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First-Year Engineering Design Challenge: Re-Evaluation of the Medical Walker

Aezeden Mohamed, Peter Oyekola, NgeneTochukwu

Abstract

Limitation in mobility is an issue commonly associated with being dependent on others to accomplish tasks. This could lead to psychological related issues like depression, infections, loss of strength, and other negative health impacts.This paper is therefore focused on the design process of a mobility aid targeted to assist senior citizens and all users to complete tasks independently while ensuring their safety and being cost effective. It is a novel research done as an introduction of first years engineering students to engineering design process in an effort to develop strong sketching and 3D modelling skills in a non-isolated manner. The goal of the design process was to create a versatile device that could replace the need for other mobility-utility aids such as electric shopping carts commonly found is grocery stores, while implementing a compact design, collapsible structure, agrabbing tool, and a basket whose purpose and functionality to ensure effortless transportation in any motor vehicle. Hence, injuries related injurie and market-analysis of existing mobility devices was studied to determine prospective designs solutions which was further to ensure safety standard were met.

Keywords: Design, Walking Aid, Mobile Walker.

1. INTRODUCTION

people with mobility challenges such as the elderly, injured war veterans ordisabled individuals may find daily chores and leaving their residence arduous and problematic due to physical impairments. Individuals on occasion are unable to maintain the same quality of living as they used to. Older adults typically face mild to moderate changes in perception, reaction, and physical ability as they continue to age which could be due to decreasing bone density, which increases the risk of serious injury should there be any slip or fall. In fact, among older adults, over 95% of hip and wrist fractures are the result of a simple fall[1]. This is a far-reaching issue, with the average adult losing 20-40% of their peak strength by the age of 65[2].At the same time, older bodies tend to experience muscle degeneration, shortness of breath, forward lean and loss of balance. Their inability to lift weight and their slow walking pace can be attributed to their muscle, skeletal and joint degeneration.

Aging people also need to be able to get out to get groceries andhousehold needs on a regular basis, as well as continue to live an active lifestyle. While preforming day to day duties, it can sometimes be difficult to do things such as use a standard shopping cart because the low basket height can put undue strain on the seniors back. It is also difficult for them to get the groceries or goods from the store to their car and into their house and this the initiates a reluctance to participate in activities they once enjoyed, such as driving or shopping which could lead to increased depressive symptoms in the elderly[3].Solutions to this problem, unfortunately, fall short as with users surviving on a low income, many optionssuch as motorized scooters, are unaffordable. Canes, while affordable and simple, offers little support and do not help transport goods.

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Several types of assistive walking devices currently exist to enhance the mobility of seniors, however many of these devices are intended to aid in moderate to severe loss of mobility possibly caused by conditions contributing to muscular and nerve deterioration. There however is an absence of mobility devices targeted towards individuals of less extreme mobility loss, that is, mild to moderate loss due to age associated muscular retrograde which will allow for a less invasive, convenient device design. The objective of the design process is to develop a device to help prevent injuries and increase independence of the user with the requirements consisting of ease of operation & maintenance, durability, weight capacity and storage.

As can be seen from Public Health Agency of Canada research, injuries to seniors also have a large burden on the public health care systems. The median total income for a person of age 65 and old in 2014 was $25,910[4]. Similarly, the budget of this population is relatively low, especially among unattached seniors and senior women (two groups that often overlap, as women tend to live longer). Of the unattached seniors, 15.5% lived below low income, which is 11 times higher than those who are part of a couple. Therefore, there is not a mass amount of expendable income for seniors to spend on expensive devices for mobility as seniors they general do not have a lot of disposable income, the cost will be a big consideration in the design process.

1.1. Course Description / Structure

As earlier mentioned, this paper represents an introduction to mechanical design challenge at the Memorial University of Newfoundland, Canada which aimed at developing first year's skill in thinking and creative design. This was a subject course taught in the department of mechanical engineering which included students from different discipline such as automotive, electrical, manufacturing, nuclear engineering ang other relate discipline. the course in itself (1030 Engineering Graphics and Design) is a three-credit unit course with an attached two hours weekly session.

Student are basically assessed by a combination of laboratories, problems, tests, assessments design projects as well as the examination at the end of the session. The use of computer aided design tools helps in visualising designs, ideas as well as for rapid prototyping through the recent advancement in 3D printing technology. The course is also structure and broken down into five major topics which are,

- Graphics which consists of sketching using freehand techniques, planar projections (orthographic, oblique and isometric projections), multiviews, auxiliary and sectional views, dimensioning and tolerances
- Design Lectures: this section consists of design definition and practice, decision making and evaluation, project management and teamwork, engineering communication, life cycle analysis and case studies
- Communication Tutorials introduces the students to the use of phone, email, logbooks, cover letters, minutes. also, technical writing, report structure, writing style, presentation guidelines, formats, content such as introductions, abstracts and references are included.
- Design tutorials section includes instructional presentations on design fundamentals, organization, report structure, logbook usage, list of engineering design challenges, student group organization, problem identification, research, concept generation,

selection, evaluation, refinements, report and presentation preparation with peer-review of materials and presentation quality.
- Computer Aided Design tutorials features weekly SolidWorks classes, assignments and project

This course structure therefore aims at a rigid learning output which expects that the students should be able to

- Apply engineering design principles to wide ranging complex problems.
- Develop team work and project management skills through design-oriented group projects.
- Develop CAD skills as a foundation for future design tasks.
- Learn hand-sketching as a means of communicating ideas and designs.
- Develop an appreciation for various workshop skills and safety protocols.

1.2. Design requirement

The basic requirement of this project channels the students towards a structured design route such that a technical report was submitted together with the designs of the completed working drawings although design calculations for verification was not required.

The major technical requirements were;

- Design a walker which allows a senior citizen to safely carry out routines such as basic shopping and other household needs.
- lightweight and collapsible design to allow for ease of transportation and movement,
- compact and low cost for an average user.

2. EXISTING DESIGNS

The consideration of design solutions and fundamental researchwhich were analysed were weight, overall carrying capacity, folding size, wheel size and type, cost, ease of operation, maintenancecompact (foldable), durable, storage and size. And from market research, we see that although there are existing walking aids, they however do not cover the entire functional requirement for this project. While some brands offer cost effective solutions, there is often a compromise in other requirements similarly, the high-quality walkers are usually expensive and not easily affordable by the average citizen.

The regular walking cane is used as a crutch to help support a person, making it easier to walk. It is lightweight and portable, typically weighing around a pound and can support up to 600 pounds[5]with prices ranging from $5, to hundreds of dollars[6]. Typically, the more expensive canes are more of a fashion or collectible item rather than therapeutic. While its design is quite robust as it can be used on practically any terrain such as stairs, gravel, or grass, the main problems that occur with the design is that people with more severe walking problems may need additional support, and it cannot be used to carry any items such as groceries, or clothing items. Walking aids that support this function could weigh between 50 to 70 pounds [7]. It is also bulky, not easily stored, difficult to navigate different terrain and not much benefit in navigating stairs.

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Table 1: Random Sampling of existing mobility aids

	Weight (LBS.)	Seat height (inch)	Seat width (inch)	Width x length (inch)	Handle height (inch)	Weight capacity (LBS.)	Price (CAD)
Xpresso Lite Mini Walker	15.0	18.0	18.0	22.0 x 26.0	30.5 - 35.5	300	385
XpressoLite Regular	15.0	21.0	18.0	22.5 x 26.0	30.5 - 35.5	300	385
Xpresso Lite Tall	15.0	24.0	18.0	22.5 x 26.0	33.5 - 44.0	300	385
Drive MEF 4 Wheel Rollator	18.6	Na	12.0	23.5 x 25.5	31.0 - 37.0	300	109
Piper DX	13.0	21.0	18.0	22.0 x 26.0	31.0 - 36.0	275	400
Piper MDX	13.0	19.0	18.0	22.0 x 26.0	30.0 - 34.0	275	400
Piper SMDX	12.0	17.0	16.5	21.0 x 26.0	29.0 - 33.0	275	400
Piper TDX	13.0	23.0	18.0	23.0 x 26.0	35.0 - 39.0	275	400
3 Wheel Aluminum Rollator	11.0	Na	Na	26.0 x 22.7	32.0 - 38.0	300	148
Sprite Walker	12.0	21.0	17.0	24.0 x 23.5	33.0 - 38.0	250	290
Sprite Mini Walker	11.0	18.0	17.0	24.0 x 22.5	30.0 - 36.0	250	290
Sprite Grande	13.0	21.0	17.0	24.0 x 25.5	33.0 - 38.0	250	290
HOMCOMRollator	17	Na	9.4	27.5 x 36.6	36.6-44.0	264	136.07
HOMCOMHeavy DutyRollator 3	15	Na	9.4	25.2” x 39.4	38.2-46.0	264	199.99

Table 1 above represents gathered information on industry standardwalking assist specifications, which will guide in the determination of some of the final attributes of the proposed design.It is observed that all models sampled had 8” wheels which is useful in navigating rough terrain withoutgetting stuck. Similarly, the designed weight was between 11 Lbs. and 18 Lbs. of which additional functionalities was the major cause of this differences. This therefore meant that the estimated load bearing capacities of the 4 models was 282 pounds.

All of the samples were made of lightweight aluminium and plastics whichincreased mobility and by reducing the designed weight. The also a clear relationship between price and luxury. The more aesthetically pleasing model had a cost of $559.00 as compared to the cheapest model at $136.07.

Some walkers also come with a basket which offer the user a space to hold small personal items and products that they obtain on an outing. The following figure demonstrates solutions that are currently on the market.

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Figure 1. Demonstrates basket styles currently on the market.

The obstacles mobility challenged people face with the use of the current walking technologyincludes traveling as some walkers do not have wheels, walker storage when not in use can be very problematic especially the four-wheeler design which might tend to be bulky. Also, not all walker comes with the compartment to hold products while shopping or even working. It is difficult to use a grocery cart and a walker at the same time. Some users have also complained of difficulty obtaining products from low or high shelves.

2.1. Design Constraints:

*Environmental:*with the current environmental challenges weface such as global warming, waste disposal, and pollution etc. possible solutions that will reduce these issues were considered. One possible way to do so is to use eco-friendly materials such as aluminium and recyclable bags in the manufacturing of our model. As well, the environment in which this product will be used in must be considered. The design must be able to traverse different terrains such as pavement, gravel, and concrete flooring.

*Social:*This design should allow the users the continue with their daily activities, without feeling limited in their abilities. With reduced mobility, many individuals feel discouraged when they lose their independence and must depend on the aid of others to help them. On the other hand, due to the technicalities of the design model, it could draw the attention of onlookers towards the user. This may cause some feeling of discomfort, and may discourage them from using the product in public places. However, these devices are currently becoming more accepted in today's society.

*Cost efficiency:*The average income for potential customer is less than $50,000. This means that the final solution must be cost efficient. However, with this affordable design, the structural features cannot be constructed with cheap and weak materials. A balance between affordability and quality must be determined and provide the users with mobility support for multiple years.

3. METHOD AND MATERIAL SELECTION

The centre piece of the course is the group design project. ENGI 1030 puts an emphasis on teamwork, a skill that first year students need to develop. The project allows the students to combine the knowledge that they have gained in both graphics and design to create a solution to a real-world design problem.

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The requirements for the group project force the students to go through a structured design process.

Students must submit details of their unique mobility aid design for the purpose to assist old people and the disable to ensuring effective tasks completion independently. The criteria of selecting the best group was through, problem definition, alternative designs, specify requirements, relevant constraints, Final design, presentation include activities such as visual aids, body language, and oral. Another specific criterion for selection was aimed at the stability, portability and effectiveness of the device in solving the proposed problem (easy and smooth mobility). Through the process of brainstorming and general idea generation, several free hand sketches were made and each group presented based on their designs. Some of the designs employed three wheels, while others had four. The 4 wheeled designs offered a more even weight distribution across all wheels, making the device more stable. This also allows setting the basket up higher and closer to counter tops while keeping the chance of the device tipping low.

Appealing aesthetics is generally associated with simplicity. To apply this concept to the walker design, all "extra" components should be hidden or be displayed in a way to draw minimal attention. Hence, the cables for the braking mechanism of the wheels was installed inside the frame of the walker rather than on the surface while the surface was a single, gender-neutral colour. To achieve a premium "feel", a metal binding, water-resistant paint similar to paint used on car exteriors was used. This contributes to the durability of the walker by offering rust protection. All these considerationscontributed in minimizing the cost of the device asthere is balance between price and quality.

In addition, students must create a short manual for their design and give an oral presentation on their final design. All of the materials must be submitted in the form of a technical report.

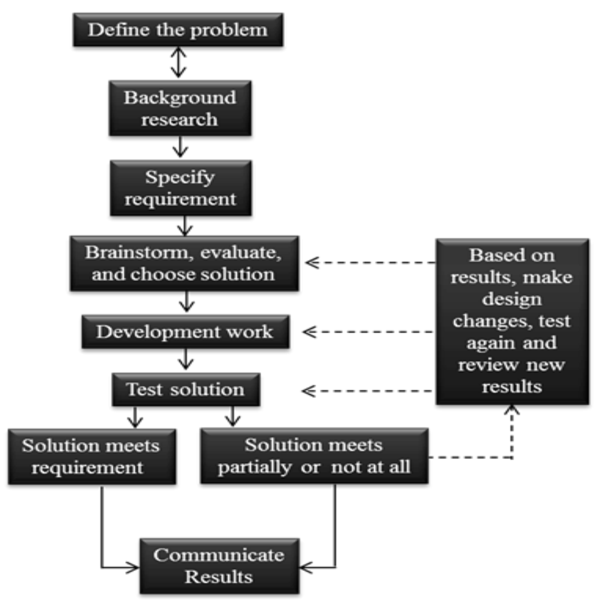

Figure 2.Development road map

*The Frame:*The design featured a collapsible frame for easy transportation and storage. This design satisfied the storage issue, however did not provide enough weight bearing support or room for other useful features to be considered. To resolve this problem, the folding component is located on the front, which allows for more weight-bearing support while, the handles are

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located at the top, and have the ability to adjust which is not being implemented in current existing designs which adjust the height from the legs. Another major requirement of the design is that it must be light-weight. Two options were considered for the material; Carbon Fibre and aluminium.

Table 2: Evaluating Carbon Fibre and Aluminium

	Carbon Fibre	**Aluminium**
Strength	Strong	Good
Weight	Strong	Good
Load Capacity	High	Medium
Cost	High	Low
Damage Resistance	High	Medium

It can be seen in the table that there are more arguments that promote the use of Carbon Fibre to aluminium. The light-weight technology of Carbon Fibre provides the users with easy mobility when in both the expanded and collapsed form. With this design needing to be structurally sound and have no risk of breaking during use, the advantages of Carbon Fibre out weight the cost in the long term[8][9].

*Basket:*To address the issue of storage in the cart, the design had to provide the same functionalities as that of a shopping cart. The material considerations are shown in the table below[10];

Table 3: Evaluating the advantages and disadvantages to using certain fabrics to make the basket

Fabric	**Advantages**	**Disadvantages**
Hemp	Strong, corrosion resistant, machine washable	Expensive, not locally produced
Polyester	Versatile, mould-mildew and water resistant, holds form, easy compaction easily, common fabric, easily cleaned, affordable	Plastic like and slow to break down (environmentally)
Cotton	Biodegradable, strong and durable, soft, widely available, machine washable	Not moisture resistant, heavy and bulky, expensive to ship, bag can shrink

A removable basked design was favouredin order to allow for easy transportation of products from the cart to a vehicle, casher register, and as well allows for easier storage and cleaning. Other designs of the basket include;

*Grabber:*This was incorporated for ease of reaching for objects. Initially a manual grabbing tool was considered as it was a cheaper solution. However, there is also a risk of dropping. This necessitated the implementation of a grabber attached to the walker. Positioning the grabber on the side was found to be more convenient, since the objects will be placed on the shelves to the side of the walker. With a mechanized option, the controls would need to be placed on each

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handle for easy access. As well, the power source for this mechanism would be a rechargeable battery, located in the handles.

*Wheels:*Three types of wheels were considered; Foam-filled, Air-filled, and Plastic. The following table compares the three types[11];

Table 4: Wheels properties considered

	Advantage	**Disadvantage**
Foam Filled	Eliminates the need to replace if punctured	Expensive, heavy
Air Filled	Light-weight, cheaper solution, common product	Must replace if punctured Can lose air-pressure over time
Thermoplastic Polyurethane	No need for replacement due to puncture, light-weight, performs well in different environments, combines the properties of plastics and rubbers, cost efficient	Heavier than air filled

In the consideration of wheel placement, two attachment options were considered. The first option allows the wheels to fold into the structure which enables users to personalize their walker to either utilize all four wheels, two wheels on the front or none at all. While the second option is a wheel triad system, that will allow the user to climb stairs, since the wheels could rotate on the axle. This was determined to be a costly option, and as a result recommended as an optional feature. The following figure demonstrates the main concept of the triad wheels attachment.

(a) (b)

Figure 3.(a) The wheels fold up into the structure [18], (b) Triad wheels design that can be used to help the cart travel upstairs [17].

The brake systemis connected to the wheels through a bowen cable similar to that of a bicycle which transmits mechanical force. The pulling force created at the handle is transmitted to the tire summing the braking system of the walker[12]. The threading on the surface of the wheel has been designed with a surface area enough to support the weight of the average adult. This threading also allows for motion in muddy landscapes by allowing the tires to grip into the surface and level the sides of the thread to get better grip[13][14].The joint of the tire to the frame of the walker will be a point of collapse to make the walker more compactable and portable.

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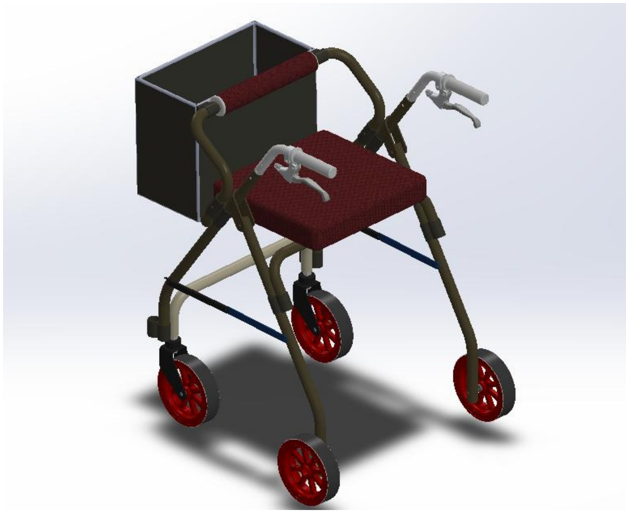
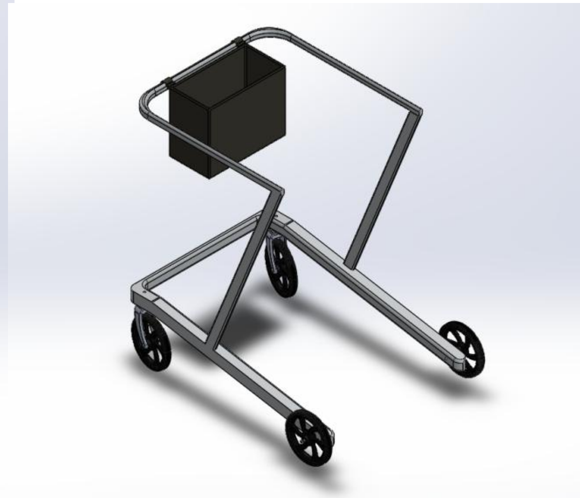
Table 5: Evaluating the choice based on the specified requirements of the final solution.

Component	Option	Safe	Portability	Light weight	Capacity	Durable	reach objects	Cost effective
Structure	Aluminum	Y	Y	Y	Y	Y	N/A	Y
	Carbon Fiber	Y	Y	YY	YY	YY	N/A	N
Basket	Polyester	Y	Y	Y	Y	Y	N/A	Y
	Cotton	Y	Y	N	Y	N	N/A	Y
	Hemp	Y	Y	Y	N	Y	N/A	N
Grabber	Robotic Arm	Y	N	N	Y	Y	Y	N
	Telescopic	Y	Y	Y	Y	Y	Y	N
	Manual	N	Y	Y	N	N	Y	Y
Wheels	Foam-Filled	Y	Y	N	Y	Y	N/A	N
	Air-Filled	Y	Y	Y	Y	N	N/A	Y
	Thermoplastic	Y	Y	Y	Y	Y	N/A	Y

(a)Team A(b) Team B (c) Team C





(d) Team D(e) Team E

Figure 4. Alternative designs

Table 6: Performance of each team per criteria over 10

Component	Team A	Team B	Team C	Team D	Team E
Problem Definition	7.70	7.52	8.40	8.53	8.18
Alternative Designs	9.60	7.90	8.51	7.51	7.90
Specify Requirements	8.10	7.70	7.87	7.80	8.10
Relevant constraints	8.50	7.20	7.30	7.80	8.00
Final Design	9.20	7.80	8.40	8.80	8.00
Presentation (Visual Aids)	8.90	8.20	8.52	8.80	8.20
Presentation (Body Language)	8.90	8.30	7.53	7.80	8.00
Presentation (Oral Presentation)	9.20	9.00	8.20	9.20	8.10

4. CONCLUSION

The design of a medical walker has been presented in this paper as an undergraduate first year course project which is an innovative graphics and design course developed at Memorial University, Canada.

From the received design presentation feedback, the final design of the walker successfully met the criteria set out which included allowing a senior citizen to safely carry out routines which involves leaving their residence to go pick up groceries and other household needs. The walker is lightweight and collapsible;therefore, it will allow seniors with smaller car sizes to benefit from it. In addition to addressing the problem stated, this device will also be able to be used for other activities such as walking for exercise, working in the garden, cooking or cleaning. It is also able to fold up small enough to accompany the senior citizen on a long-haul bus trip, or to be stored in the overhead compartment of a plane. The collapsibility feature of this device is what sets it apart from the competition as it ensures versatile edge over the competition. The major focus of this course was the design project which enables the first-year engineering students with critical skills which are capable of completing rather complex and innovative solid modelling design projects.

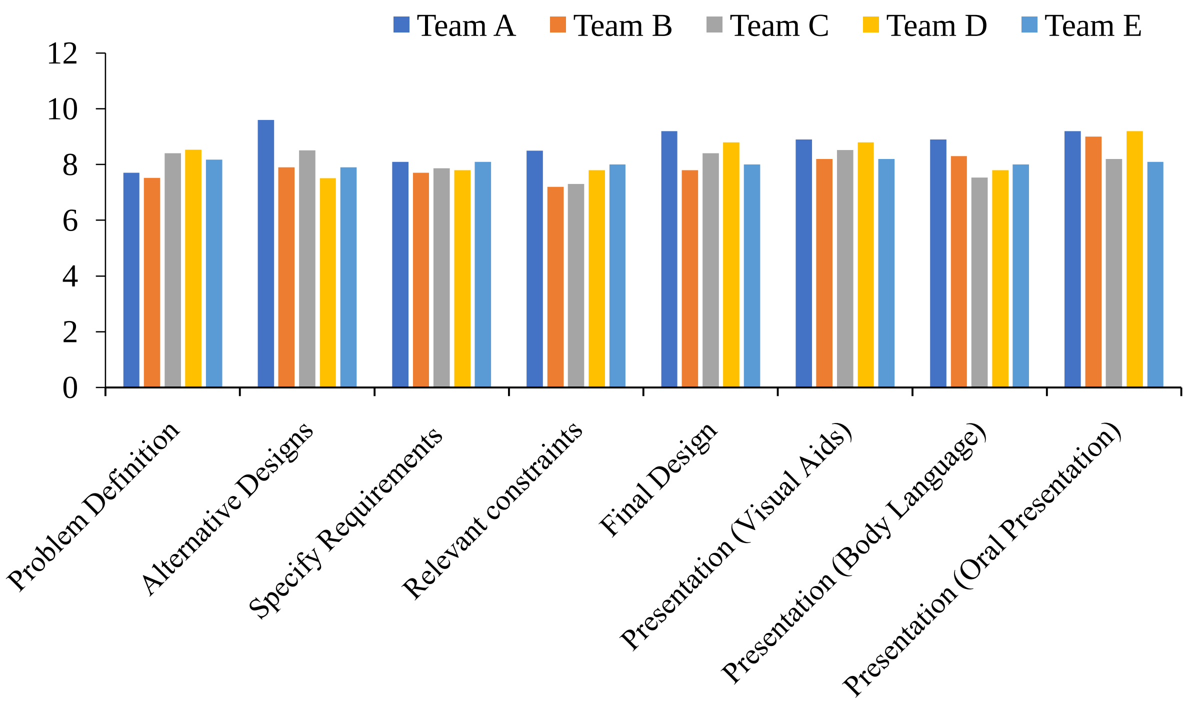


Figure 5. Chart showing students teams project performance

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