project 2

Furniture for Govt. Primary Schools

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November, 2016

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Introduction to Project

i. Birth of the idea

“Why do they sit on ground? Why is there no furniture? Why is the furniture in these schools so badly maintained?”

These were the questions which came to my mind when I visited government schools, regardless of the place/city/village the school was situated. But, these were not the only questions which bothered my mind and I’m sure that I’m also not the only one to have noticed this.

Being a part of a family where teaching is a major profession, I have had quite a share of exposure to schools and educational facilities. Evidently, the quality of the furniture (if present) depends upon the kind of school it is and the kind of funds available for it. But, its not just about the funds available, but also the nature and design of furniture which is a major part of the problem, which will be discussed later in the report. As a student of design, it was a natural instinct to look for a design intervention for this scenario. It might however be a system level intervention, but one can look it as a approach to a level where apparent flaws in design could be removed. Hence, I started looking for clues.

It was even more surprising to get to know that there had been fair amount of research done on this topic throughout the country, to understand the issue behind the *ill-designs of furniture* in schools especially in rural and remote areas. After going through a few of these reports the validity of the issue was more clear and I took it as a challenge to turn this potential topic in successful design intervention.

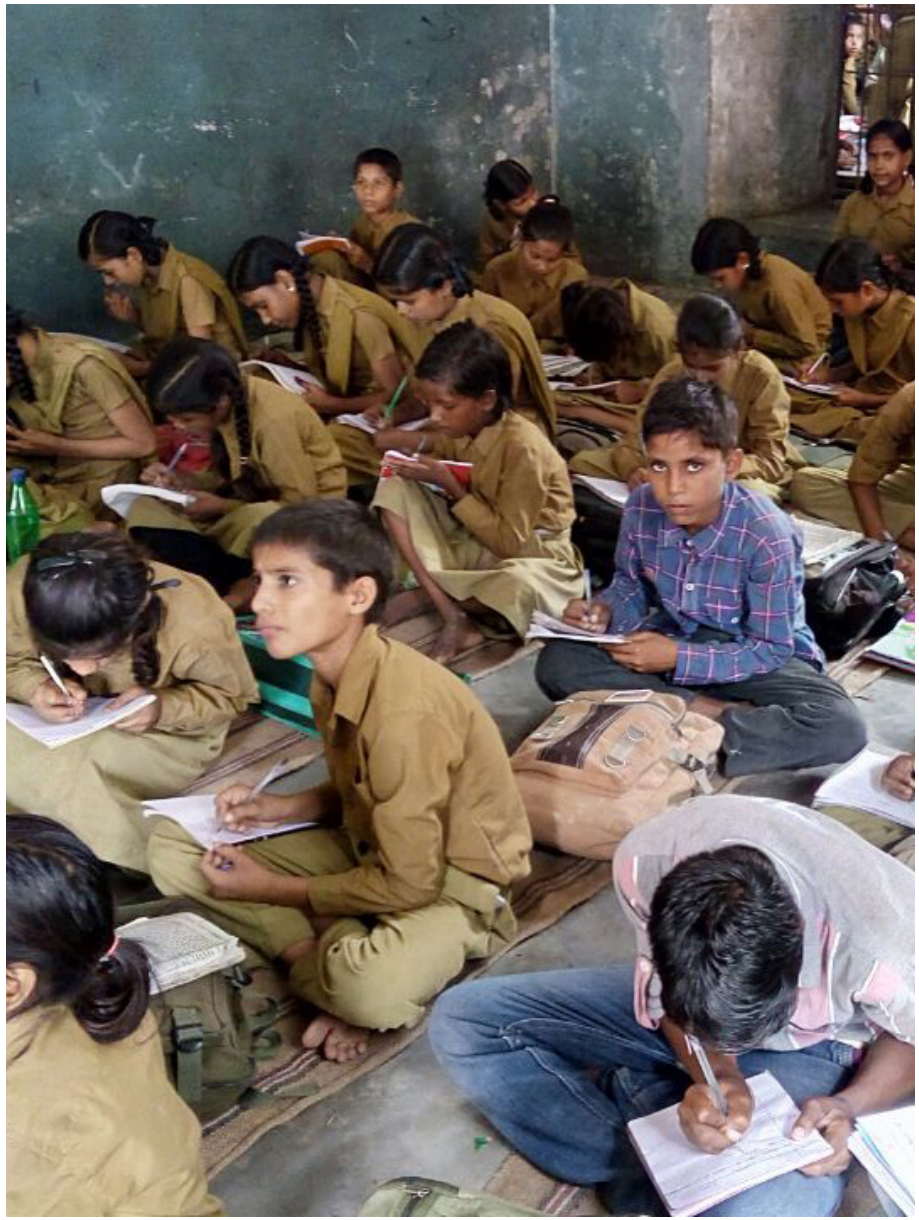


Fig 1: A scene of primary classroom in a school in Uttar Pradesh.

ii. Abstract

School furniture is an integral part of any student. Whether the students notice or not, a major part of their activities and time during school are spent on them. They play on them, make friends on them, fight for them and sometimes fight on them.

Having been to a no. of government schools I could easily remember those uncomfortable chairs and desk which used to make us yawn and tired even before recess, and those desks which become absolutely redundant once the school is over. Such a huge infrastructure, plays no part in learning, and leave that, is not even able to do its job, to provide comfortable learning environment. But comfort here in these government schools is itself a luxury, because presence of furniture itself bears a big question mark.

Hence, the issue does not lie only in not being able to provide comfort but also in bad maintenance and/or absence of furniture in these schools, and it all raises a question of why if the ill condition of the furniture is visible to everyone, still exists? In this regard it is more important to understand that it's not only the financial aspect which is responsible for such a scenario but also the nature of design of these furniture.

In 2012, Department of Human Development and Family Studies, presented some facts about the ill designs of classroom furniture, especially in government schools. The report shows a even technical picture where it discusses about the mismatch in these furniture designs to the anthropometry of the students using it. This makes the argument even more valid.

However, various facets of this issue of furniture design in govt. schools are so deeply rooted to the system that its difficult to solve each of them. Hence, as a focus of academic research it is well understood to take it as a design exercise and tackle issues only in critical design perspective.

Nevertheless, this would be helpful in understanding the real life problems and problem solving in a first hand experience. And, through this research, if one is able to improve the conditions of these schools even with a very less margin, then it should be considered a success.

Keep reading.

i. Methodology
ii. Time-line

Initiation

i. Methodology

Project 2 at IDC, IIT Bombay this year focusses on Redesign of Industrial Products. The idea of project 2 is generally to implement critically the design thinking gathered over previous year in a real life setting. The focus is more on design and design process rather than just extensive in-depth research, due to the time constraints.

The methodology would be to critically analyse the issue in form of primary visits and observations followed by secondary data collection, leading to a project brief and a set of design directives. This will be followed by an iterative process of design and testing, concluding in form of a design as per the directives and brief.

On a broader note, the objective of the project would be described as follows:

1. Look for problems and issues in real life scenarios and products, which require serious design intervention.

2. Understand issues in a critical manner with the help of user studies and site visits

3. Literature study on the respective area of work, looking for clues and approach for similar projects

4. Selection of design directives critical for the project and finalizing design brief

5. Design interventions in form of ideations catering to the design directives and evaluation

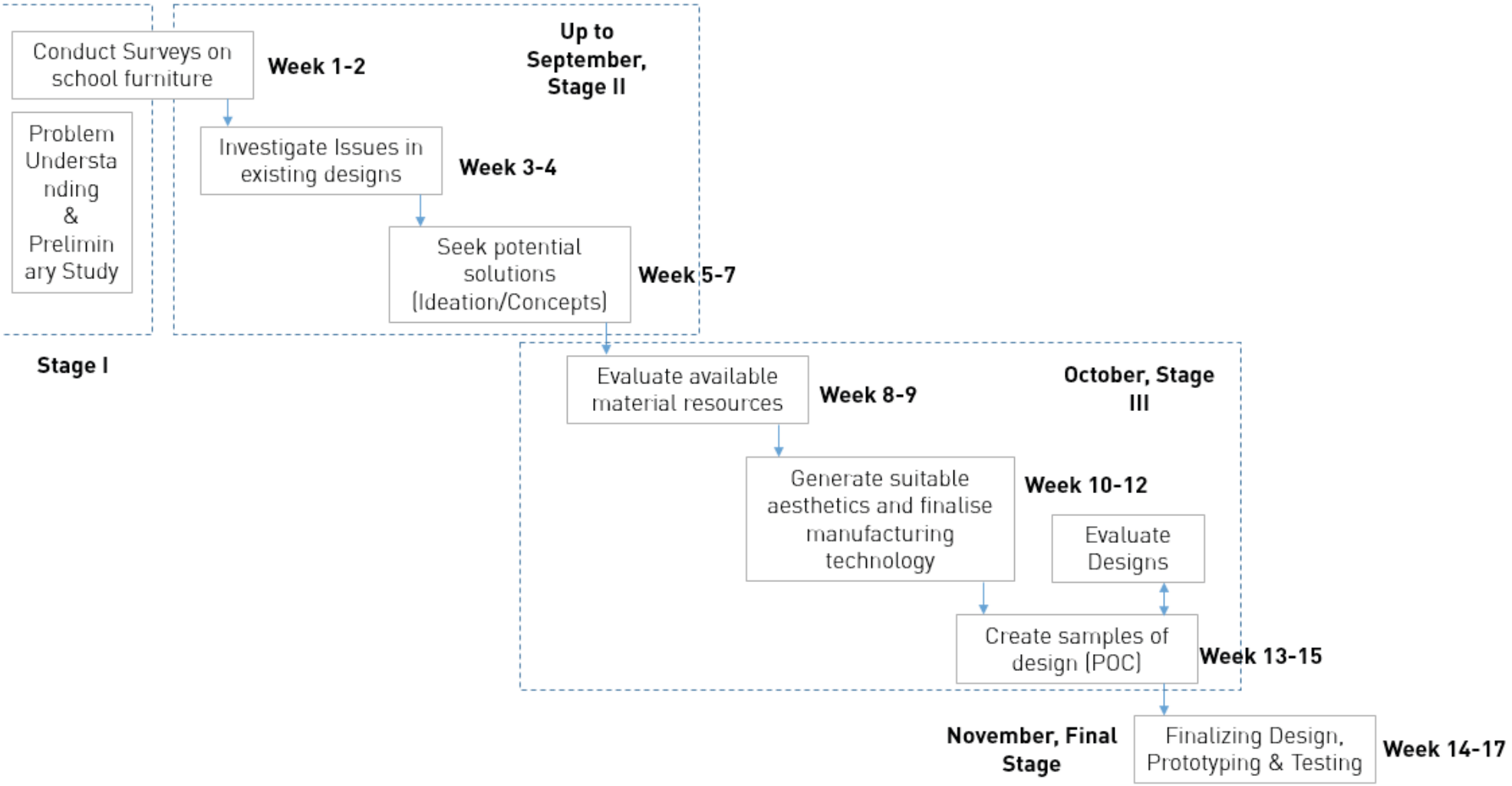
6. Concept generation on the basis of ideations.

7. Evaluation of concepts

8. Prototyping and user testing

This is however just an indicative list of objectives, this might change and steps would iterate as needed during the project process.

ii. Time-line


Problem Understanding & Preliminary Study
Stage I
Conduct Surveys on school furniture
Week 1-2
Investigate Issues in existing designs
Week 3-4
Seek potential solutions (Ideation/Concepts)
Week 5-7
Up to September, Stage II
Evaluate available material resources
Week 8-9
Generate suitable aesthetics and finalise manufacturing technology
Week 10-12
Evaluate Designs
Create samples of design (POC)
Week 13-15
October, Stage III
November, Final Stage
Finalizing Design, Prototyping & Testing
Week 14-17

i. School Furniture Current Trends
ii. School Visits
iii. Govt. Policy Study
iv. Case Studies
v. Material Analysis
vi. Ergonomics and Anthropometric Study

Investigation

i. Current Trends

Background

Classroom furniture design can affect educational activities because it is an important component in any classroom which helps in providing a comfortable and functional classroom environment for the children. Improper furniture design can result in defective posture which could affect children's academic performance. Hence it is essential to facilitate school furniture in accordance to the requirement of school children. To focus on the issue of furniture design the present study is conducted with an objective to identify the issues in existing furniture in primary schools.

In 2012, a no. of urban and rural schools were selected randomly from the selected urban and rural areas of Lucknow district of Uttar Pradesh, India by Department of Human Development and Family Studies. The evaluation of the study was made by using the self made questionnaire standardized along with anthropometric checklist. The results of the study revealed mismatch between existing furniture with children's body dimensions which mayresult in various health problems in later life.

The report shows that a surprising number of school children are reported to have regular back pain, neck pain and headache by using ill designed furniture that result in bad postural habits, while good posture habits reduces organ crowding, strain on soft bone and muscle. Most of the researches have revealed that in most of the schools, the furniture is designed by manufacturer without considering the anthropometric dimensions of the users of different age groups. As an outcome, benches and desks become unsuitable, uncomfortable, inconvenient, affecting classroom learning activities of school children while attending their classes. On the other hand, the inflexibility of these furniture was another point of consideration.

Issues at a glance

A high percentage of the school children of different grades become fatigued after sitting for longer hours on same furniture.

*To achieve temporary relief from these discomforts, they frequently change their sitting positions during class. They are also compelled to sit in various inappropriate postures. [1]

*The occurrence of neck ache is high in the school children of lower age group, and it decreases as the age of the school children increases.

*Back problems among the school children of higher grades are more prevalent than in lower grades.

However, these were some of the long term issues and the ones which have health influence on the user. If one looks at the government schools, the situation is even worse, the provision for furniture till primary classes is not even present, let alone the ergonomics and design. Even though sometimes, there are funds available for this, either the funds are not sufficient for buying good quality durable furniture or the quality of furniture available in that amount lasts only for a very short period of time.

This introductory research sparked the urge to understand the scenario in a more structured manner and indepth. The following research is done first hand through primary and secondary resources.

** Department of Human Development & Family Studies – Nov. 2012*

i. Current Trends

Market Analysis

Fig 2.

Fig 3.

i. Current Trends

Cost: 2500/piece

Cost: 6300/set

Cost: 2500/set

Fig 4 & 5. Market Survey

ii. School Visits

In order to understand the situation better a no. of schools were visited. The prime focus while school visits was to look at the real issues and current scenario in furniture design of schools.

The schools visited were:
1. Model School, Shahjahanpur, Uttar Pradesh
2. Kendriya Vidyalaya, IIT Bombay
3. Campus School, IIT Bombay

The study focusses on the design of various furniture at these schools and to look for problems which are present or likely to arise because of them.

1. Model School, Shahjahanpur, U.P.

The school is located in the outskirts of Shahjahanpur District of U.P. The reason nehind selection of this school was firstly it being accessible to the author. The school functions under state board till 8th class with english as mode of teaching. The study revealed that situation of furniture at the school was quite uncomfortable. The furniture provided to students were not at all upto the standard anthropometric dimensions.

The image below shows 5th grade classroom, just looking at this image one can figure out the situation of the class. SImilar furniture is being given to sit to all the students whereas you can clearly see the physical variation.
The dimension of furniture is roughly as follows:
Table: 450x1000x700
Sitting Desk: 300x1000x450

Fig. 6. Model School Shahjahanpur, 5th grade classroom.

ii. School Visits

Summary of observations
at Model School, Shahjahanpur.

The furniture was similar for all the students in one class, irrespective of their physical anthropometry.

The primary section specifically doesn't have any furniture for them. They have to do away with the matts and carpets for sitting in classes.

The students beacause of ill designed furniture or no funiture, get fatigued and hence keep on changing postures entire day.

The imporatant elements of furniture which helps in providing support to one's back are necessary and this poor implementation might lead to serious health implications.

One of the reason for not having furniture was that the furniture available is quite expensive and difficult to be made anywhere closeby. Thus, affordability of furniture is a major issue in this case.

Fig. 7&8. Model School Shahjahanpur, 2nd grade (up) and 3rd grade classroom. (Source: Author)

ii. School Visits

2. Kendriya Vidyalaya, IIT Bombay

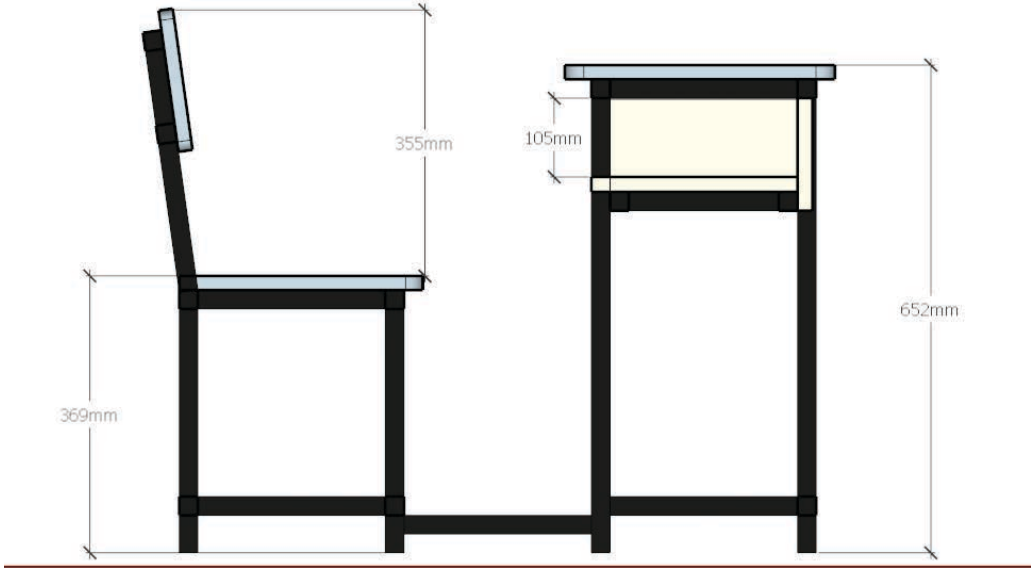
The school is located in IIT Bombay. It runs under CBSE Board with classes from Kinder Garten to 12th.

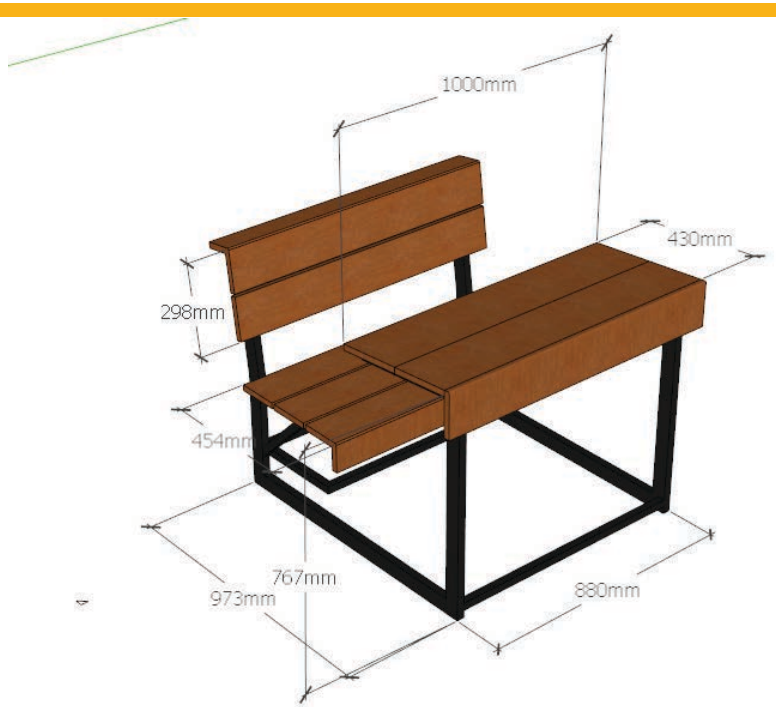
It is a known fact that KVs are considered to be one of the best govt. Schools in the country in terms of its facilities and quality of education. However, the situation of furniture was not so different form any other school. This made it important for me to study it and look for the loop holes and opportunities for future.

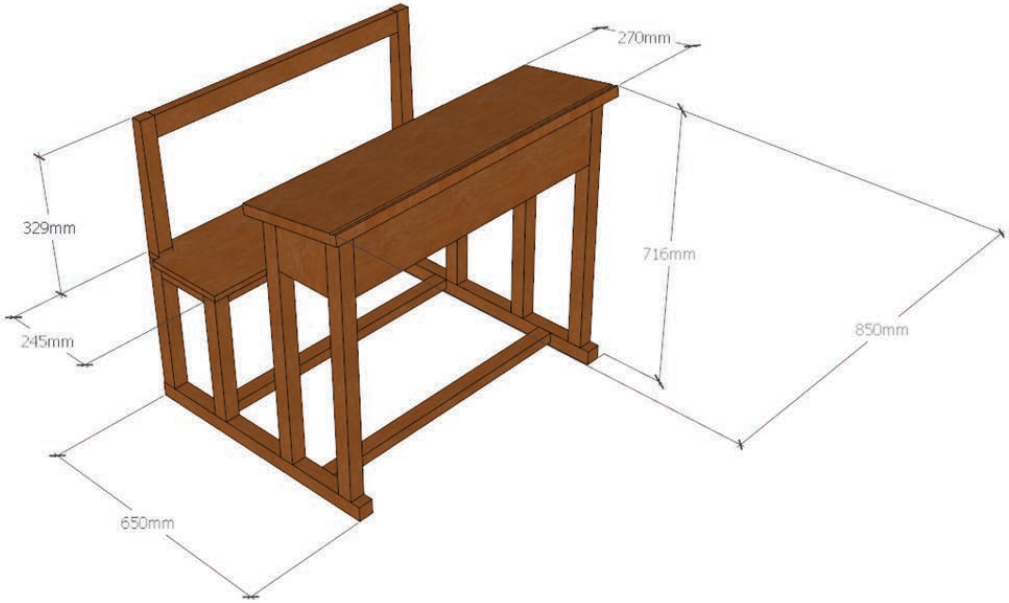
Fig. 9. 6th grade classroom in Kendriya Vidyalaya (Source: Author)

Fig.10&11. 3rd (up) and 8th (below) grade classrooms in Kendriya Vidyalaya (Source: Author)

ii. School Visits







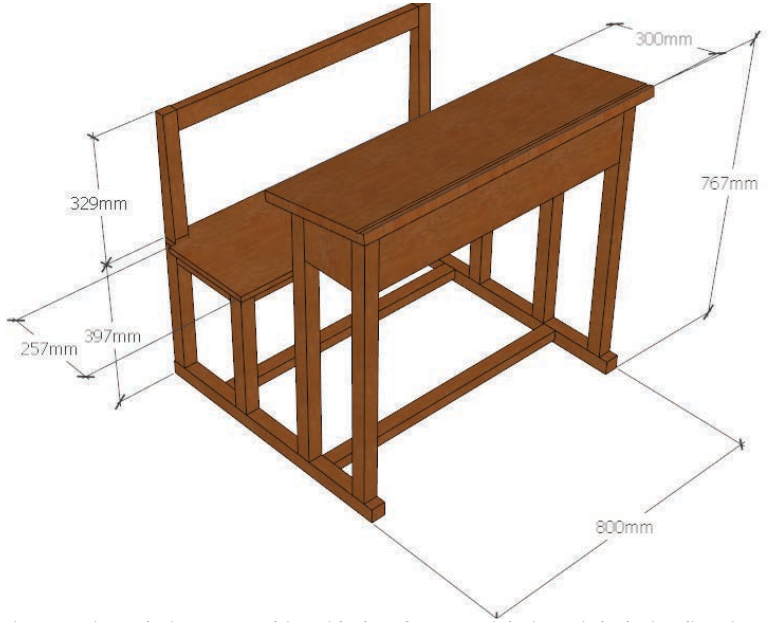


Fig.12. Various Furniture designs at Kendriya Vidyalaya from top right in anti clockwise direction (2nd, 3rd, 5th and 7th). (Source: Author)

ii. School Visits

Summary of observations
at Kendriya Vidyalaya, IIT Powai.

The furniture was different for most of the classes.
Although, the maintenance was poor and designs did not cater to the vandalism.

Seats are permanent, students have to lean in front while working.
Non-ergonomic design.

Slanted tables help in writing.

The dimensions of furniture did not match as per standards in some classes, which indicates that design was not a consideration while choosing furniture.

After, talking to school officials, it was found that the furniture is ordered through a quotation and the manufacturer which comes up with lowest bid wins the contract.

Design is not even present in the entire picture!!

Fig.13&14. Various Furniture designs at Campus School, IIT Powai

ii. School Visits

3. Campus School, IIT Bombay

The school is located in IIT Bombay. It runs under CBSE Board with classes from Kinder Garten to 12th. The furniture present in this school is in three ranges 1st-5th, 6th-8th and 9th-12th. These categories have similar furniture irrespective of the standards. The students however are comfortable in this situation as the opportunities for this furniture are quite limited. The fact that children grow at a quite faster rate around 8th-10th grade, is not considered and hence create problems in providing comfortable postures while studying on this furniture.

Fig. 15. Campus School Furniture.

Summary of observations
at Campus School, IIT Bombay.

The furniture being exactly similar for a range of classes is indicative of the fact that design was not a constraint while using this furniture.

Students seem to be adjusting with given furniture, because of the lack of resources.

In order to create room for standing/egree/ingress, the working posture has been compromised. Students have to lea to work on the desk.

The ill designed furniture might lead to serious health loss to the students.

Affordability is a constriant here also, as the furniture here also is chosen through lowest bid.

The effects of this on learning in the classes could prove to be drastic.

ii. School Visits

4. Poddar International School, Mumbai

Fig. 16. The presence of ergonomically comfortable seating space and table. However, the similar furniture for all and absence of adjustability is an issue.

Fig. 17. Colours helps in creating appropriate learning, which is generally missing in classrooms.

Summary of observations
at Poddar International School, Mumbai.

The furniture is well maintained and industrially sound.

Injection moulded seating base and laminated wood table tops over powder coated metal structure.

Colours are being used in furniture, which creates a different ambience in classrooms.

Repair is not an issue as finances are not the major consideration.

iii. Govt. Policy Study

Rural v/s Urban

A prominent study concludes that students in rural schools in comparison to urban schools perform less because of affected learning environment and classroom facilities.

In rural schools it is often seen that the same size of furniture are used in several classes either in pre-classes or in secondary.

*"Appropriate design of classroom furniture with consideration of the body dimensions of school children and other ergonomic factors may be helpful for reducing health complaints and improving the posture of the school children in the classroom."**

*Complaints arising from a mismatch between school furniture and anthropometric measurements of rural secondary school children during classwork, Department of Human Development & Family Studies, Nov. 2013

Govt. Policy for Primary School Furniture

As per the framework of SSA, there is a provision for furniture at government upper primary schools and for that matter ₹ 500 per child is provided as a one-time grant to every school that do not have furniture.

Around ₹10 lakh are provided to upper primary schools for lifetime.

At the same time, there is no facility for benches at primary level, but a sum of ₹ 5,000 is provided to each primary school annually so that they can buy new jute mats or 'taat-patti' (mats) or repair any wear and tear on the same.

However, future plans are indicative of intervention of furniture in primary level as well.

Design is not even mentioned in the entire policy!!

iv. Case Studies

Ergonomic Design of Desk and Chair for Primary School Students in Taiwan

In this report, the author says that the traditional desk and chairs are not able to fit all students in different body figure. How to achieve the requirement of students for different body situation is the major consideration in this study.

The procedures were adopted for the assessment included the current school furniture survey, a design analysis and a subjective comfort evaluation. On the basis of their research, the designer gave proposals while considering the following chart (Fig. 14) for various design provisions.

The various designs generated are given on the right. (Fig. 11, 12, 13)

代號	item	5 %	50 %	95 %	Design
A	Seat surface height	28.8 cm	35.2 cm	40.4cm	Adjustable design
	Adjustable range	27-33 cm	33-39 cm	39-45cm	
B	Seat surface width	38cm	38cm	38cm	Extremely design
C	Seat surface depth	37cm	37cm	37cm	Average design
D	Seat surface angel	3- 5°	3 - 5°	3 - 5°	Average design
E	Back support length	30cm	30cm	30cm	Average design
F	Back support width	40cm	40cm	40cm	Extremely design
G	Back support angel	100 - 105°	100 - 105°	100 - 105°	Average design
H	Desk surface height	58cm	64cm	70cm	Adjustable design
	Adjustable range	56-62cm	62-68cm	68-74cm	
I	Desk width	65cm	65cm	65cm	Average design
J	Desk Depth	50cm	50cm	50cm	Average design
K	Desk angel	0~10°	0~10°	0~10°	Average design
L	Drawer width	55cm	55cm	55cm	Average design

Fig. 18. Various Designs generated in the project.

iv. Case Studies

Wheelbarrow

A wheelbarrow is a small hand-propelled vehicle, usually with just one wheel, designed to be pushed and guided by a single person using two handles at the rear.

Summary of the study

Wheel barrow is a fine example of minimalistic approach to design.

The details have evolved over time while the keeping the basic form intact.

Shows excellent way of creating manufacturing details with minimal material usage.

The structure itself is so stable that the material required is quite less.

The innovation lies in the detailing and material choice, which is accompanied with pleasing industrial aesthetics.

Fig. 19. Wheelbarrow designs

Fig. 20. Wheelbarrow designs

iv. Case Studies

Bicycle

Bicycles have been studied to understand the manufacturability in metal. Also to understand industrial aesthetics and innovation in details.

The evolution of bicycles gives a rather innovative picture of evolution of diamond structure of bicycles. It lets one understand, how metal tube structure is evolved with the technology and possibility of detailing in tube structures.

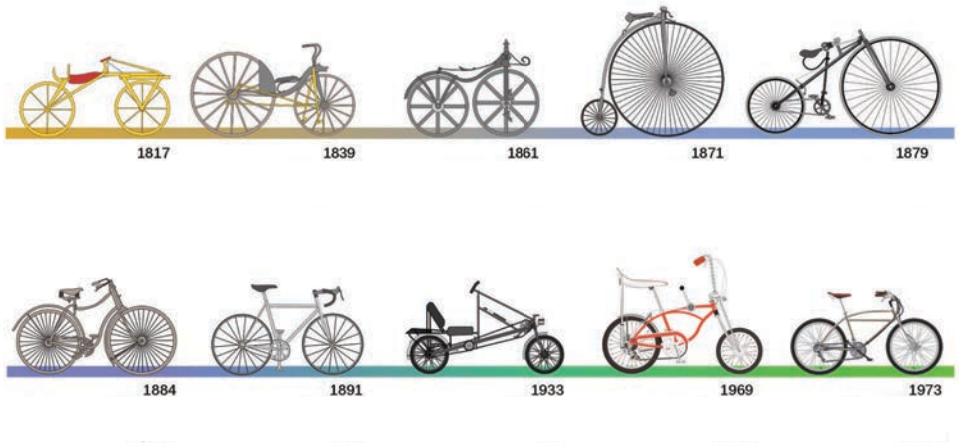


Fig. 21. Evolution of bicycle

Summary of the study

The diamond structure has gone through an evolution which shows various ways of innovation in metals structure.

The kind of aesthetics it portrays shows pure industrial detailing and manufacturability in metal. The innovation in colours, branding and surface treatment provides opportunities for similar structures.

A fine example of aesthetic approach while not compromising with the structural details.

Fig. 22. Various kinds of bicycles (Source: Google Images)

iv. Case Studies

IIT Bombay Lecture Halls

In order to study the various failures and other methods of innovation in academic furniture, lecture halls at IIT were studied.

A good example of material optimisation. However, the details make it a little difficult to maintain. Welded details make it extremely difficult and expensive to transport while it's also very difficult to repair parts.

Fig. 24. The base detail for chair, being rotating enhance stress and failure point. Welded details make it difficult for repair and part replacements.

Fig. 23. Lecture hall furniture

Fig. 25. Lecture hall furniture

iv. Case Studies

IIT Bombay Lecture Halls

The furniture is quite optimised in terms of material. However, the optimisation as led to creation of failure points in it.

Fig. 25. Lecture hall furniture

Fig. 26, 27. Lecture hall base detail

v. Material Study

Why ‘material selection’ is extremely critical for this project?

The choice of materials at the start of a project, as well as being a matter of economics and design, should be made on the basis of the availability of materials and their price in the long term. This choice is very important.

A material that might be right, in terms of availability and price, at the start of a project may be difficult to find and uncompetitive at the end.

School furniture is usually priced very finely and shifts in price and the availability of materials can render designs obsolete very quickly.

It is a long-term choice that should be made with great care.

The most widely used materials for school furniture are
Sawn-wood
wood-based panels
Plastics
Metal - mainly steel

The following study is to understand the pros and cons of these materials and also to understand to use them efficiently.

PLASTICS

The price of plastics has risen with the cost of energy. Here plastics are at a disadvantage compared with other materials, such as metals, wood or glass, because they have two energy components:

the feedstock, based on oil and gas from which the polymers are derived
the energy required to convert the feedstock into polymers and plastics. There is a wide range of polymers, they fall into two broad categories:

Thermoplastics
materials which soften on heating and can be subsequently reshaped
by further heat treatment. Polyethylene is a typical example of this class of material.

Thermosets
materials that are cured during the forming process so that they become infusible and cannot be reshaped by subsequent heat treatment.
A typical example is phenol-formaldehyde (Bakelite).

In considering the use of plastics rather than traditional materials such as wood and metal, cost is not the only criterion. The performance of an item of furniture made with plastics as compared with the same article made of traditional materials must be considered under a number of headings:

v. Material Study

1. Expected life-span before replacement

2. Cost of maintenance during use

3. Suitability of plastics in terms of actual performance, that is the ability to function adequately under all anticipated conditions

4. Plastics do not compare favourably with timber in regard to combustibility. They can be more of a hazard than timber in a fire, producing a greater amount of toxic fumes and contributing to the rapid spread of fire.

Plastics in case of FIRE !

Like wood, plastics materials contain high amounts of carbon and hydrogen in their structure and consequently all plastics, including those advertised as 'self extinguishing' or 'low flame spread', will burn if the temperature is high enough.

Fire retardants do not prevent plastics from burning if the temperature of the fire is sufficiently high, further they many increases the amount of smoke and toxic fumes once the material is alight.

It is useful in the context of fire to compare the behaviour of plastics to that of wood:

Wood decomposes with heat to produce inflammable gases at a higher temperature than the plastics used in furniture
the thermoplastics usually melt before they burn, spreading fire downwards and out, in a very different way from wood.

Under certain circumstances a char of carbon is produced on wood which tends to cut off the supply of oxygen to the rest of the material. It is possible that char may be formed with certain thermosetting plastics.

Mechanical Properties

In many ways, these properties show advantages over traditional materials; they can be summarised as follows:

Light weight and high strength to weight ratio, this being particularly the case with glass-reinforced polyesters. In the case of thermoplastics, the strength properties are reduced as the temperature rises but this is not so with thermosets. Thermoplastics, however, need not present a problem as the designer can make allowances for any abnormal environmental conditions.

The impact strength varies from one plastics material to another but the plastics likely to be considered for school furniture will be perfectly adequate in this respect

The scratch resistance is not as good as hardwoods but is comparable with softwoods.

Durability

The durability of plastics is naturally of great concern where these materials are used outdoors. Plastics tend to degrade in bright sunlight, the colour may change and in time there will be some loss of mechanical properties.

v. Material Study

Costs

Between the extremes of injection moulding and hand lay-up the various plastics forming techniques can be placed roughly in the following order, in terms of cost:

injection moulding
compression moulding
extrusion
casting
rotational moulding
foam casting
hand lay-up

Environmental Effects

Non-biodegradable: Plastic is a non-biodegradable material. So, even though no trees are cut to make a plastic material, it is equally harmful as it cannot be destroyed or degrade by natural agents and will remain on this earth for almost forever. This is very dangerous for our ecosystem.

Harmful fumes liberated when plastic is processed are very dangerous for our atmospheres. It is one of the reasons of air pollution.

Longevity

Compared to the wood or metal furnishings, it tends to fail after a shorter time period. This is usually thought-about to be one of many predominant disadvantages of this kind of furnishings.

Types of Plastic Furniture
Injection Moulded

The injection moulded furniture or parts are generally cheaper if manufactured on a bulk amount. However, making of the dyes are costly, hence if intended for lower production , its not considered suitable.

Other than costs, injection moulded furniture are genrally lesser strong, they fail one way or the other structurally and their life is

Fig. 28. Broken injection moulded furniture

v. Material Study

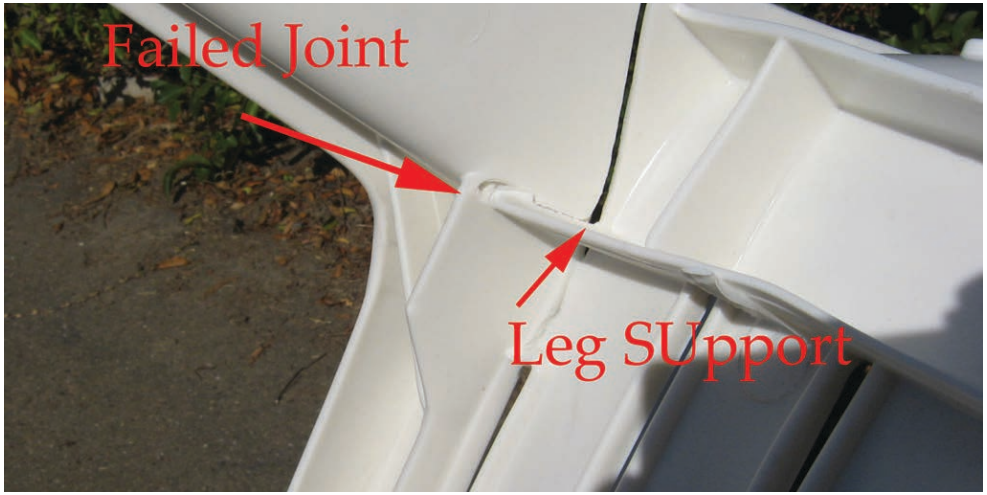
The plastic or moulded furniture loses its aesthetic and structural strength if kept in sun for a longer duration. This makes it a very non-reliable material. Its very difficult to predict plastic's longevity or strength as its properties changes drastically with surrounding environment.

Fig. 29. Broken injection moulded furniture

Fig. 30. Broken injection moulded furniture

v. Material Study

Case Example: Failures in injection moulded furniture



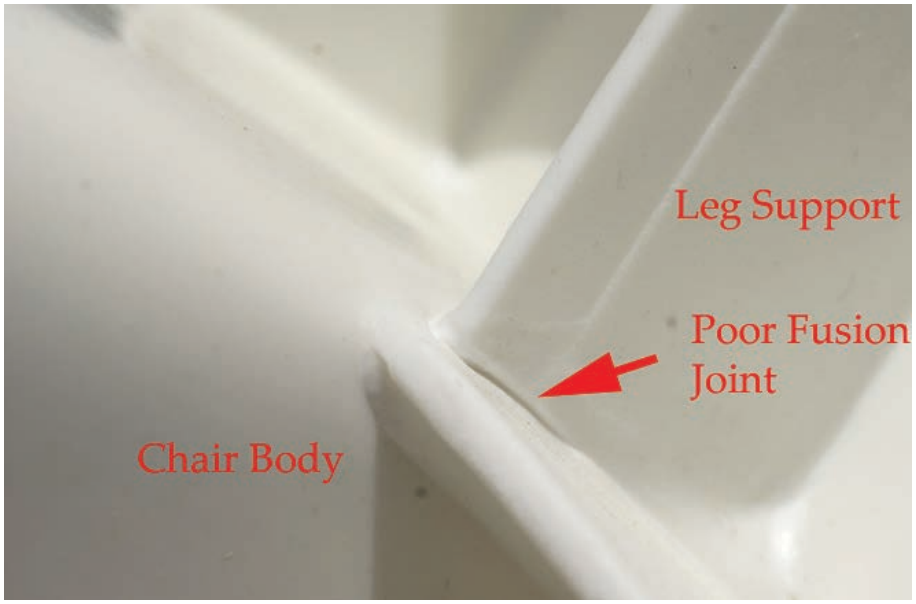


Fig. 31-34. Failures in injection moulded furniture

v. Material Study

Rotational Moulded Furniture

PROS

Lower mould cost
Ability to produce large pieces
Low initial investment
Good for lower quantities
Aesthetically Pleasing

CONS

Higher price per piece than other processes
Difficulty of doing larger part runs
The manufacturing times are long
The choice of melding materials is limited at present
The material costs are relatively high due to the need for special additive packages and the fact that the material must be ground to a fine powder
Some geometrical features (such as ribs) are difficult to mould

Why Roto moulding is not much suitable for this project?

Roto moulded furniture generally are made in one piece. Other than the fact that it is costly affair, roto moulded furniture is non-durable at low costs of material, if one goes for better quality material/plastic the costs rise drastically.

Fig. 35-37. Examples of roto moulded furniture

v. Material Study

WOODEN Furniture

PROS
Wooden furniture is sturdy and durable.
Timber furniture is eco friendly.
Wooden furniture can be refinished to get an entirely new look.\
You can find furniture that fits your budget.

CONS

Sudden temperature changes, moisture, and sun can damage the furniture.
The surface can be damaged by stains or sharp objects.
Wood becomes darker over time.
Untreated desk surfaces are prone to corrosion, leading to a shorter life.

Fig. 38. Corrosion on wooden furniture reduces its life

Fig. 39 (a,b). Corrosion on untreated desk surfaces reduces its life

v. Material Study

WOODEN Furniture

Fig. 40. Fully wooden furniture needs quiate maintenance hence is not much durable (Source: Author)

Why entirely wooden furniture is not suitable as durable school furniture?

Entirely wooden furniture gets corroded very easily and needs high maintenance and details get weaken up after some time usage. Repair of wooden furniture is easy but it looses elegance after repair, unless done very carefully.

Fig. 41. Desk surface even after painting loose elegance and surface aesthetics (Source: Author)

v. Material Study

METAL Welded Furniture

Issues with Welded Details in Academic Furniture

Details are generally prone to damage. Also, once broken it's difficult to repair.

The extra material is required for welding and strengthening the joinery, which makes furniture lose its elegance.

Fig. 42-44. Metal Furniture at IIT Bombay

v. Material Study

METAL Welded Furniture
Issue of Repairability

Welded metal furniture is however cheap and easier to make, but has other drawbacks also. Major amongst them is its issue of repairability. The metal joinery, however strong it is, is very difficult to repair and because of its easy availability in market, schools genrally prefer metal furniture.

But, problem here is not the material but the way it is being used. The potential positive points of metal being durable and strong is overpowered by the bad detailing and complex tooling and joinery. **The details which are complex and are fixed difficult to reair and replaced**.

Such a kind of furniture thus after being damaged can't be replaced or repaired and hence instead takes place in school junkyards. Such scenario is acceptable for schools with sufficient funds available, but this creates issues with schools who have very limited amount of funds for a quite longer duration of time.

Hence, such a furniture instead of helping them in a longer run becomes nothing more than a piece of junk which can only be sold in weights as scraps.

Fig. 45,46. Junk Created by welded metal furniture

v. Material Study

Fig. 47. A government school, in Salamba, Haryana. The faulty furniture.

Fig. 48. Junkyard in a school.

Fig. 49-51. If not treated well, metal furniture leads to rusting

v. Material Study

COMPOSITE Furniture
Wood With Metal

Moulded plywood is generally used with light weight mild steel tube. Many firms make up their own moulded plywood components from veneers, using heated presses.

The light weight mild steel tube used varies in thickness from about 1.2 mm to 1.5mm. Sections can be bent one by one in a simple plumber's pipe-bending machine or more sophisticated machines or presses can be used, which can bend several pipes at a time.

Plywood and tube furniture can therefore be made profitably in either small workshops or large factories.

If the price of chairs is to be kept low, there must be as few bends and welds as possible. If stacking chairs are required, the number of possible configurations will be limited.

COMPOSITE Furniture
Plastic With Metal

The all-plastics chair is a rarity. None have been made sufficiently cheaply for use in schools. The usual arrangement is a steel tube frame with plastics seat end backrest. The seat can be made in a piece with the backrest

The chair with separate seat and backrest avoids this drawback. Further, when producing a range of chairs, the same set of seats and backrests can be used for two different sizes of chair, whereas with the shell chair, a moulding must be made for each chair in the range. This can mean a considerable saving in moulds. Polypropylene is the most usual moulding material.

v. Material Study

LEAN Manufacturing Method
Sustainability in Furniture Production

Shipping
How manufacturers package and ship their products?

Maintenance/Repair
Do furnishings have easily replaceable parts so that entire products don't have to be scrapped if only one component breaks or gets worn

Recyclability
When furniture reaches the end of its useful life, how easily can it be disassembled? What elements can be recycled or upcycled?

Flexibility
Furniture that has multiple uses throughout the classroom is more sustainable.

Quality
Exceptional quality almost always equates to durability and longevity.

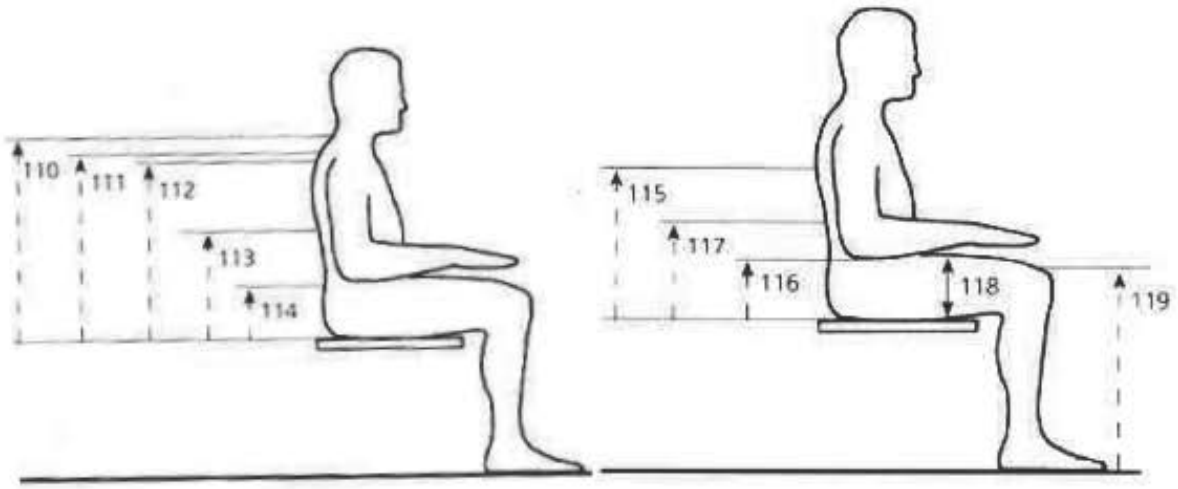
Color Choices
Lastly, let's talk about aesthetics.

Optimised Furniture Design

Furniture which is low cost and can be manufactured while catering to the following terms:

Durability / Longevity
Cost of making
Tooling Cost
Transportability
Flexibility
Recyclability / Eco-friendly-ness
Maintenance and Reparability
Surface Treatment and Colour Diversity

vi. Ergonomics



Sitting Posture Anatomy

110. Cervical (Trunk): Most prominent Spinous process

111. Mid Shoulder: Upper most part of the middle level of shoulder

112. Acromion: Most lateral point on the acromion process of scapula

113. Upper lumbar: Uppermost part of the lumbar vertebra

114. Lower lumbar: Lowermost part of the lumbar vertebra

115. Tip of the shoulder blade: Lower tip of the shoulder blade

116. Elbow rest: lowermost part of the elbow

117. Waist: Upper margin of the lateral disc

118. Mid thigh: Top of the middle thigh

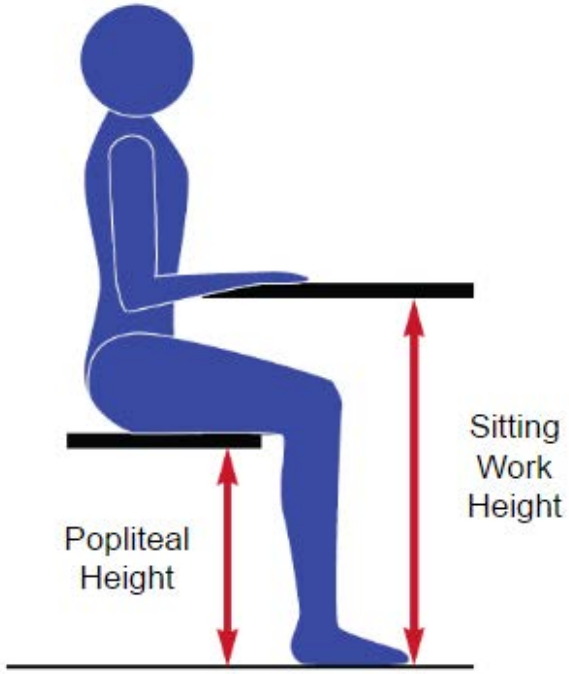
119. Knee: Uppermost point on the knee

Fig. 52.

vi. Ergonomics

Major Considerations for classroom furniture.

No pressure under the knees
Free space back of inside angle of knees
Room above the thighs
Back edge of table overlaps with the front edge of chair
Low back open at bottom, support of hollow of back only
Major criteria for school furniture is working and it takes most time, hence it cannot be compromised at all while designing.



Age in Yrs.	Male Children: Design standing height	Male Children: Seat height	Male Children: Table height	Recommended: Seat height	Recommended: Table height	Recommended: Furniture type
	Dimensions in mm					
5	1016	254	417			
6	1079	270	442	270	440	A
7	1134	284	465			
8	1187	297	487			
9	1233	308	506	300	500	B
10	1284	321	526			
11	1334	334	547			
12	1386	347	568	340	560	C
13	1442	361	591			
14	1504	376	617	375	620	D
15	1557	389	638			
16	1595	399	654	400	660	E
17	1615	404	662			

Body Dimensions considered

Floor to popliteal - 5th percentile
Buttocks to popliteal - 5th percentile
Thigh clearance - 95th percentile
Lumbar - 50th percentile
Knee to knee relaxed - 95th percentile

*A lot of dimensions are given by analyzing the comfort level of students in the present furniture used.

i. Issues Identification
ii. Inferences/Design Directives
iii. Scope
iv. Limitations
v. Final Design Brief

Planning

i. Issues Identification

After having understood the design flaws in the existing school furniture scenario, the following issues were found to be more critical for a rural and remote setting and to be responded in the further design intervention:

1. Affordability: The funds for the furniture are anyways least possible and hence an an economic approach should be adopted to cater to the scenario.

2. Replacability of parts: The current furniture designs available in market are mostly welded or majorly plastic made, which reduces the possibility replacibility of parts. Hence, the furniture becomes redundant and hence should be able to be repaired for better longevity.

3. Ergonomics: The mismatch found in furniture gives a clear proof that the furniture needs serious design thinking.

4. Tranportability: The furniture mostly has not been designed for transportability hence this increases cost of each furniture.

5. Vandalism: The material and treatment done to furniture makes prone to vandalism and corrosion.

6. Material Reduction: The costs of furniture is not only increased by the material used but also the design which involves multiple and complex parts designed without considering optimisation in material.

ii. Design Directives

The understanding of the issues has led to finalisation of design directives. These design directives include:

1. Affordability
2. Replacability of parts
3. Ergonomics
4. Design for manuafacturing
5. Material Reduction
6. Transportability
7. Industrial Aesthetics
8. Vandalism proof detailing

iii. Scope of project

An ergonomic and anthropometric intervention is required to redesign the classroom furniture for school children of different age groups in order to reduce furniture-related health complaints. Although, the implementation of such furniture to a large scale is unpredictable hence, the project will only deal with the design aspect of it.

Beneficiaries
Beneficiaries would be govt. schools and those schools which are generally short on funds for various facilities.

iv. Limitations

The timeline of the project restricts to be completed in stipulated period. Solutions might not be tested for longer durations, hence, long term effects can't be forecasted.

Scaled prototypes are necessary which might cost quite enough. Thus, cost in design development could be a constraint.

Being a part of the govt. system, the intervention needs support and proper channelling for real life implementation.

v. Design Brief

Primary level furniture design for govt. schools, which is easy to manufacture, ergonomic and affordable enough to be implemented in real scenario.

This would be highly focussed on the design directives discussed earlier. Various objectives of the project are also in response to the issues identified earlier in case studies, school visits and material analysis.

In order to cater to the nature of the project, optimised design methodology would be adopted. Thus, the aim would be to design furniture which is low cost and can be manufactured while catering to the following terms:

Durability / Longevity
Cost of making
Tooling Cost
Transportability
Flexibility in terms of materials
Maintenance and Reparability/Part replce-ability
Surface Treatment and Colour Diversity

Along with this, Lean Manufacturing methodology would also be used to achieve required results.

i. Stages of Development - Ideations
ii. Concepts
iii. Concepts Evaluation
iv. Final Concept
v. Re-evaluation
vi. Further Concepts

Implementation

i. Stages of Development

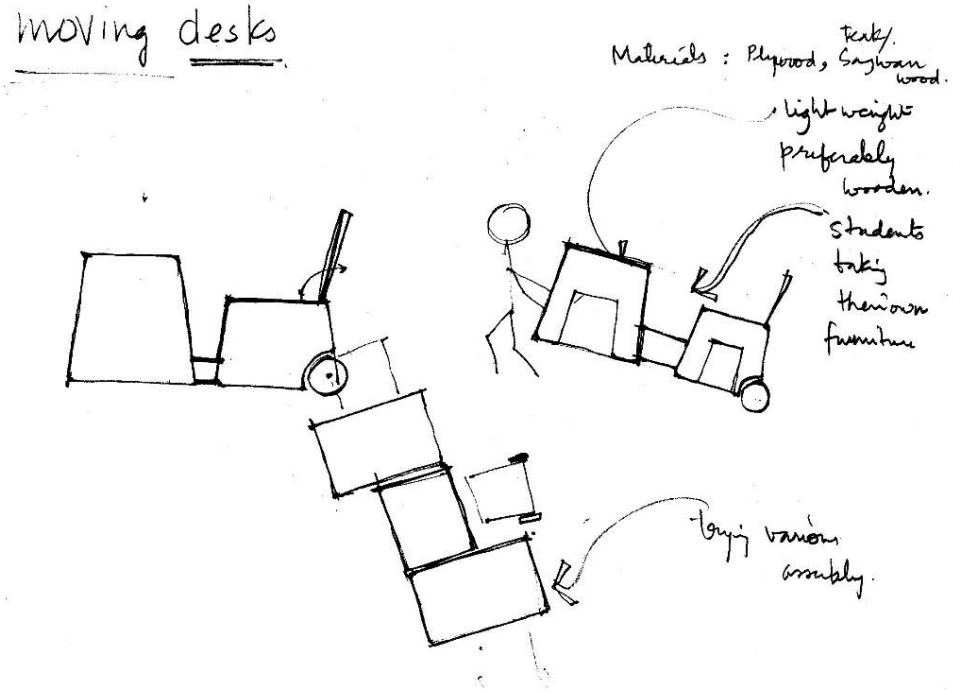
STAGE 1, Ideation level 1:

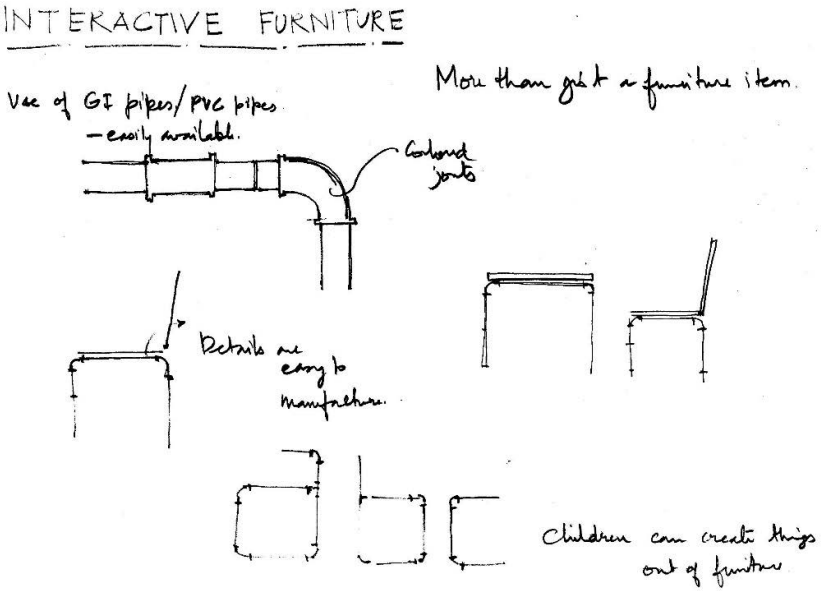
The initial ideations were quite feature based, which means that they had some additional feature as its USP.

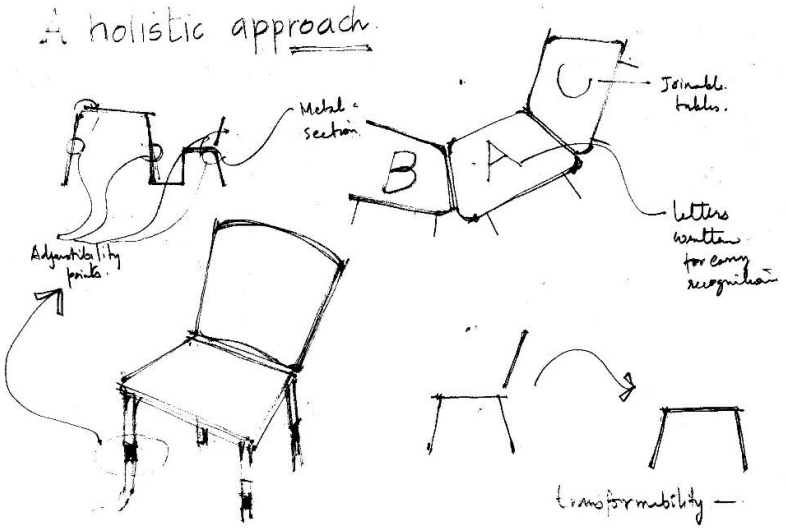
The details were based on interaction of furniture with kids.

The optimisation of material and affordability were not considered at all.

The ideations lack critical approach to the issue.







i. Stages of Development

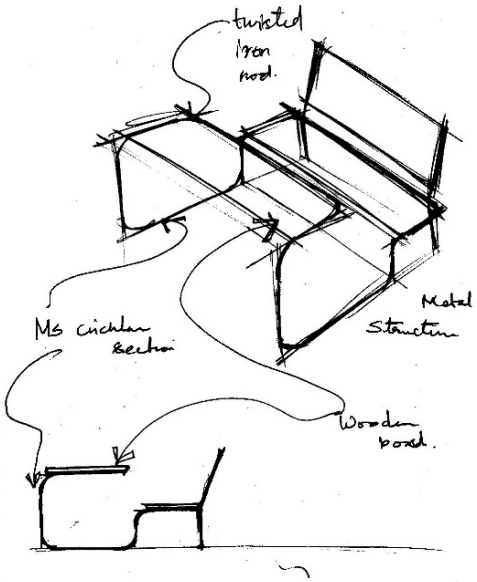
STAGE 2, Ideation level 2:

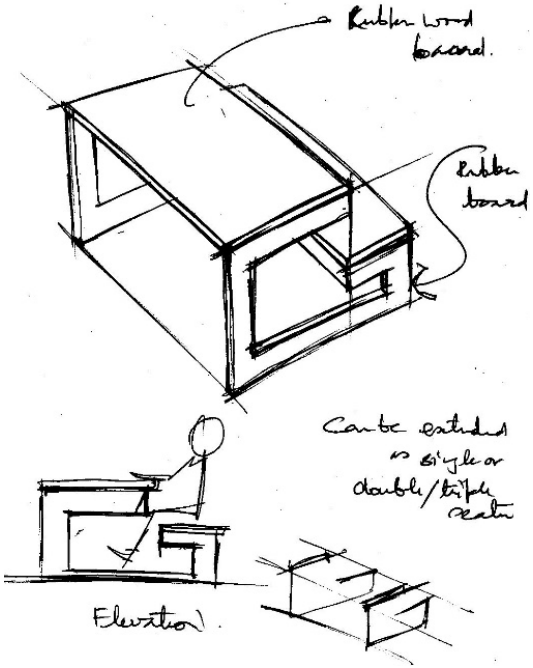
The ideations at this stage were more manufacturing oriented and practical.

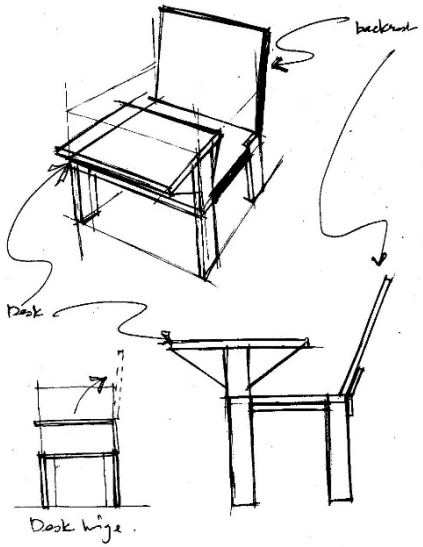
Various ways of sitting on furniture and various materials were explored.

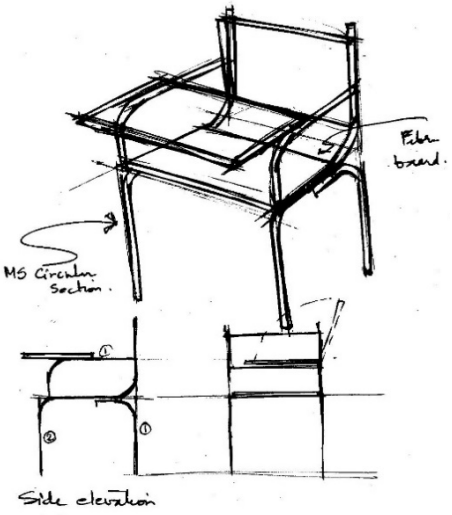
However, the furniture lacked a certain direction and it was decided to later concentrate on one material and explore possibilities with it.

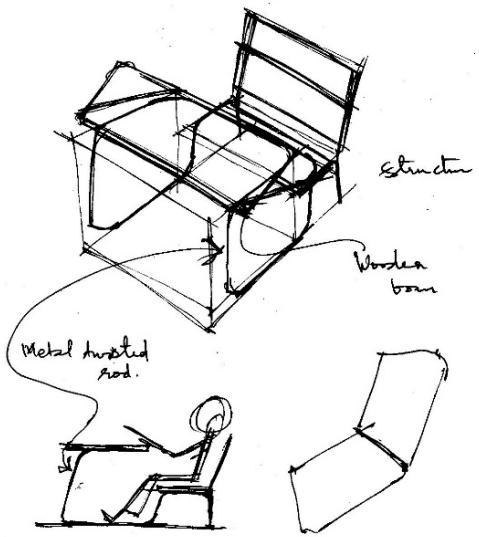
Thus, for later explorations primarily, metal tube is going to be considered for structure.







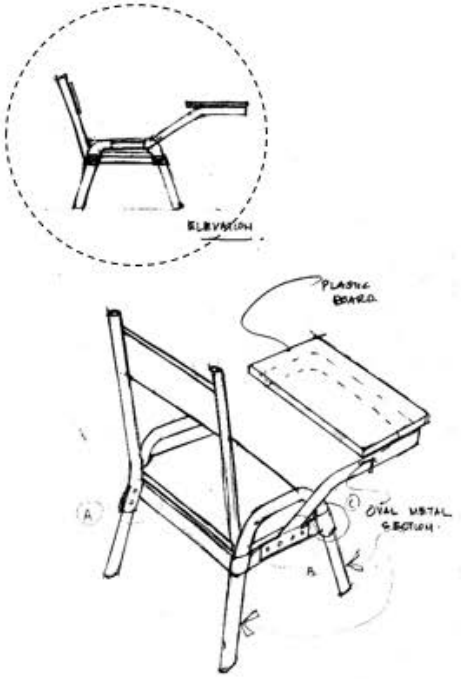




i. Stages of Development

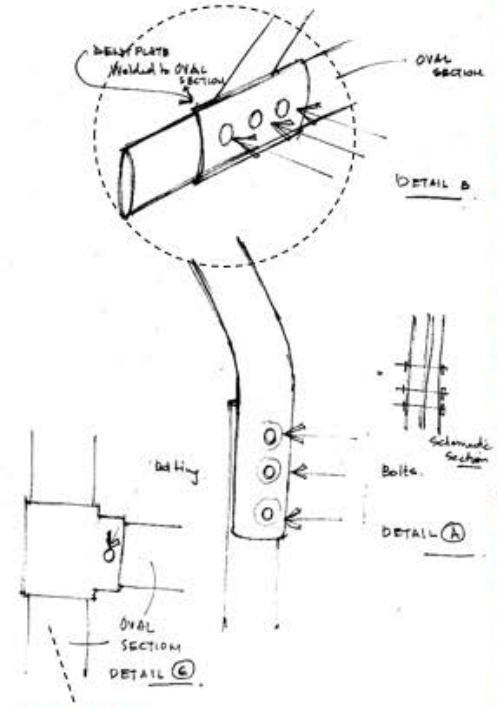
STAGE 3, Ideation level 3:

Material Reduction:
Usage of less material



Weak Detailing:
The detail for desk seemed weak and prone to failure

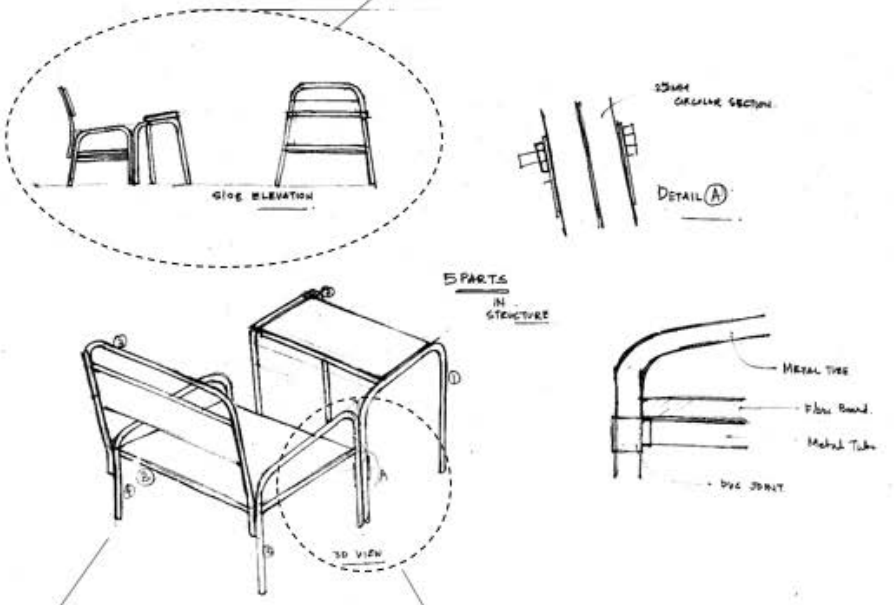
Section detail:
Usage of oval section for strength, however it'll be costly to manufacture and maintain.



Detailing:
Experimentation in detailing, using plastic caps increases costs

Ideation 3.a

Industrial Aesthetics:
Aesthetics has been looked at while figuring out the detailing



Stability:
Form is stable

Weak detailing:
Joinery seems to fail due to so much of stress while usage

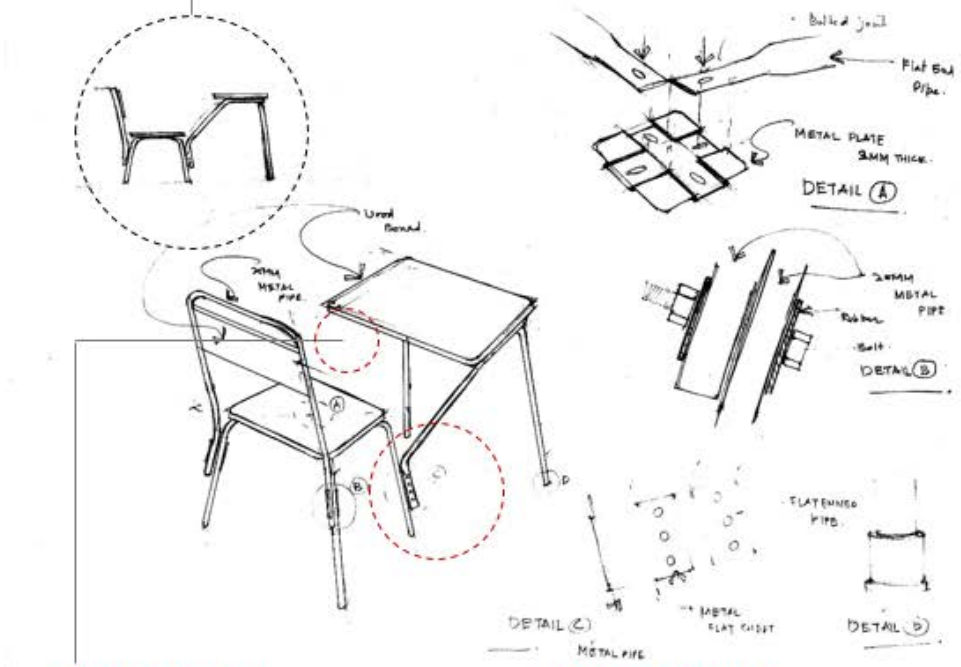
Ideation 3.b

i. Stages of Develop-

STAGE 3, Ideation level 3:

Material Reduction:
Usage of less material

Material exploration:
Tube flattened to create joinery detail



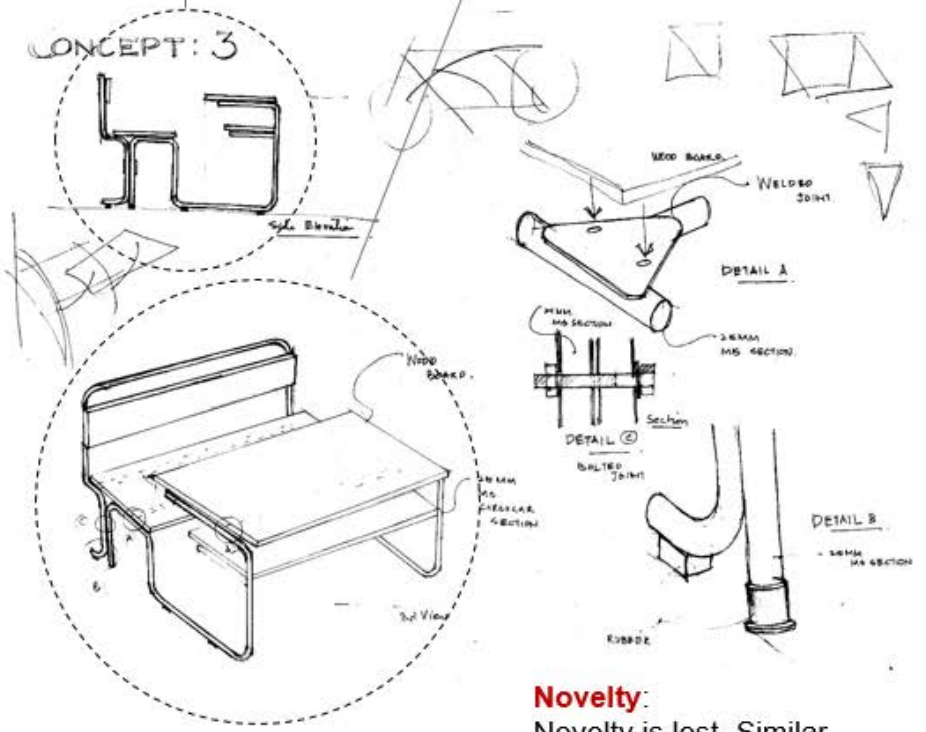
Stability Issues:
Absence of a third leg creates issues with stability

Detailing Issues:
Detail is weak for joinery of chair with desk.

Ideation 3.c

Industrial Aesthetics:
Form is more refined, better usage of metal tube

Stability:
Form is stable unlike the previous ideation



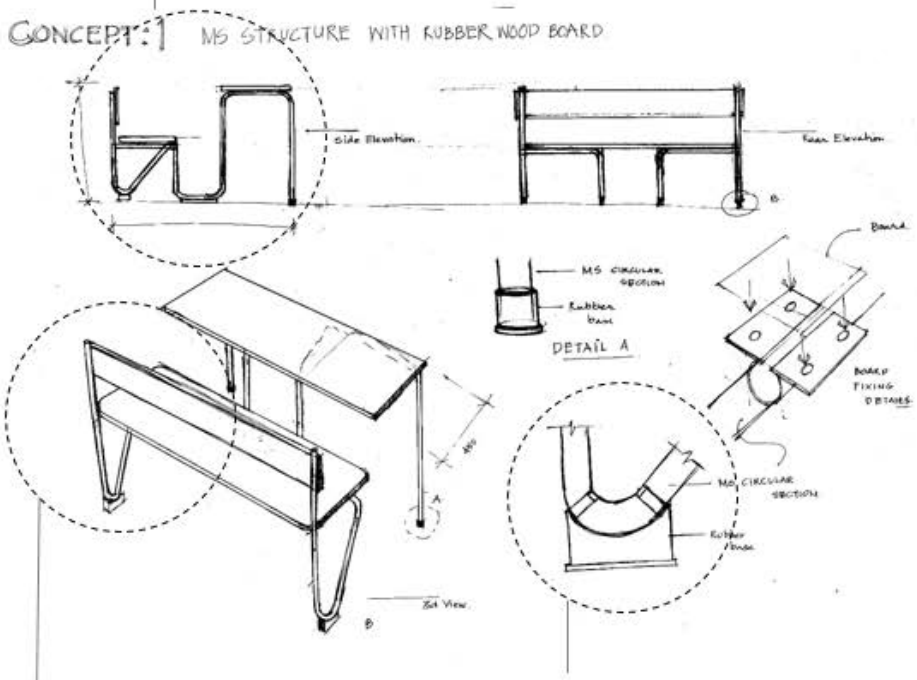
Novelty:
Novelty is lost. Similar furniture already exists.

Ideation 3.d

i. Stages of Development

STAGE 3, Ideation level 3:

Material Usage:
Usage of less material



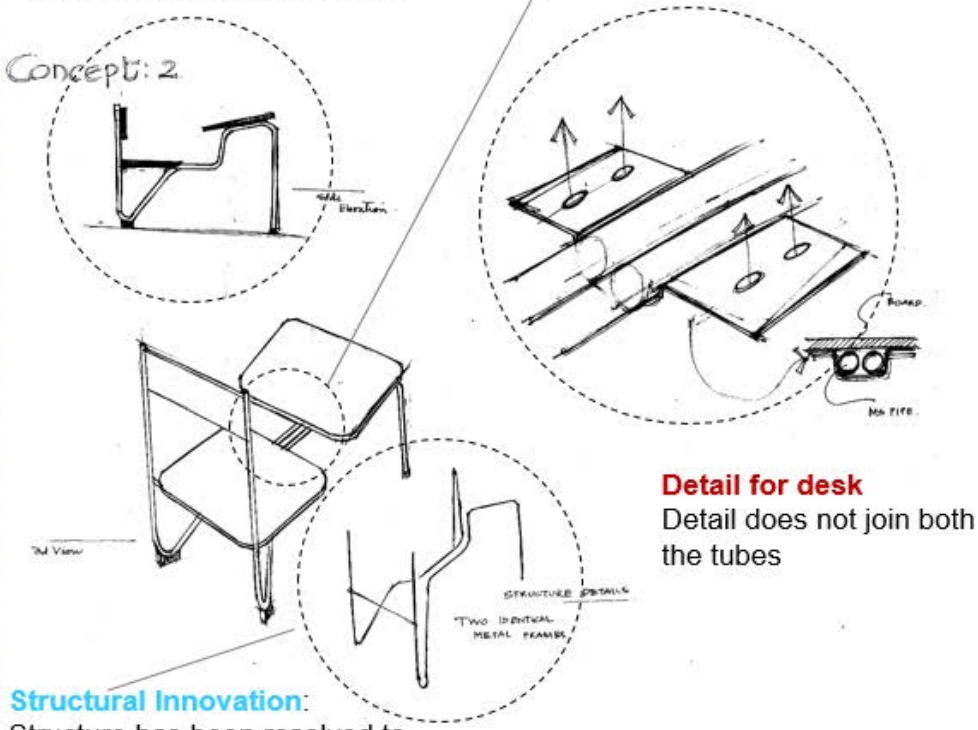
Comfort Issues:
The perpendicular back would be uncomfortable and redundant

Detailing:
Further minute details have been explored, however becomes additional design-wise

Ideation 3.e

Industrial Aesthetics:
Design is able to explore new facets of industrial aesthetics

Usability Issues
Because of the pipe in the centre, usability issues will occur.



Detail for desk
Detail does not join both the tubes

Structural Innovation:
Structure has been resolved to incorporate lesser & identical parts for quicker manufacturing

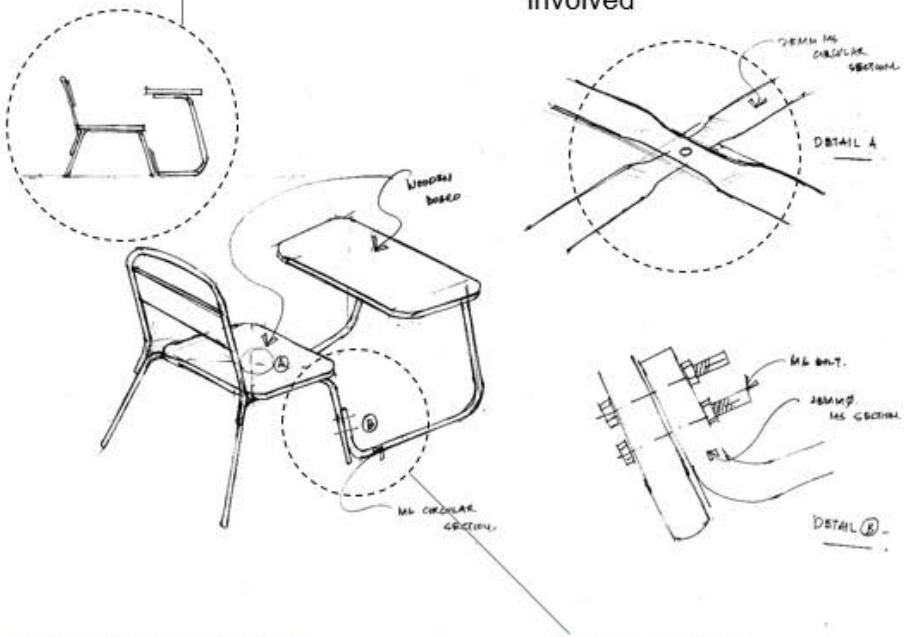
Ideation 3.f

i. Stages of Development

STAGE 4, Ideation level 4:

Judicious use of material
Material has been used judiciously while achieving suitable aesthetics

Refined detailing
Detail has been improved to decrease the no. of parts involved



Structurally Stable

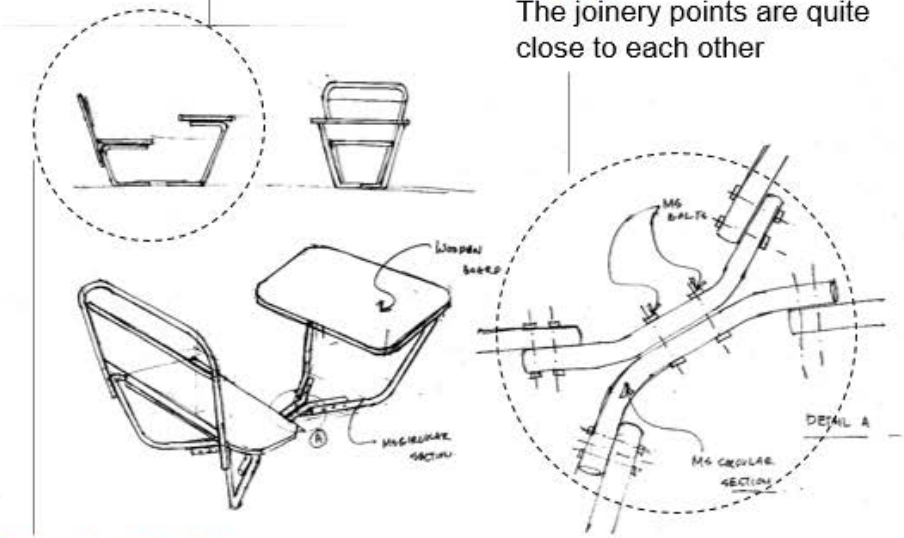
Ergonomically Comfortable

Stress points
The design still carries some stress points which have to be resolved

Ideation 4.a

Judicious use of material
Material has been used judiciously while achieving suitable aesthetics

Joinery
The joinery points are quite close to each other



Structural Stability:
The structure is prone to toppling if used improperly.

Novelty:
A new language has appeared with the form exploration.

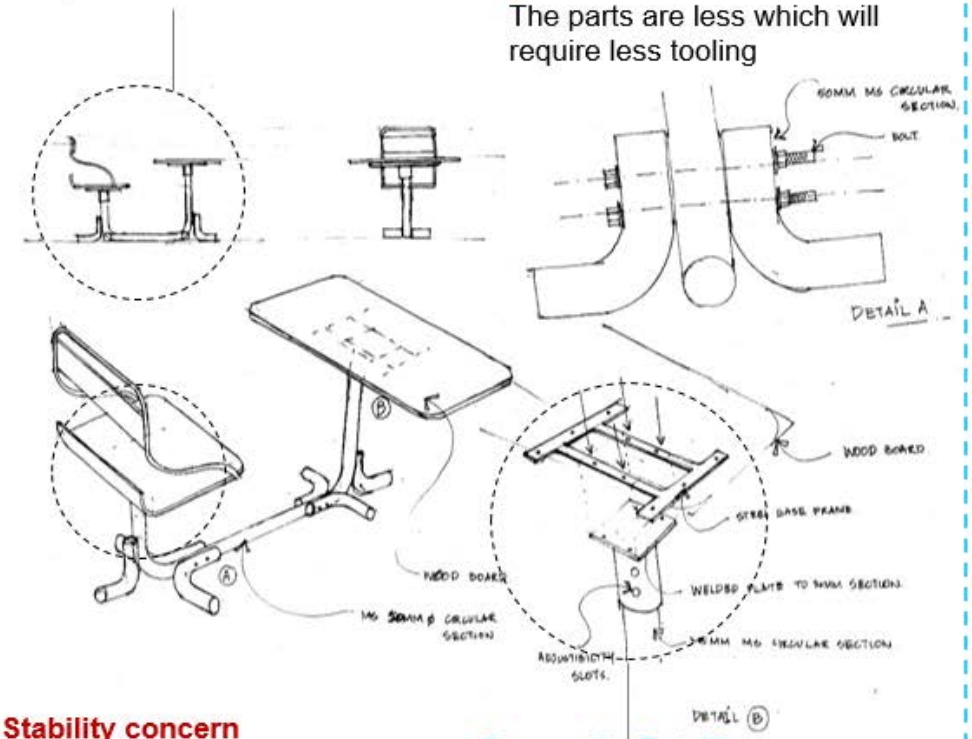
Ideation 4.b

i. Stages of Development

STAGE 4, Ideation level 4:

Use of material
Optimised use of material

Less Tooling and identical parts
The parts are less which will require less tooling



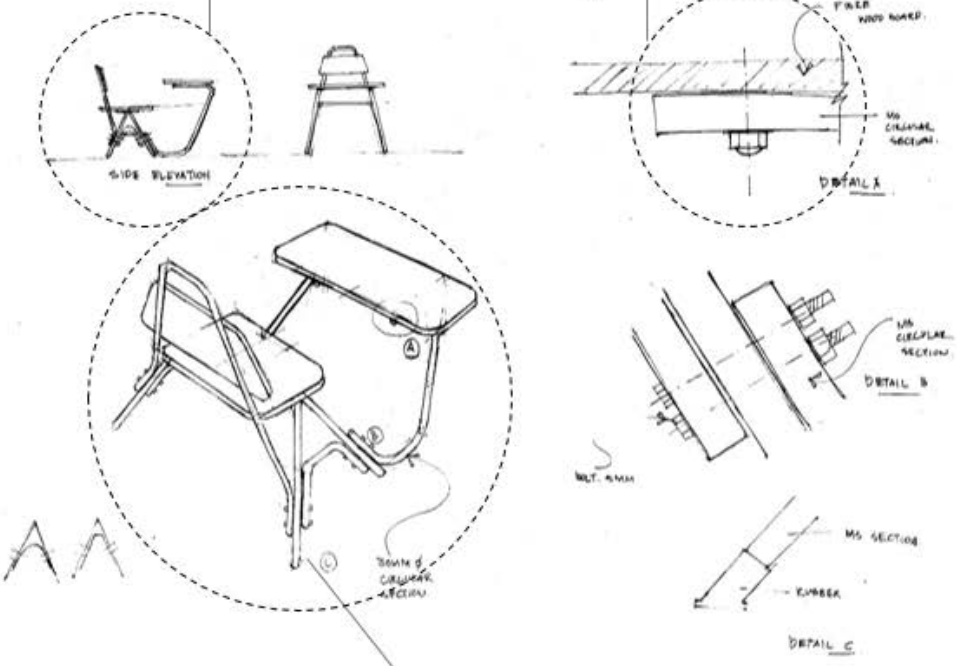
Stability concern
Toppling might happen if the details at base of seating and desk are weak or insufficient

Composite Detailing
The details which don't take much stress are kept bolted with incorporation of welded joints

Ideation 4.c

Novelty in approach
The way the structure is being resolved shows a unique aesthetics

Intuitive detailing
The details are basic and easy to understand, mostly involving bolting.



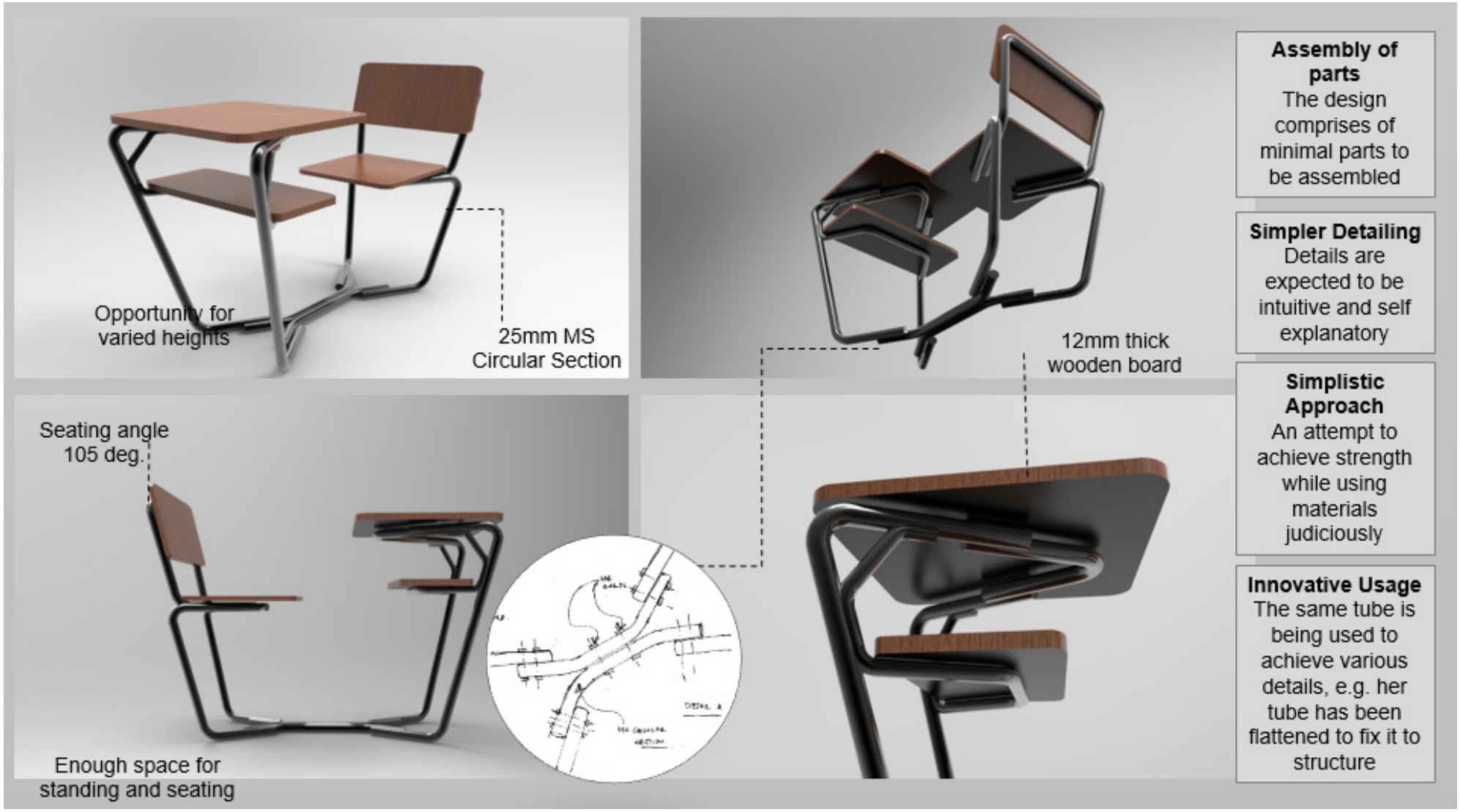
Stability Issues for toppling

Visual Appeal
A design language has appeared.

Ideation 4.d

ii. Concepts

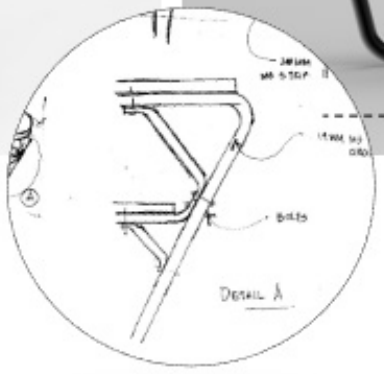
Concept 1



ii. Concepts

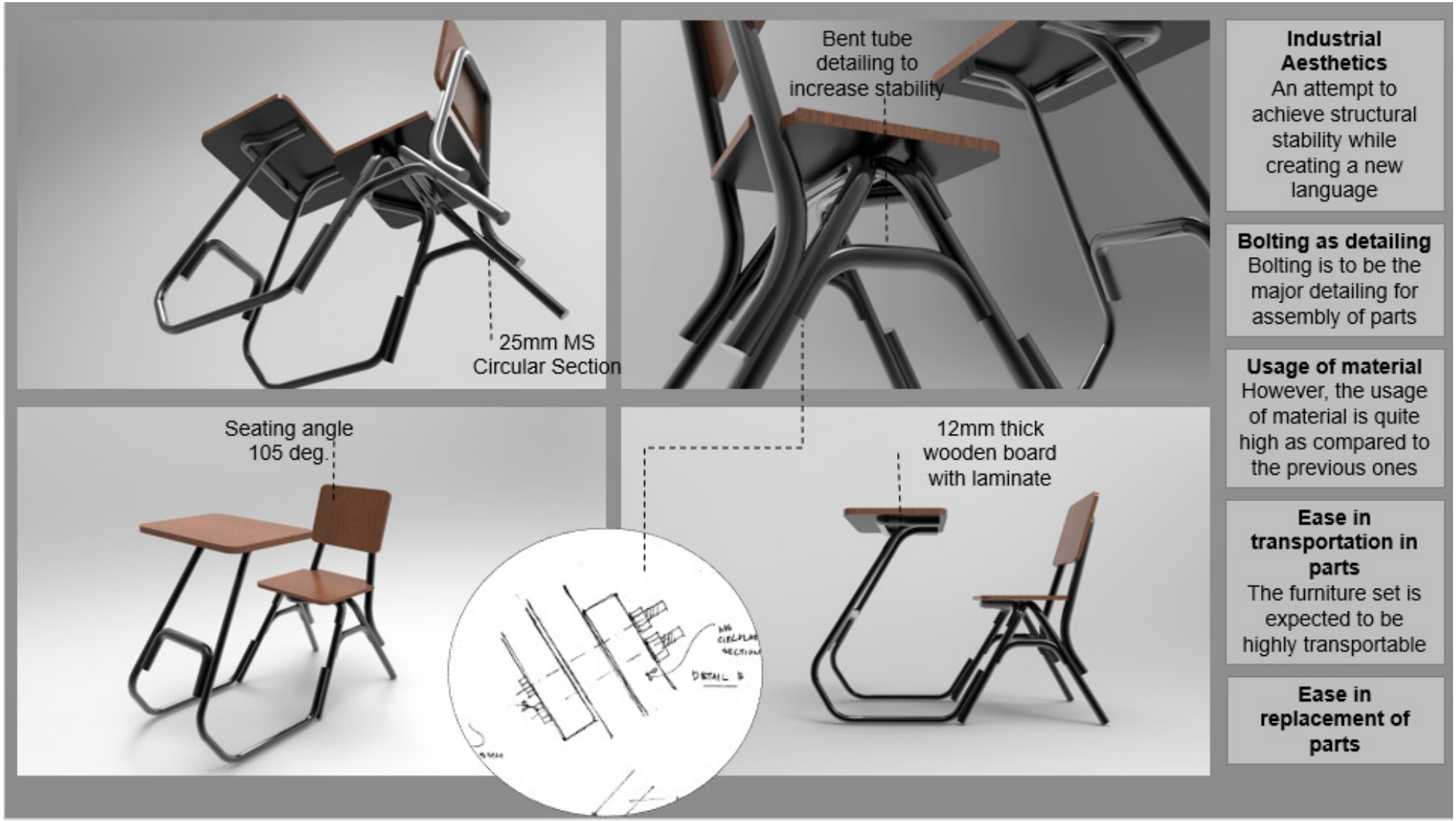
Concept 1

Double Seater



ii. Concepts

Concept 2



Industrial Aesthetics
An attempt to achieve structural stability while creating a new language

Bolting as detailing
Bolting is to be the major detailing for assembly of parts

Usage of material
However, the usage of material is quite high as compared to the previous ones

Ease in transportation in parts
The furniture set is expected to be highly transportable

Ease in replacement of parts

ii. Concepts

Concept 2

ii. Concepts

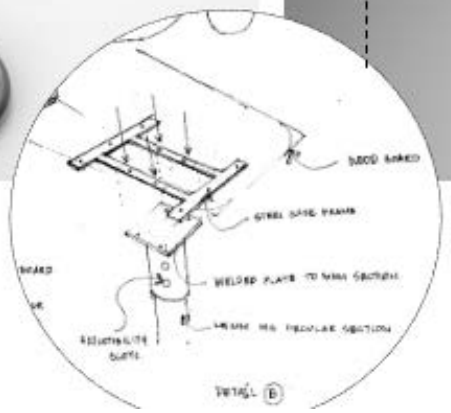
Concept 3

ii. Concepts

Concept 2

Circular Support
The detail is changed here to decrease one bend and explore aesthetics

Exploration in base detail
The detail for base of table and seating has been explored with welded plate bolted to the upper wooden surface



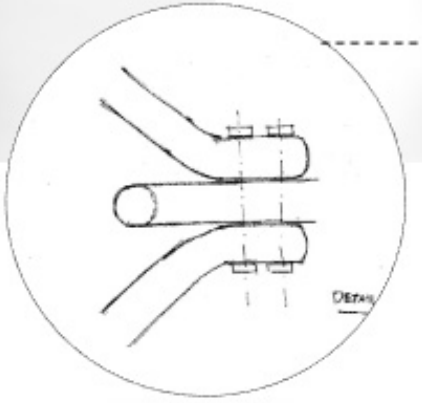
Version 2

ii. Concepts

Concept 2

Double Seater

Structural Innovation
The structure has been explored in various ways to optimise material usage



Separate Seating
The chairs are kept separate, in order to keep the identity of the design intact

iii. Concepts Evaluation

Concepts were evaluated on the following terms:

Structure
- Stability
- Ergonomics

Inventory
- Replicability
- Customisability
- Transportability
- No. of Parts involved

Materials
- Amount of material used
- Flexibility for various materials

Manufacturing
- Costs
- Ease in production

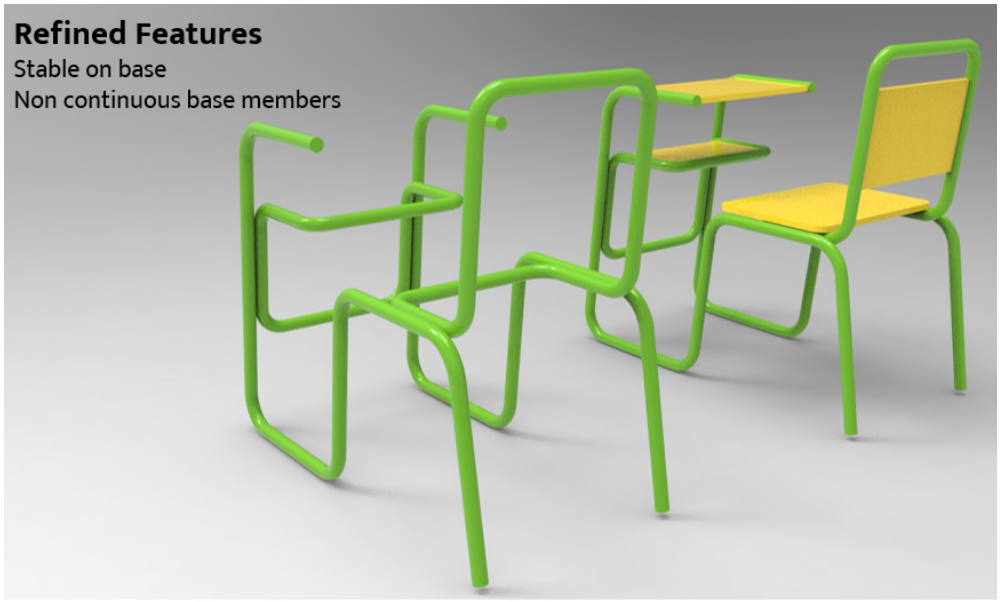
Aesthetics
- Classroom Semantics
- Edges and Surface treatment

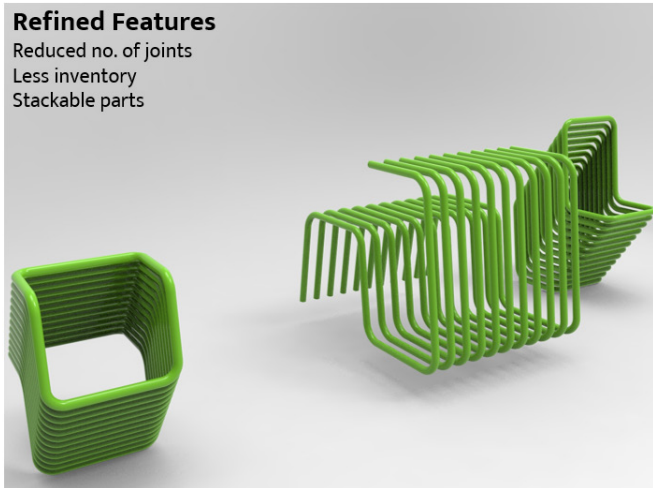
iii. Concepts Evaluation

	Stage II	Ergonomic Issues	Structural Stability	Transportability /Stackability	Inventory	Material Usage	Replicability of Parts	Approx. Costs	Aesthetics	Complexity of parts in terms of manufacturing	Customisability	School Semantics/Aesthetics	Remarks/Evaluation
Concept 1		Footrest not present	Structure would be stable, but there would be too much stress on joinery	Parts are transportable	Inventory is less, three major parts	Extremely less material Usage	Parts are replicable	-	Aesthetically looks unstable	Parts are simple, but require extremely efficient joinery	Non customizable for double seater	Loses existing school furniture semantics	It was a good exploration, but would be difficult to go ahead with, as chances of failure are more than other options and inflexible for double seater
Concept 2		No non-solvable issues	Stable	Non transportable parts	Too many parts and joinery	Excess material Usage	No identical parts	-	Aesthetically better than Concept 1	Parts are simple to manufacture	Customisable	Relevant School semantics present	Could be explored further, there are possibilities of improvement
Concept 3		Footrest not present	Stable	Transportable	Too much Inventory	Optimised material usage	Parts are replicable but one is mirror image of other increasing inventory	-	Most aesthetic option in all three	parts need non imposable mirror parts, which could be tricky to make	Non customizable for double seater	A little non recognisable as school furniture	Can be improved further

iv. Concepts Refined

Concept 2





iv. Concepts Refined

Concept 3

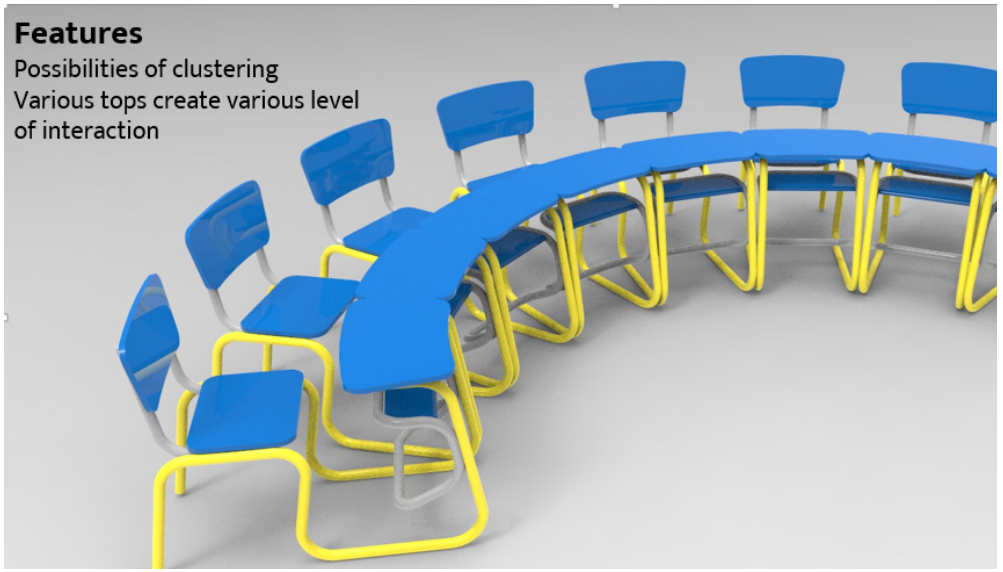
V. Concept Evaluation

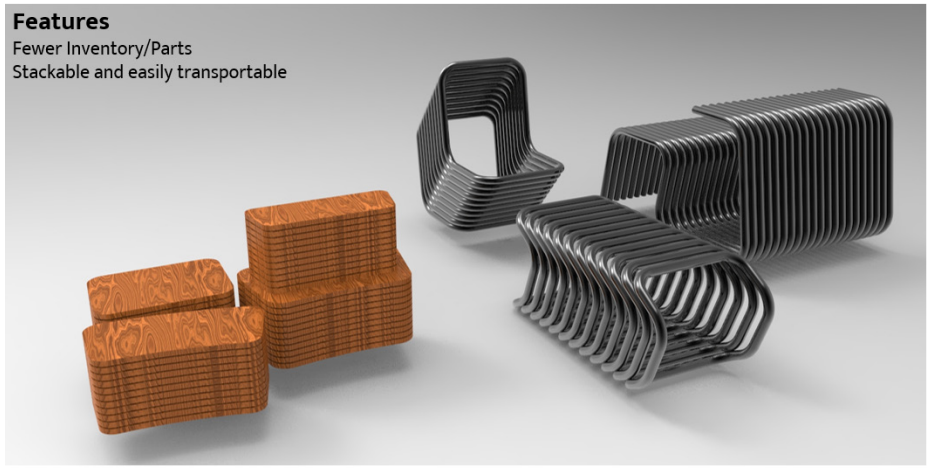
Concepts after refinement were evaluated again to bring down to the final one to proceed.

Concept 2 improvement		Footrest non ergonomically designed	Stable	parts are extremely transportable and stackable	Less inventory, just three parts	optimised material usage, lesser than concept 3	Parts are replicable	-	Aesthetically neutral, was better previously	Extremely simple parts to manufacture, simple bends	easility customisable for double seater and various sizes	Suitable school Aesthetics	Promising to go ahead. Would be chosen for final improvements, suitable to project brief
Concept 3 improvement		Footrest not present	Less stable because of draft angle	non imposable parts, and non stackable parts	inventory is mre than concept 2	material usage is optimised	Parts are replicable, but non imposable parts still present	-	Aestetically better than concept 2	Difficult to manufacture in smaller industries because of presence of multiple 3d bends	Customisable	A little non recognisable as school furniture	Many un resolvable issues because of the nature of design. To be left at this stage.
	Final Concept												
Concept 2 Finalised improvement		No non-solvable issues	Stable	parts are extremely transportable and stackable	Less inventory, just three parts	optimised material usage, lesser than concept 3	Parts are replicable	-	Aesthetically better than last version of it	Extremely simple parts to manufacture, simple bends	easility customisable for double seater and various sizes	Suitable school Aesthetics	**Finalised**

COncept 2 was found more appropriate and was taken ahead after evaluation.

vi. Final Concept





Other Explorations done for Concept.

iv. Final Concept

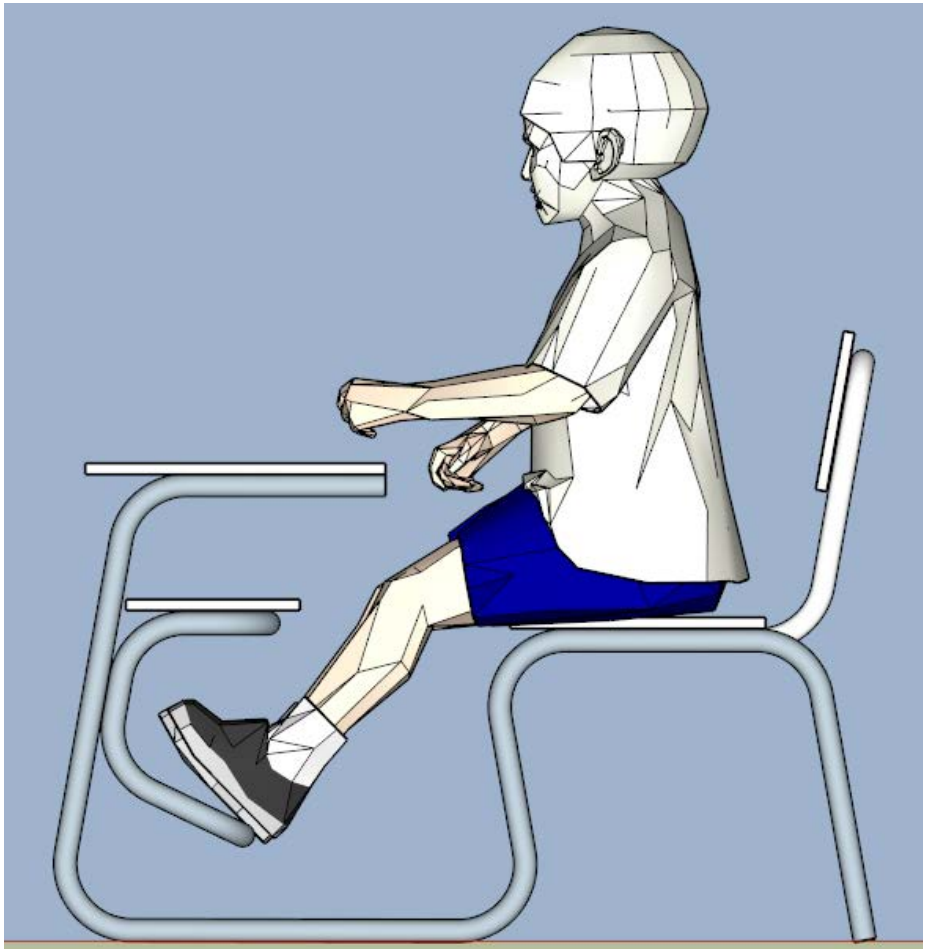
Options with Plastic and Formed wood. Various Versions.

Surface Exploration
Injection Moulded/Formed wood surfaces
A new aesthetics
Waterfall Seating
Curvilinear Edges

Surface Exploration
Injection moulded entire seating

iv. Final Concept

Sitting posture.



Various Colour options

Specifications

1.6mm thick, 1” dia. MS Tube
Rubber/Particle/Laminated Plywood Board
75mm bending radius
8 points of joinery of structure
Bending angles used are two i.e. 80, 100.
Lockbolts 3/8, 2.5” length

iv. Final Concept

A mockup rig was also made for testing the final design. This helped in understanding the design flaws and ergonomic issues.

Fig. 53.

Fig. 54, 55.

iv. Final Concept

Fig. 56

Student of 5th class was tested on the furniture. Various issues were found, e.g.:

Ergonomics is not resolved

Structure becomes weak for 95th percentile

Fig. 57

iv. Final Concept

Industrial Validation

- The design is quite cost effective and durable.
- Replicability & Reparability of parts, is good feature for a large scale implementation.
- Transportation would be extremely easy, and so would be the assembly on site.
- Manufacturing would be easy, similar angle of bends make it easy for manufacturing even in smaller factories

Mr. Raju, Krystal Enterprises,
Saki Naka, Mumbai

For Single Seater Option B

	Amount	Cost/Unit	2.79 sq.f./Unit	Total
MS Pipe	4.25m	65		345
Plywood Laminated (85/sq.ft.)	2.79ft	85		239
Metal Bends with Powder coating	22	15		330
Lockbolts	8	12-15		120
Miscellaneous				100
				1134

For Double Seater

	Amount	Cost/Unit	2.79 sq.f./Unit	Total
MS Pipe	8.9m	65		723
Plywood Laminated (85/sq.ft.)	6.31ft	86		536
Metal Bends with Powder coating	26	15		390
Lockbolts	8	12-15		120
Miscellaneous				100
				1869

V. Re-evaluation

After evaluation and protyping, feedbacks were taken from faculties. Feebacks were quite in terms of why optimisation has been taken too much into the project. The final form was not looking novel and looked way too minimalistic, and use of plastic and other materials were not considered as it could have been. Other than that, ergonomics issue were also found in the design which had to be resolved.

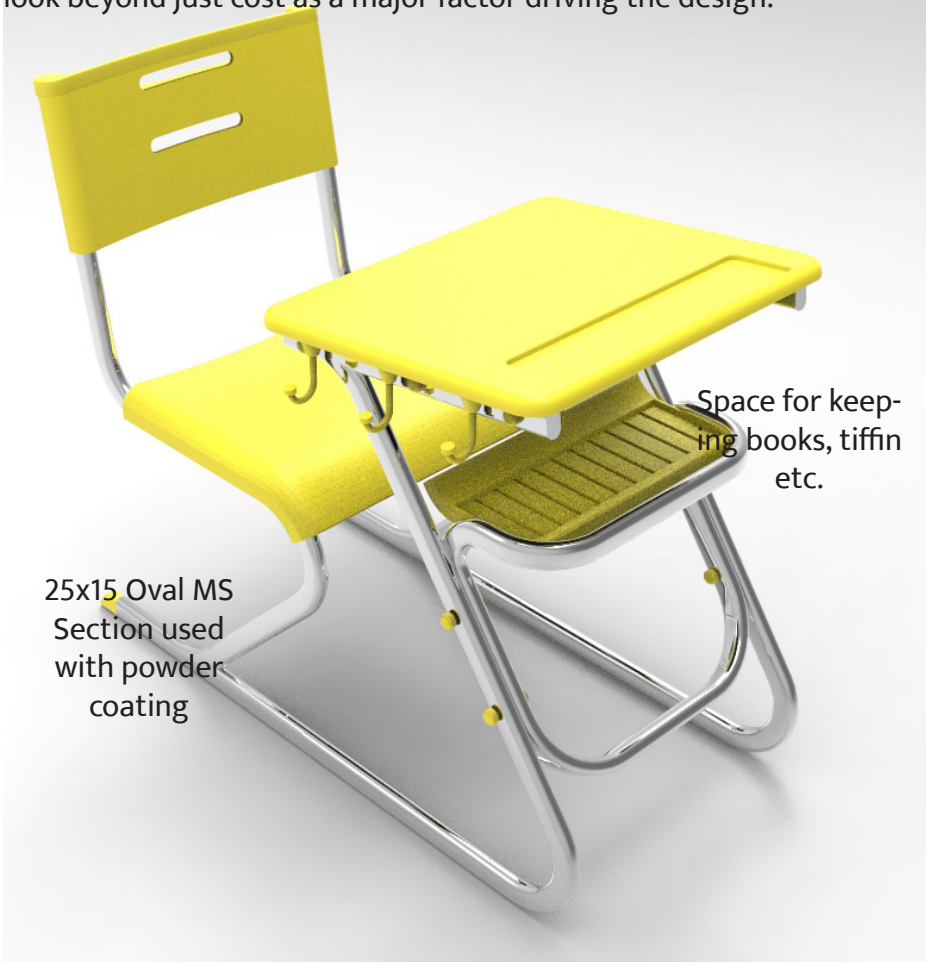
Hence, it was decided to relook the concepts revise the design brief a little while putting less emphasis on the optimisation and costing part. The design has to be explored further and various constrints had to be removed in order to generate some novel designs.

vi. Concepts Further

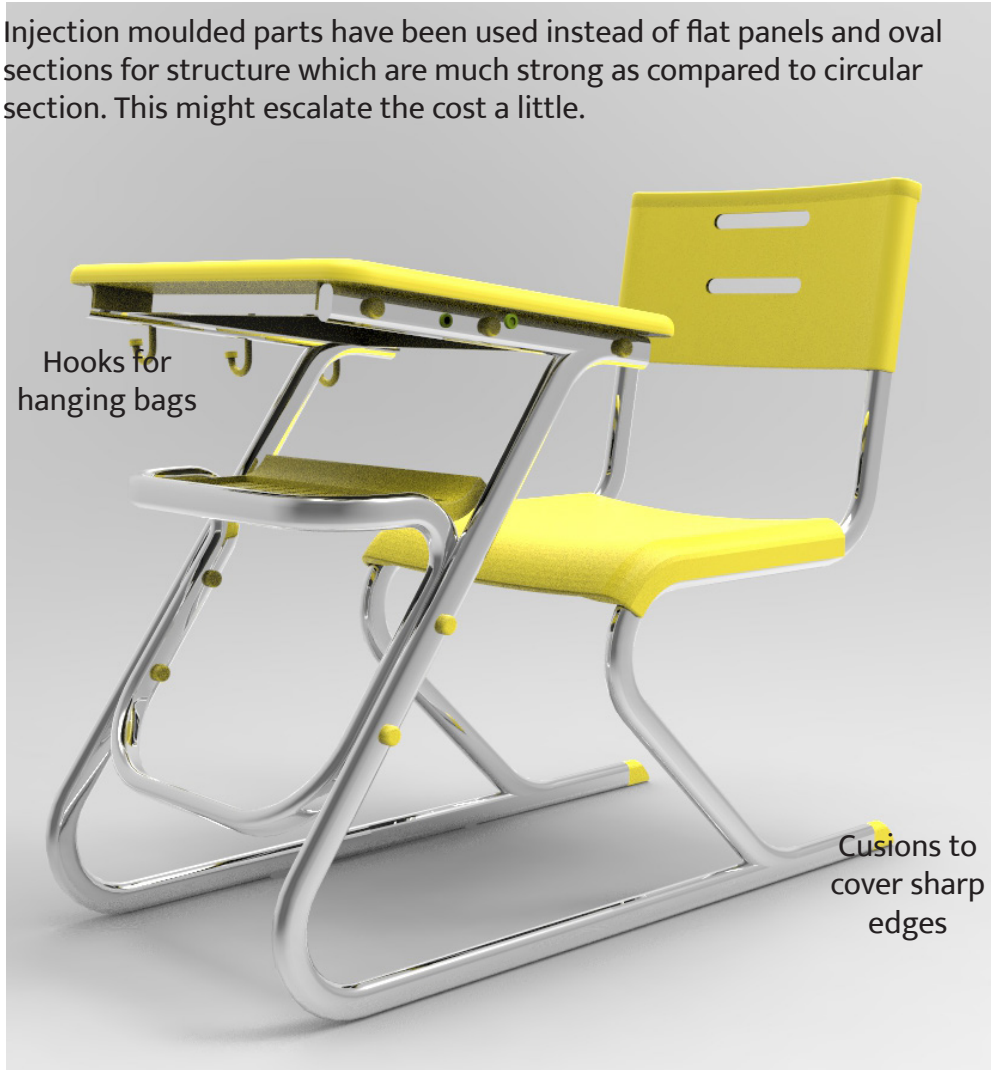
Various other designs were explored as shown.

vi. Final Concept 2

In this design, possibility of plastic and other metal sections has been explored while trying to achieve a newer aesthetics and also to look beyond just cost as a major factor driving the design.



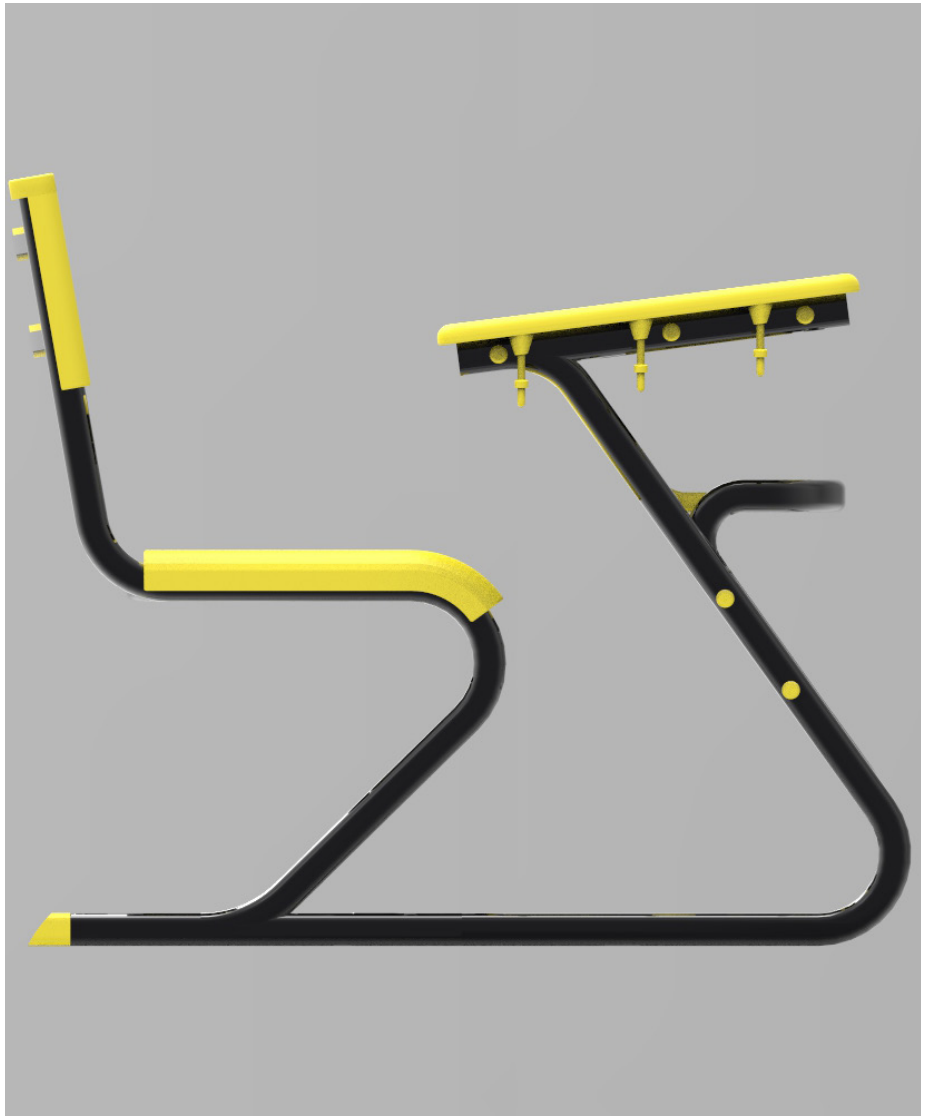
Injection moulded parts have been used instead of flat panels and oval sections for structure which are much strong as compared to circular section. This might escalate the cost a little.



vi. Final Concept 2

Ergonomics Trade-off:

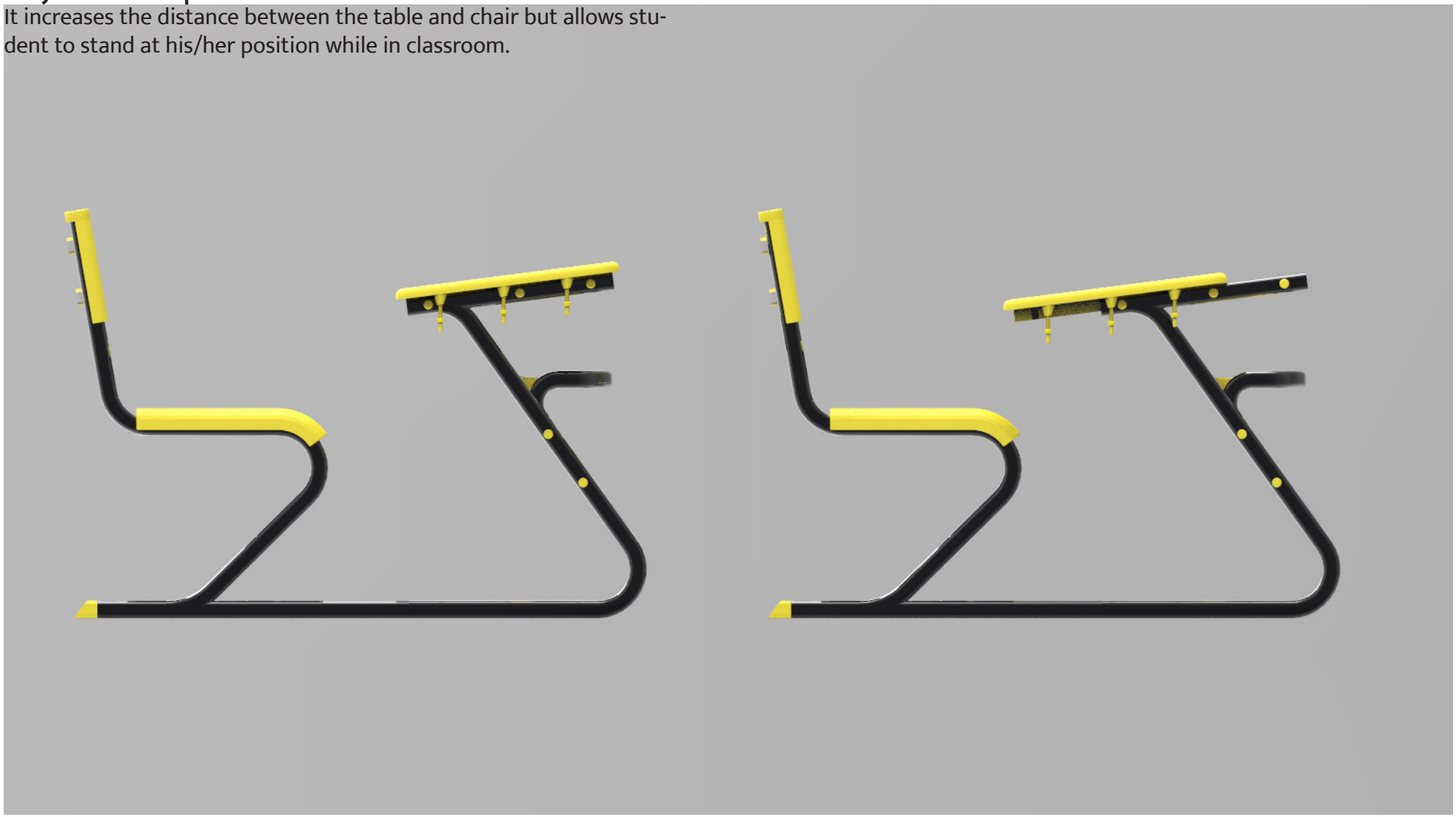
Ergonomics issues were also resolved, however, the design is not incorporating the standing of students at the desk. Student will have to come out to stand, which is an **ergonomic tradeoff**. Another possibility is making the table top adjustible or separating chair and table from each other.



vi. Final Concept 2

Adjustible Option

It increases the distance between the table and chair but allows student to stand at his/her position while in classroom.



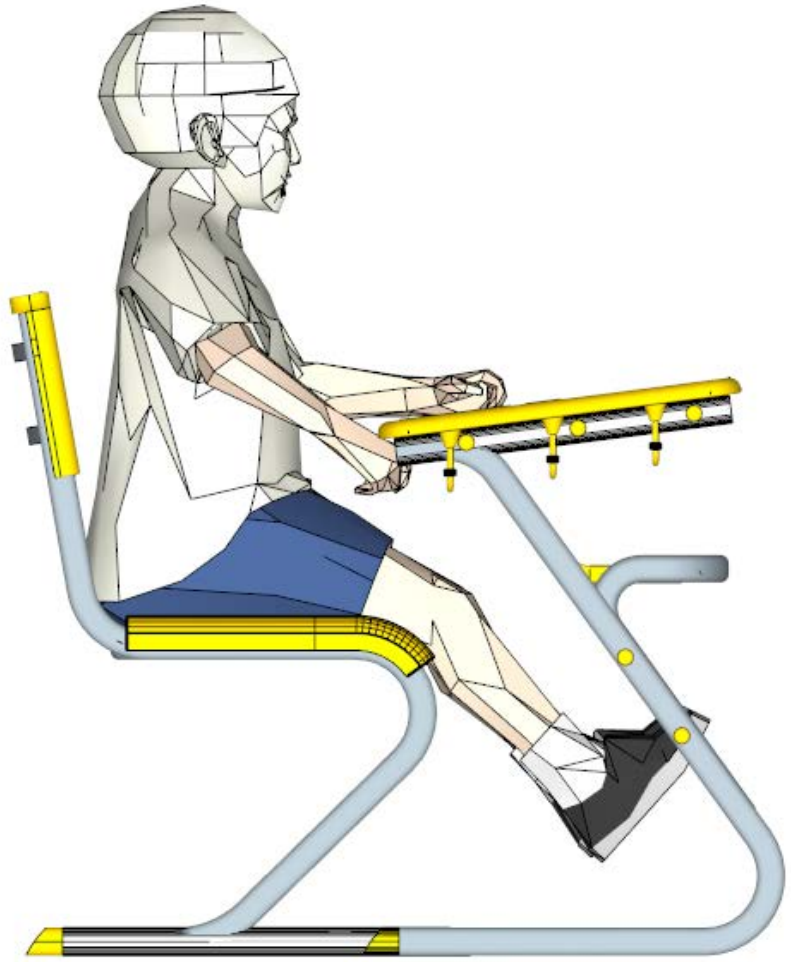
vi. Final Concept 2

Separate Table-Chair Option

It solves the issues with ergonomics, however increases no. of parts and inventory.

vi. Final Concept 2

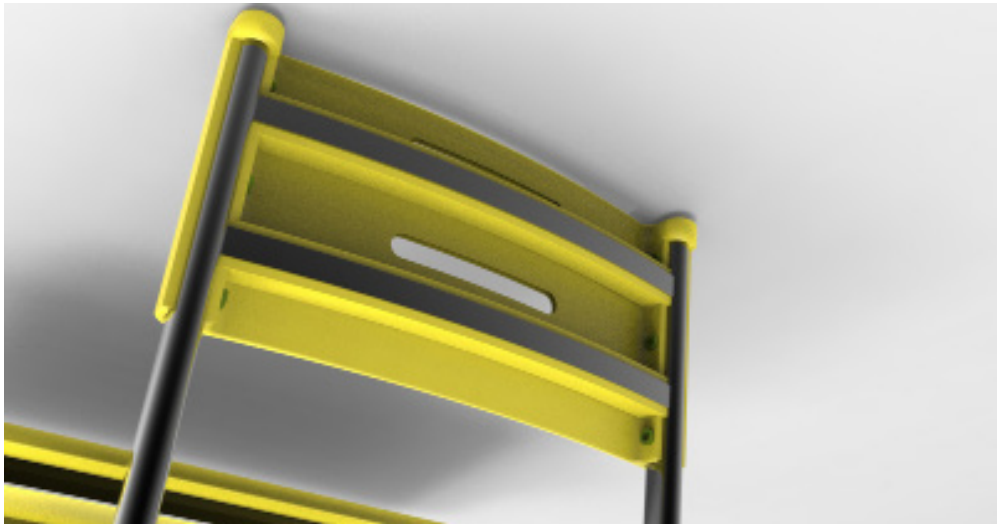
Slant Table tops reduces strain on the neck and helps in studying while sitting.

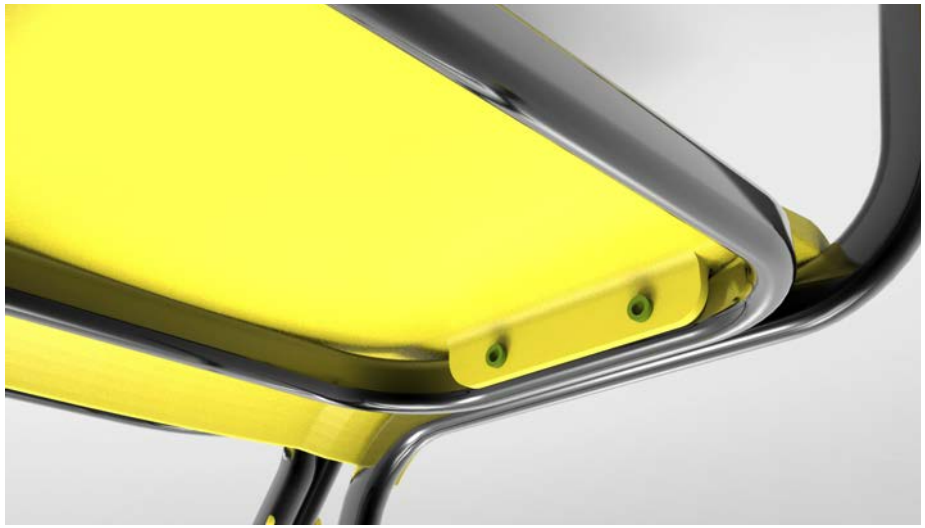


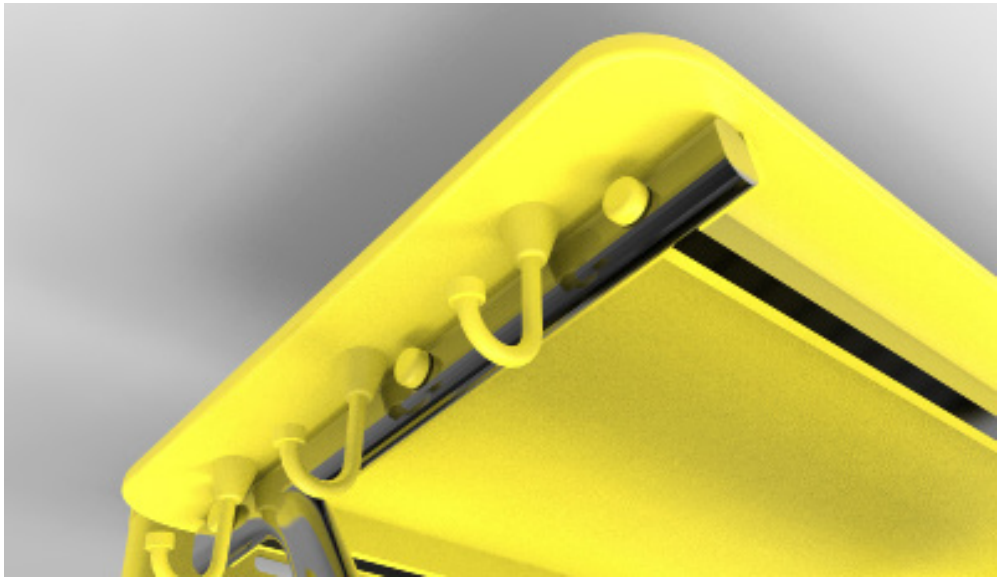
Body Dimensions considered

Floor to popliteal - 5th percentile
Buttocks to popliteal - 5th percentile
Thigh clearance - 95th percentile
Lumbar - 50th percentile
Knee to knee relaxed - 95th percentile

vii. Details





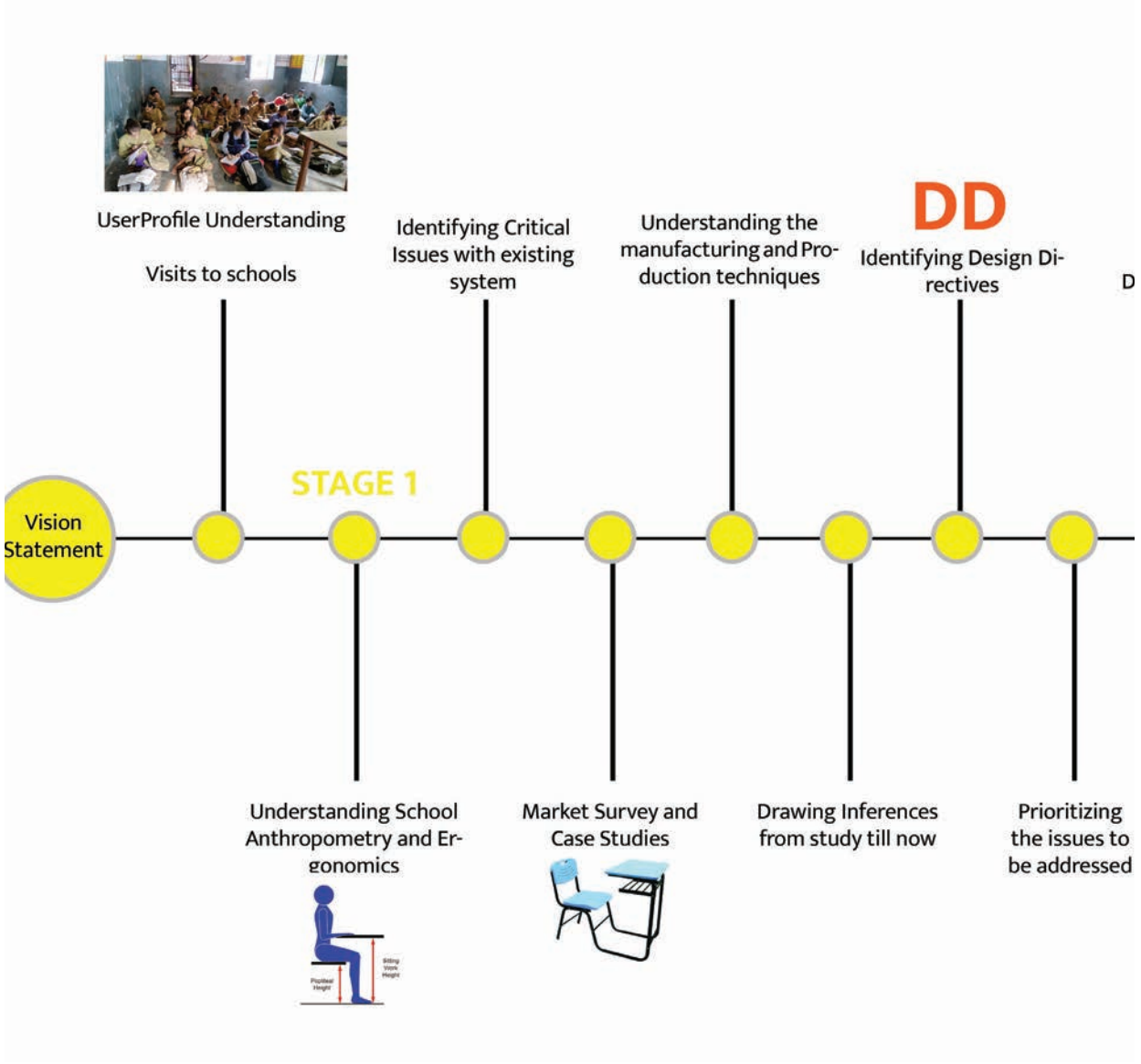


vii. Colour Options






Appendix


UserProfile Understanding
Visits to schools
Identifying Critical Issues with existing system
Understanding the manufacturing and Production techniques
DD
Identifying Design Directives
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STAGE 1
Vision Statement
Understanding School Anthropometry and Ergonomics
Market Survey and Case Studies
Drawing Inferences from study till now
Prioritizing the issues to be addressed

Project Timeline

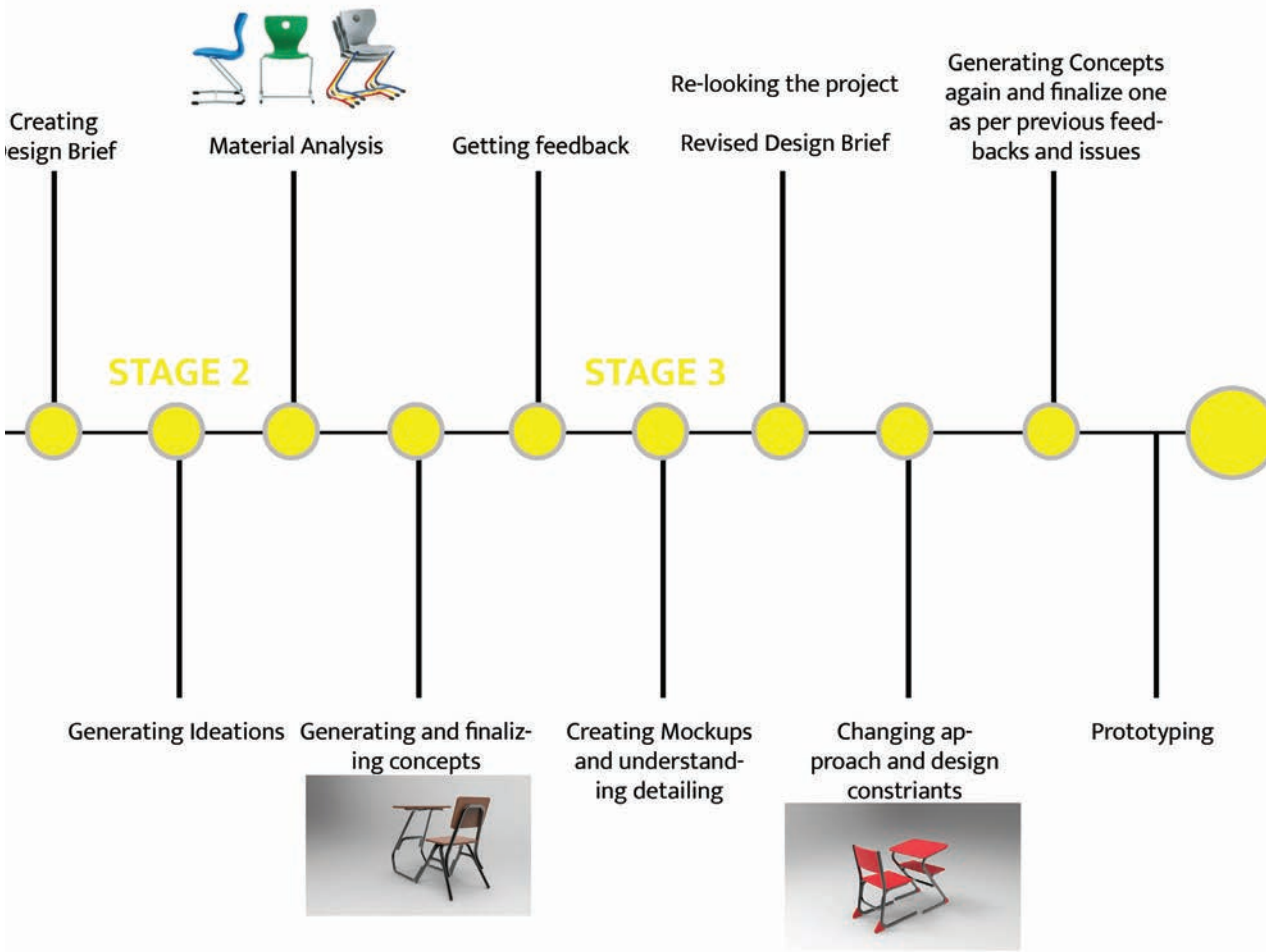

Image References

Fig. 1. Author during school visiti on 22/05/2016
Fig. 2. https://goo.gl/2Tr4Nq
Fig. 3. goo.gl/6hg3le
Fig. 4. https://goo.gl/r9Vk2i
Fig. 5. https://goo.gl/r9Vk2i
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Fig. 18. https://goo.gl/n7Kikh
Fig. 19. https://goo.gl/QBglkj
Fig. 20. https://goo.gl/QBglkj
Fig. 21. https://commons.wikimedia.org/wiki/File:Bicycle_evolution-en.svg
Fig. 22. https://goo.gl/7Ajycs
Fig. 23. Author
Fig. 24. Author
Fig. 25. Author
Fig. 26. Author
Fig. 27. Author
Fig. 28. https://www.flickr.com/photos/27267470@N04/2834704819
Fig. 29. https://www.flickr.com/groups/1112465@N21/pool/74516167
Fig. 30. https://www.flickr.com/photos/mink/5106877462
Fig. 31. readconsultingblog.blogspot.in
Fig. 32. readconsultingblog.blogspot.in
Fig. 33. readconsultingblog.blogspot.in
Fig. 34. readconsultingblog.blogspot.in
Fig. 35. http://www.ecvv.com/product/3167679.html
Fig. 36. http://www.ecvv.com/product/3167679.html
Fig. 37. https://goo.gl/o0tHks
Fig. 38. Author
Fig. 39. Author
Fig. 40. Author
Fig. 41. Author
Fig. 42. Author
Fig. 43. Author
Fig. 44. Author
Fig. 45. education-fact.blogspot.in
Fig. 46. education-fact.blogspot.in
Fig. 47. education-fact.blogspot.in
Fig. 48. https://goo.gl/qqQN7U
Fig. 49. https://goo.gl/qqQN7L
Fig. 50. https://goo.gl/qqQN7U
Fig. 51. https://goo.gl/qqJH4G
Fig. 52. Indian Ergonomics, NID Ahmedabad
Fig. 53. Author
Fig. 54. Author
Fig. 55. Author
Fig. 56. Author
Fig. 57. Author

Bibliography

Indian anthropometric dimensions for ergonomic design practice
Author :- Prof. Debkumar Chakrabarti
Publisher :- National Institute of Design, Ahmedabad
Year :- 1997

School Furniture Classroom, Recommendations: IS4837: 1990

Building Research Note, CBRI, 2000

A STUDY OF INFRASTRUCTURE FACILITIES IN SECONDARY SCHOOLS OF ASSAM STATE WITH SPECIAL REFERENCE TO SIVASAGAR DISTRICT, India, 2000

An Analysis of Anthropometric Data and design of a Writing Desk for rural Bengalee Primary School Children, NJMAS, 2012

Project 2 report, Keith D'Souza, 2012, IDC, IIT Bombay

Project 2 Report, Vaishali Borker, 2006, IDC, IIT Bombay

Websites

http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2684770/ (As on 02/12/16)

http://lmrindia.in/school-furniture.htm (As on 12/10/16)

http://www.sudamafurniture.com/school_furniture.htm (As on 15/11/16)

http://www.ergonomics4schools.com/lzone/seating.htm (As on 12/10/16)

http://casasbonitasremodeling.com/ergonomic-classroom-furniture-bysimon-dennehy-for-perch/ (As on 02/12/16)