2	1	2	1
45	X-Ray Gallery	Anatomy- Skeletal and Biomechanics	2	2	1	2	1
46	Stretch	Anatomy- Flexibility	1	2	2	1	3
47	Hall of Fame	Information	3	1	1	1	1
48	Engineering Challenge	Structures- building blocks	1	2,3	1	1	4
49	Roller Coaster	Structures, Energy Conversion	1	1	1	1	3
50	Bike Generator	Energy- Convert Human-> Electricity	1	2	1	1	2
51	Spinning Chair	Angular Momentum	2	1,2	1	2	3
52	Race Against Time	Human Body	2	2	1	1	3
53	Perception	Logic- Brain Puzzles	2	2	1	1	2
54	3 Soldiers	Logic- Brain Puzzles	2	2	1	1	1
55	Drilling Rig	Information	1	1	1	1	1
56	Hurricane Simulator	Weather- hurricane	1	2	1	2	1

Appendix B – Vendor Quotes

I received two quotes from vendors who built roller slides. They are both attached here with the information about which company from whom they were received.

QUOTATION

Date	Quote #
Apr 22, 2013	**13-9052**

Quoted To: Holly Algra

5269 Morris St
C360
Halifax, NS B3H 4R2

Phone: 902-818-2667
Fax:
Email: holly.algra@gmail.com

Project: Science Centre

We are pleased to submit the following quotation for Landscape Structures Playground Equipment and SofTiles.

Qty	Model #	Description	Unit Price	Ext. Price
1	Dwg#130431	PlayBooster Structure	$11,661.00	$11,661.00
1	2010	SofSurfaces for 501sf, includes Softiles, 2.25" thick, Adhesive - tile to tile, Adhesive - tile to base, Battery Powdered Dispensing Unit - 18v, and Installation Manual.	$4,290.98	$4,290.98
			Shipping	$2,150.00
			SubTotal	18,101.98
			HST	$2,715.30
			Total	**$20,817.28**

Delivery: 4 to 6 Weeks

Conditions for Playground Equipment Supply & Delivery Only:

* Above items are shipped unassembled. Off loading is the customer's responsibility. The Transport Company will provide a ½ hour allowance to complete offloading. If offloading requires more time, rerouting, or alternative vehicle (ie: truck with Liftgate), additional charges may apply.

ARIHANT INDUSTRIAL CORPORATION LIMITED

Arihant Complex,Opp.Sagar Petrol Pump,N.H.No.8,Sativali,Vasai (E). -401208

QUOTATION NO. : PT/QTC/00/315/1213

BUSINESS PROPOSAL

DT. : 26-Jul-2012

To.
DALHOUSIE UNIVERSITY
HALIFAX,
NOVA SCOTIA
CANADA

CONTACT NO :   1-902-8182667
E-MAIL : holly.algra@dal.ca

Kind. Attn. :   Mr. **HOLLY ALGRA**

Dear Sir/Madam,

We Are Pleased To Offer You Quote for Children Playground Equipment/Garden Decor/Rubber Flooring.

All Amounts are in   USD

Sr. No.	Particulars		Qty.	Rate	Amount		Total Amt.
1	DOUBLE FRP ROLLER SLIDE 1.5 MT	*	1.00	2,730.00	2,730.00		2730
2	DOUBLE FRP ROLLER SLIDE 2.1MT	*	1.00	3,615.00	3,615.00		3615
					6,345.00		6345
					Net Amt. :		6345

CONTACT DETAILS:-*Mobile: 7875333444 | Email: playtime@arihant.com/ playtime@vsnl.com | Website:www.arihant.com*
|
Board Line: 07507778271 / 72 / 73 / 74

1

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Appendix C- Mattress Packed and with Details

Mattress	Packed	Details
Brown		
Blue		
Green		
Orange		

Mattress	Packed	Details
Silver		
Foam		
Yellow		
Cot		

Appendix D- Complete Instrument

Sleeping Mat Assessment:

1. Please Circle: Male or Female

2. Height

3. How easily do you normally fall asleep?

1	2	3	4	5

Need Specific   Can Fall Asleep

Sleeping Surface   Anywhere

4. How often in a year do you go camping?

Never   1-2 times   3-4 times   5-6 times   7 or more

5. How many of those are multi-day trips (more than one night?) _____

6. During which months do you typically camp? (Choose all that apply)

Jan   Feb   Mar   Apr   May   Jun   Jul   Aug   Sept   Oct   Nov   Dec

7. How do you normally get to your campsite?

Car   ATV   Hike   Other_____

8. Where do you typically sleep while camping?

Cabin   Tent Trailer   Car   Tent   RV   Other_____

10. Try the mattresses and rank them in terms of which you think is the most comfortable to the

least (please identify the mattresses by color as labeled)

Most   Least

11. Please rank the mattresses in terms of which you think is the most durable to the least

Most   Least

12. Please rank the mattresses from your over-all favourite to your least favourite

Most   Least

13. Ask the administrator for the price of each mattress. Please rank them in order from most

likely to purchase to least

Most   Least

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