THE ELEMENTARY SCHOOL WORKING ENVIRONMENT

A PROPOSED DESIGN SOLUTION FOR:

A CHILD'S DESK/WORK STATION

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The undersigned certify that they have read, and recommended to the Faculty of Environmental Design for acceptance, the Master's Degree Project entitled:

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Abstract

To improve the working environment of elementary school students, a new desk/work station should be designed, a conclusion reached by reviewing existing school furniture. The proposed design solution was achieved after performing an ergonomic needs analysis, and a video taped analysis of school children. A literature research was conducted regarding the existing and future school environments, and related working environments. The design, manufacturing, and production techniques were considered to take into account the needs of all its users; students, teachers, manufacturers, and purchasers.

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Section One - The Design Brief

1.1 Purpose

The purpose of this brief is to outline factors pertinent to the design of the proposed work station.

1.2 Objectives

1. To establish critical aims, constraints, and criteria through:
   a. researching the learning environment.
   b. analyzing related working environments.
   c. reviewing video tape of elementary school students.
   d. reviewing an ergonomic needs analysis of elementary school students.
   e. reviewing production technology interviews.
   f. reviewing testing data.

1.3 Assumptions

1. children are seated and/or using the work station for most of the school day.
2. the user group are children 8-12 years of age.
3. the computer component of the design will be limited to a fixed and removable monitor, keyboard and/or Mouse.
4. electrical wiring for the computers can be wired into the floor or the ceiling of the classrooms.

1.4 Critical Aims

The work station will consist of the following:

1. writing surface
2. seating device
3. storage facilities
4. a computer
    a. allowance for monitor
    b. allowance for keyboard
    c. allowance for Mouse

1.5 Constraints

The following are limits on alternative design solutions.

1. left handed and right handed students must be allowed for.
2. materials must be in accordance with safety considerations.

3. the curriculum selected for consideration is as follows (based on Alberta curriculum):
   a. language arts
   b. math
   c. science
   d. social studies
   e. physical education
   f. music
   g. health
   h. foreign language
   i. art
4. physical changes to the classroom will not be addressed in the proposed design solution.

1.6 Criteria

The following table displays:

a. criteria
b. factors pertinent to the criteria

The criteria which may affect the proposed design are listed along the horizontal axis while factors are listed on the vertical. From this table one can see how factors overlap into different criteria. This information was obtained by doing research as outlined in Appendix One.

Design Brief 4

FACTORS		CRITERIA															
		Aesthetics	Vandalism	Maintenance	Costs	Materials	Production	Worksurface	Cultural	Environmental	Ed. Benefits	Adjustability	Safety	Posture	Anthropometry	Seating	Storage
individuality of education		x														x	
materials		x			x			x	x		x	x	x			x	
color		x				x										x	
texture		x				x											
grouping of forms		x										x					
entry/exit to form		x														x	
mar-proof worksurface		x	x		x	x											
sustain weight			x			x										x	
sustain impact			x			x											
replaceability of parts			x	x	x											x	
access to clean				x													
production					x	x					x					x	
shipping					x	x	x										
durability			x	x	x	x					x					x	
fire resistant			x			x							x				
mass production					x	x	x										
territoriality		x						x		x							
envelopes - leg and arm								x		x					x		x
square desk cultural bias									x	x							
glare/dust										x							
heat/cold						x				x							
ability to fulfill tasks											x						
footrest												x		x	x		
seating device												x					
height adjust												x					
body support												x					
document holder								x				x					
monitor								x				x					
keyboard								x				x					
protrusions/rounded edges													x				
ergonomics								x					x	x			x
lordosis														x			
strain on different body part														x			
arm/feet														x			
suitability to tasks at hand														x			
head posture														x	x		
adolescence															x		
clearance															x		
backrest															x	x	
anthropometry								x						x		x	x
lumbar																x	
books																	x
drawer																	x
location of element		x															x
shelves																	x
stability of form													x			x	

Table #1. Work Station Criteria

Section Two - Final Design

2.1 Description

This section illustrates the proposed final design. The following areas will be discussed.

1. Basic description of main elements of the design.
2. Aesthetic description and rationale of the form.
3. Ergonomic rationale of the work station.
4. Production techniques, material selection, and costs of the work station.
5. Vandalism/Maintenance.
6. Safety concerns.
7. Territoriality.
8. Educational benefits.
9. Conclusion.

The final design of the educational work station considers six elements: storage, worksurface, accommodation for computer, seat support, seat bracket, and seat pan.

2.1.1 Storage

The storage is located to the left of the user (see section 2.3 for explanation). The child has three levels of storage at his/her disposal. The top, triangular drawer is designed to accommodate such items as pens;

pencils, erasers, crayons, rulers, and eye glasses. The second level is the display shelves, which are large enough to accommodate binders and text books. Below the bottom display shelf is the area to store a napsack or indoor shoes (see section 3.4 for explanation).

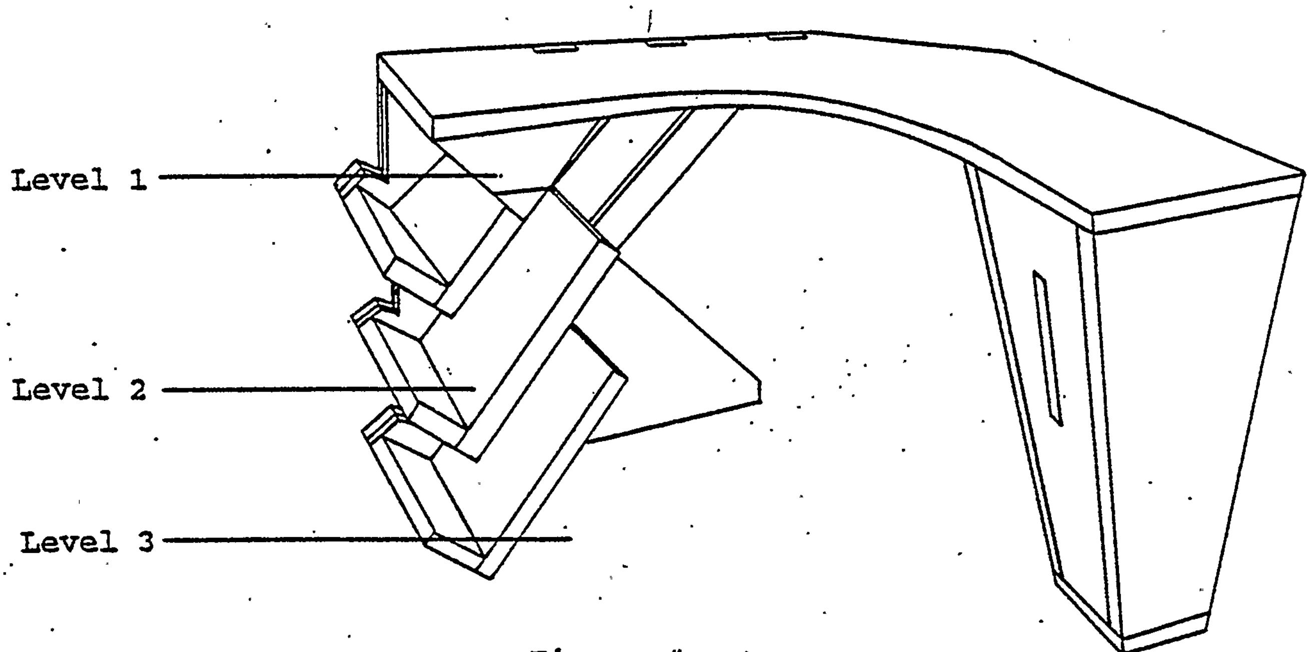


Figure #1 Storage

2.1.2 Worksurface

The worksurface is symmetrical.

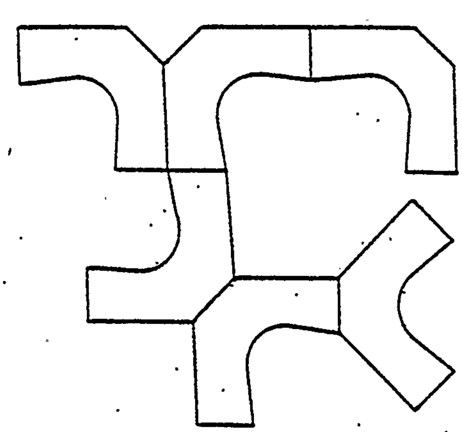


Figure #2 Worksurface

The symmetrical top allows for the grouping of the work stations (see section 2.3 for explanation).

2.1.3 Accommodation for Computer

The structural support on the lefthand side of the work station protrudes through the worksurface in three separate locations. These protrusions not only accommodate the electrical wiring for the computer, but also a pivot point for a monitor and source document support. The diagram below illustrates these features.

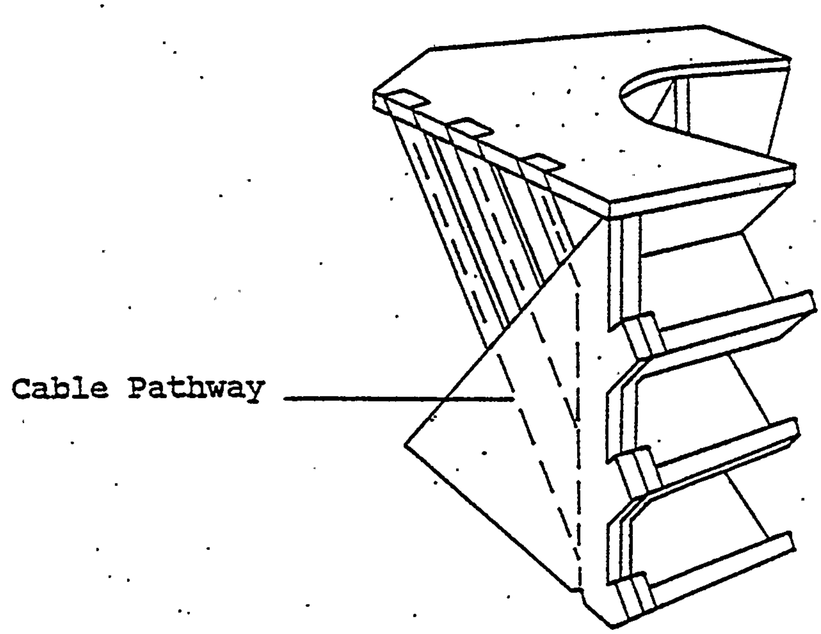


Figure #3 Cable Pathway

2.1.4 Seat Assembly

The seat and seat bracket are connected to the work station on the righthand side by the use of a hinging bracket, and a screw mechanism, both located inside on the seat support structure.

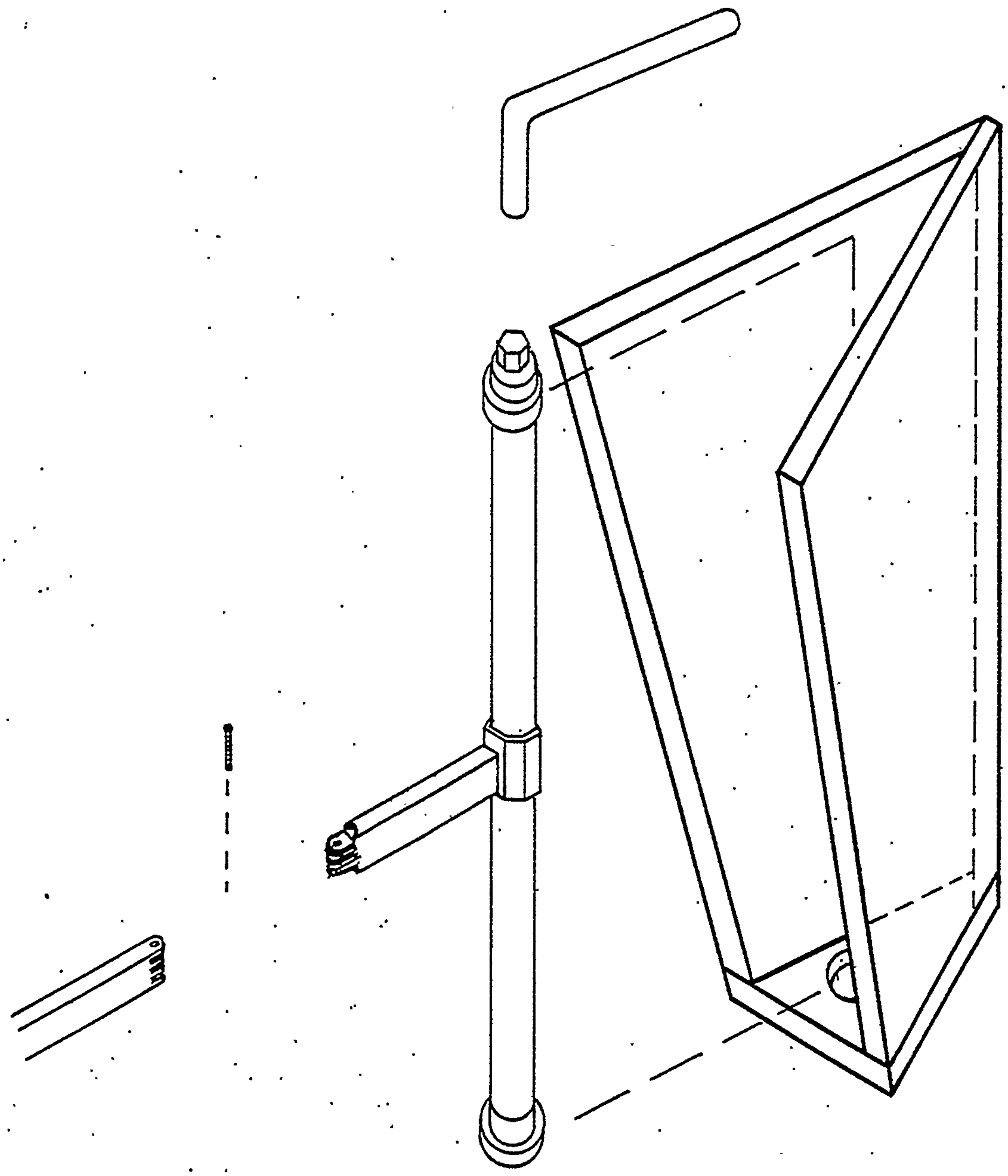


Figure #4 Seat Support Structure

Adjustments to the height of the seat are performed manually by turning the screw mechanism with a removable handle. The handle could be stored with the teacher.

The seat bracket has two pivot points. It pivots where it connects to the work station and under the seat pan. The seat pan is without contouring and negatively sloped. The backrest has a lumbar support which moves independently from the seat pan. The backrest is 'high' and tilted negatively at an angle of approximately 110 degrees relative to the seat pan. Connected to the seat is a footrest which adjusts in height independently from the seat.

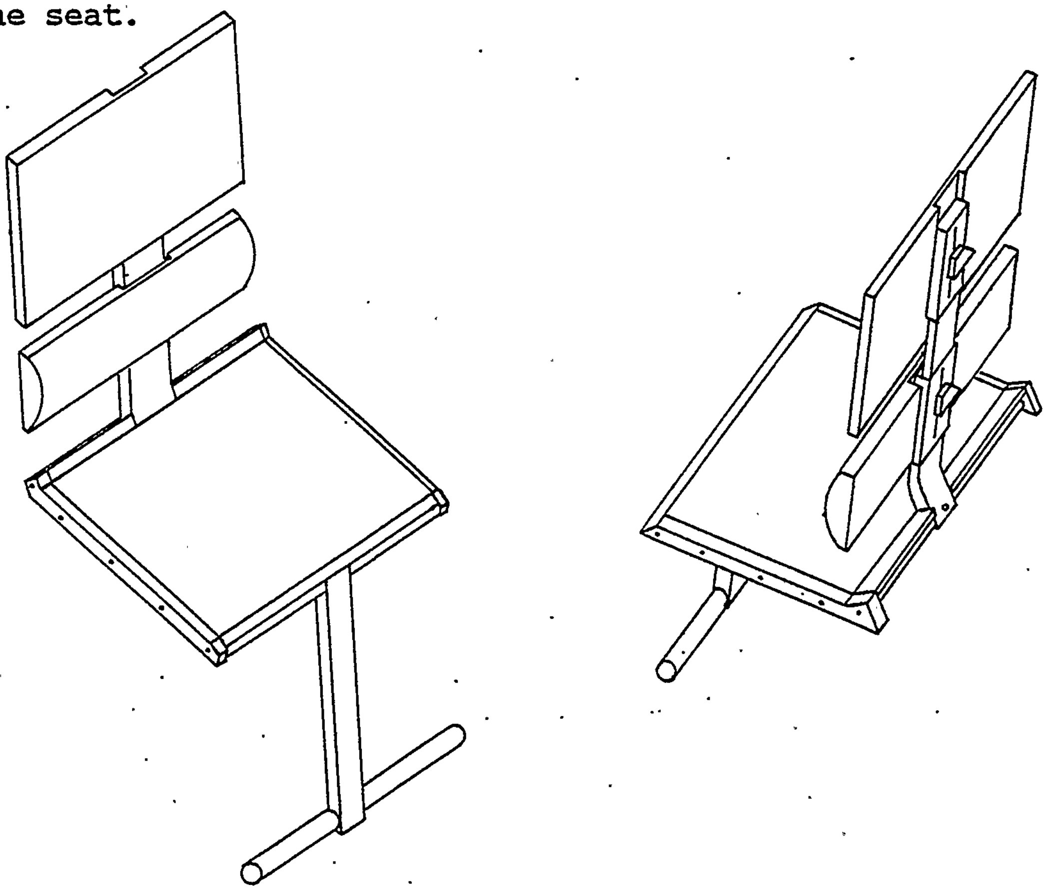


Figure #5 Seating Device & Footrest

2.2 Aesthetics

The aesthetics of the work station represents an evolution towards individuality in education because the child is the focus of its direction.

The form addresses individuality by taking into account ergonomic, cultural, and environmental needs of the student.

The impact of the aesthetics of the work station will be presented under five headings: the worksurface, storage area and its support structure, the seating device support structure, the seating device, and color.

2.2.1 The worksurface

The reach envelope of a child can establish borders to the form. By utilizing a curved interior, the child can now get closer to the worksurface because the worksurface contours around the abdominal area of the child (see figure 2). Leg room is enhanced by adjusting the horizontal angle of the worksurface as it merges with the curved interior (see figure 2). This enhances the visual aspects of access. The outside borders or lines of the form are angular and distinct. The work stations can be grouped utilizing available space or different instructional methods. The functional aspects of the worksurface dictate its form.

2.2.2 The storage area and its support structure

The storage area represents an evolution from traditional drawers or shelves to a more dynamic display-oriented configuration. The shelves step up the side of the form and merge with the worksurface and support structure. The structure, supporting the shelves, indicates that the traditional (shelves) has been linked to the contemporary (computer). This is achieved by continuing the direction or angle that the shelves have indicated. The structural flow is from the ground up through the worksurface.

2.2.3 The seating device support structure

As the form sweeps around the student from left to right it is met with an angular vertical element (the seating device support structure) which has risen from the surface below. Its form is angularly consistent with the shelf support structure since it too has evolved from the ground up. The arm for the seat is cantilevered from the seating device support structure, which is consistent with the shelf support structure and its shelves. The seating device support follows the <u>function and the form</u> the shelf support structure, and the worksurface.

2.2.4 The seating device

The seat and backrest height adjustment changes the proportion of the chair to match every individual.

The lumbar support and thoracic support connected to the spine are cantilevered like the shelves and seat bracket. It is important to maintain the aesthetic of having a form dependent on another.

The angular nature of the entire seating device allows it to blend well with the work station. It is inconsistent with the design to aesthetically disconnect the chair from the work station.

2.2.5 Color

The aesthetics of the work station would not be complete without taking color into consideration. Color can play a major role in whether the form blends into its surroundings or whether it is an aesthetic statement on its own.

The work station should be a neutral color, including the plastic version. The work station is maple brown in color. Maple wood is visually neutral.

To enchance the overall appeal of the form, cool grey, and green were combined with the maple brown. The work surface is light green, and the accenting features are dark green. All metal parts are cool grey.

The spine of the seating device is the same color as the cable pathway guides (extrusions) and the seat bracket. This is to accentuate the consistency of the form.

Overall the form is clean and playful, yet undisturbed by overwhelming bright colors.

2.3 Ergonomic Considerations

These considerations will be presented as they relate to six elements of the work station: storage shelves, worksurface, computer and shelf support structure, seating device support structure, seating deviced color. Ergonomics is very important as it applies to the interaction of the user and a design problem.

2.3.1 Storage shelves

The shelves are placed to the side of the user. This solves the problem of students bumping their knees, or impeding entry or exit to the work station. The shelves are within reach of the smallest child. The vertical configuration of the shelves allows the student to prioritize material placement. The personal drawer is located at the top as it is accessed most often. The last level of storage is at the bottom where students may store shoes or other items which are accessed less often. Overall the storage provides privacy for the students but also allows the teacher to control its cleanliness. An open storage area decreases the opportunity for the student to pack it full of materials.

2.3.2 Worksurface

It appeared from the video taped analysis (see section 3.3 for explanation) that children did not have enough worksurface area to perform their activities. The worksurface area has been expanded to partially encircle the student since they enjoy spreading the work from left to right (see section 3.3 for explanation). The depth has been decreased to save space and is within reach of the students designated in the design strategy (see section 3.6 for explanation). The interior line of the worksurface allows for easier access and allows the student to get closer to the worksurface, which is an important postural concern. The worksurface height is the same for all work stations, thus allowing work stations to be grouped in various configurations. Grouping the work stations establishes a creative environment and a less formal approach to space planning. Because the height of the work stations is the same, students can spread work onto more than one work station if desired. Grouping within a larger classroom can now be created to meet varying instructional needs.

2.3.3 Computer and shelf support structure

This structure is not only designed to house unsightly cables, but also provides overall support to the form. The three protrusions in the worksurface allow for some variability of an elevated monitor or document support.

If a student preferred the monitor to be placed further away, then he/she would choose point #1.

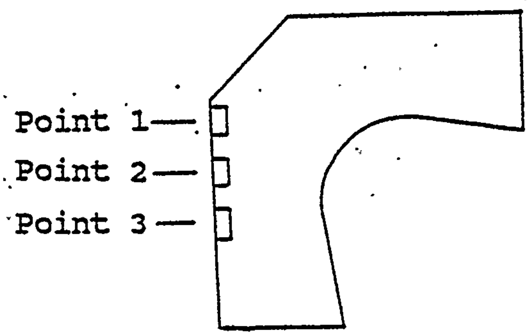


Figure #6 Monitor Placement

The monitor can be placed directly on the worksurface or be elevated by a pivoting support. It is preferable to elevate the monitor in some situations so the child's viewing angle is not compromised. Points #1, #2, #3, can accommodate a pivoting support.

2.3.4 Seating device support structure

This structure houses the mechanisms needed to adjust the height of the seating device to fit all users. The pivoting bracket and seat allows the user to get closer to the worksurface, to maintain a proper viewing angle, and to be able to use the entire worksurface. The tendency of a student to stoop over his/her work is reduced because the near point has been improved. The work station and seat can be used in conjunction with each other thus reducing neck, back, and shoulder strain (see section 3.4 for explanation).

2.3.5 Seating device

The seating device consists of 3 elements, the seat pan, the backrest, and the footrest. The seat pan depth is sized according to the 5th percentile 8 year old female (see section 3.6 for explanation). Sizing the pan to a smaller individual ensures that the seat pan will not stick into the back of the knee of a small user. This will not adversely affect the 95th percentile 12 year old girl because the seat pan edge will not reach to the back of the knee. The width of the seat pan is sized according to the 95th percentile 12 year old female. A small student will not be hindered by a wide seat pan as the pan will not be contoured inwards. This means that the knees of the smaller student will not be forced together, limiting leg movement. The seat pan is negatively sloped. The front and side edges are rounded to reduce pressure on the softer tissues of the thigh and the back of the knee.

The backrest is much more difficult to size than the seat pan. According to research the backrest should be as high as the shoulders. This allows the user to stretch and lean backwards as long as the backrest moves independently of the seat pan. If a 5th percentile 8 year old female shoulder height is used then undoubtedly the backrest would jab into the shoulder blades of a taller student. If a taller student's measurements are used then a smaller student may loose the ability to move laterally or stretch because the backrest is physically bigger than the student. Mobility of the smaller student should not be a major problem as the 95th percentile female is only approximately 10cm wider than the 5th percentile female (Pheasant 1986). It is therefore necessary to provide height adjustable backrests for the different students. This may add to the overall cost of the work station, but it is a necessity. Measurements used could include torso width, shoulder breadth, and shoulder height.

The lumbar area is also supported by the use of a lumbar support. This support is adjustable as the height for the lumbar spine area for 8-12 year old students ranges from 11-22cm, measured from the seat pan (see section 3.6 for explanation). This means that again an adjustable lumbar support is needed.

In addition to the adjustable seat is an adjustable footrest. The footrest reduces pressure on the back of the thighs and knees. The student can maintain a proper seat height because the footrest can be independently adjusted to the different sizes of legs evident at this age range.

2.3.6 Color

The colors for the work station were chosen for the following reasons:

1. safety
2. indication of important features
3. gender neutral
4. restful mental effect

Dark green was used to highlight special features of the work station. Examples include the dark green triangle on the drawer and the dark green cable anchoring device. In each case the user will notice it as being important in its own way. Coloring the cable anchoring device dark green enchances safety and gives the overall form a splash of color.

The color green and light brown are gender neutral. The work station should not encourage a separation of girls and boys in the classroom. It is the intention that the work station 'fit' every individual.

The overall form is calming and neutral. This is particularily important over long periods of time. While bright colors may be very stimulating at first, they can be disturbing and counter productive (Sleeman 1981). The work station does not conflict with work displayed on the walls or other devices. If the work station and walls were brightly colored then the classroom could be very busy and distracting.

2.4 Production Technology

While every material and production process has advantages and disadvantages, it is advisable to narrow the possibilities of which material or production process is most suitable for the manufacturing of the educational work station. The most notable factor concerning production processes and the use of materials is <u>economies of scale</u>. Savings to the manufacturer and purchaser can be realized if larger volumes of work stations are manufactured. Economies of scale can affect the following six areas of manufacturing.

1. Cost of materials
2. Material selection
3. Production process selection
4. Cost of production process
5. Cost of shipping
6. Costs to wholesalers and retailers

I have chosen two scenarios which will affect the above factors.

Scenario 1 - production volumes of 1-20,0000 units/year

Scenario 2 - production volumes of 20,000-100,000+ units/year

2.4.1 Scenario 1

This scenario will limit the production process to a fabrication technique because automated machinery is very expensive. The machinery can be amortized into low volume production but it will add to the total unit cost. The following are characteristics common to this type of process.

1. High amounts of labor
2. Local materials are preferable
3. Local distribution of the product
4. Low to medium technology

Labor involved at this level could range from cutting, fastening, or welding of pieces to manual packaging of the product.

Locally available materials are used to minimize total unit costs. Materials native to a country or region, or those which are quickly obtainable are preferred.

The final product will usually be limited to local distribution, thus shipping costs are minimized. Low production volumes does not allow the product to be shipped nationally or internationally as the cost must again be included into the total production, thus raising the price significantly.

Automation, robotics, and flexible manufacturing techniques are uncommon at this level of manufacturing.

2.4.2 Scenario 2

This scenario has the following characteristics:

1. Low to medium amounts of labor
2. Greater flexibility in choice of material
3. Local to international distribution
4. Medium to high technology

Labor is usually involved with setup and finishing the product at this level of production. Preparing a numerically controlled machine is an example of setup. Cutting the scrap off of a plastic molded product is an example of finishing a product. Technology substitutes labour. For example, labor may be decreased by linking computer aided design to automated production process machinery.

Because production volumes are higher there are larger savings in purchasing greater amounts of materials. The larger inventory of materials required to sustain the manufacturing of the product allows the manufacturer to realize quantity discounts. Different technologies also allow the manufacturer to choose different materials. Injection molding allows greater use of plastics instead of the wood used in the labour intensive fabrication processes outlined in Scenario 1. If demand warrants higher production volumes then it is likely that the market is not only local, but national or international. Shipping costs are lower per unit if larger amounts of product are exported to another region. Larger volumes result in lower shipping costs per unit allowing the manufacturer to be price competitive.

Technology at this level of manufacturing involves some automation of the manufacturing process. Computer aided design, CNC machines, and assembly lines are only a few examples. As production expands it may reach a point where the design process could be linked with manufacturing processes via computers, resulting in a flexible manufacturing system. A system like this links design, production, inventory, and shipping using automated machinery and robotics.

Because economies of scale play such an important role in choosing a suitable material and production process the design of the product may be different from one scenario to another. If the above two scenarios are applied to the manufacturing of the educational work station, the following results would most likely occur.

2.4.3 Manufacturing Scenario 1

Scenario 1 - Volumes up to 20,000 units per year

1. Materials

   a. maple wood

      - used on all panels and seating device
      - will not be used for the seat bracket

   b. cold rolled steel

      - used on the seat bracket and part of the shelf support structure (cable pathway extrusions)

   c. laminates

      - used to cover the worksurface

   d. baltic birch plywood

      - used for the worksurface

2. Fasteners

   a. wood glue

      - used to glue the shelves to the shelf support structure

   b. wood screws

      - used to secure panels to one another
      - used to secure metal to wood

   c. machine screws

      - used to secure all metal pieces together

d. contact cement

- used to glue the laminate to the worksurface

3. Finishing

a. powder coating

- used to coat all metal parts

b. catalyzed lacquers or polyurethane coating

- used to coat all wood surfaces

4. Production processes

a. hand tools

- used to drill holes, round edges, and smooth edges

b. welding

- used to construct metal parts

c. industrial table saws

- used to rough out the worksurface and wood panels

d. industrial planers

- used to establish thickness of material after glueing has been done

e. plunge routers

- used to finish edges and round corners

5. Costs (Woodsworth Design)

   a. Material costs

      - $1.60 - $2.30 per board foot
        (depending on # of units)

   b. Labour costs

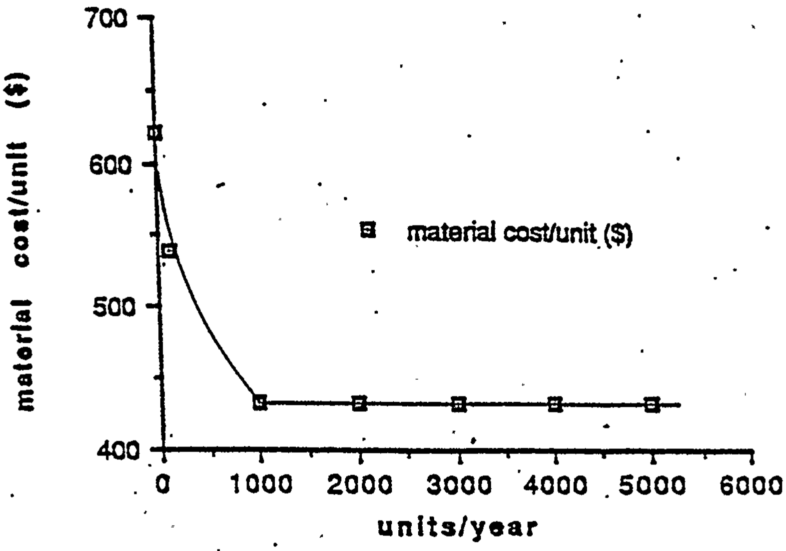
      - $15.00 - $20.00 per hour

   c. Overhead cost

      - $ 5.00 - $10.00 per hour

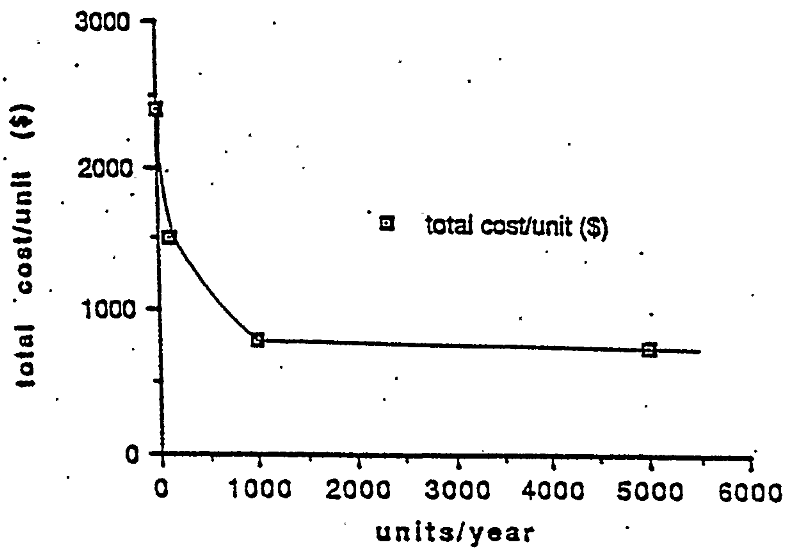
   d. Costs per Unit (based on estimate of 270 board feet of material/unit)

Pieces	**Unit Cost**	**Material Cost**	**Overhead Cost**	**Labour Cost**
1	$2400.00	$621.00	$450.00	$675.00
	Profit per Unit $648.00 (27% of total cost)			
100	$1500.00	$540.00	$240.00	$360.00
	Profit per Unit $360.00 (24% of total cost)			
1000	$800.00	$432.00	$ 92.00	$138.00
	Profit per Unit $138.00 (17% of total cost)			
5000	$752.00	$432.00	$ 80.00	$120.00
	Profit per Unit $120.00 (16% of total cost)			



Graph #1 Material Cost of Wooden Work Station

The above graph illustrates the decrease in material costs with increased unit production. But after 1000 units, the material costs remain the same. The nature of the material, even if bought directly from the supplier, does not significantly alter the material costs. The manufacturer is therefore forced to lower other costs. The ability to increase volumes depends on the number of table saws and routers at the disposal of the company. Each of the work station parts is cut and routered therefore the capacity of the manufacturer is directly related to these machines.



Graph #2 Total Cost of Wooden Work Station

The graph above illustrates that after 1000 units, the total cost/unit will not decrease significantly. Therefore one must expect that, even at units of 5000, the price will not decrease a great deal.

Materials chosen in this scenario offer abrasion resistance, strength, as well as the ability to sustain weight and impact.

Due to its density, maple wood will take a great deal of abuse. Maple has the disadvantage of experiencing expansion and contraction under extreme humidity shifts. However, because the heat and humidity are controlled in the school environment, use of maple indoors is appropriate. Maple alone is very durable and strong, but the addition of catalyzed lacquers or polyurethane coatings make it more wear resistant. Plywood will be used for the worksurface because it has a great deal of flexural strength. A laminate is used to cover the worksurface top to aid the overall durability of the work station. The use of laminates also offers color options.

Cold rolled steel is used for the seat bracket because of its durability and is easier to machine compared to other steels (stainless steel). It would most likely be roll and seam welded to the appropriate cross-section.

The fasteners used vary in type. Wood glue is used to aid the connection of the shelves to the shelf support structure. The middle shelf will not be glued as it may be need to be removed more often than any other piece due to breakage. Wood screws will be used to join panels. Machine screws are used in the seat bracket and screw device. These screws are strong and again allow parts to be removed or replaced. Contact cement is used to glue the laminate to the worksurface because the cement is the best fastening device.

Wood surfaces, not including the worksurface, are finished with catalyzed lacquer. These surfaces are not subject to as much abuse as the worksurface. To achieve a hard surface on the metal pieces they are powder coated. Powder coating also allows for color options as any color can be mixed and baked onto the metal parts.

2.4.4 Manufacturing Scenario 2

Scenario 2 - Volumes of 20,000 to 100,000+ units per year

1. Material
   a. glass reinforced polypropylene or a polycarbonate/polyester alloy
      - used throughout the work station
   b. baltic birch plywood
      - used for the worksurface to be inserted into an existing plastic worksurface frame
   c. laminates
      - used to cover the plywood top
   d. cold rolled steel
      - used for the metal parts

2. Fasteners
   a. contact cement
      - used to glue the laminate onto the plywood

b. metal screws

- used to secure the panels to one another

c. machine screws

- used to secure all metal pieces to one another

3. Production processes

a. injection molding

- used throughout the work station

b. industrial saws

- used to rough out worksurface

c. plunge routers

- used to finish worksurface

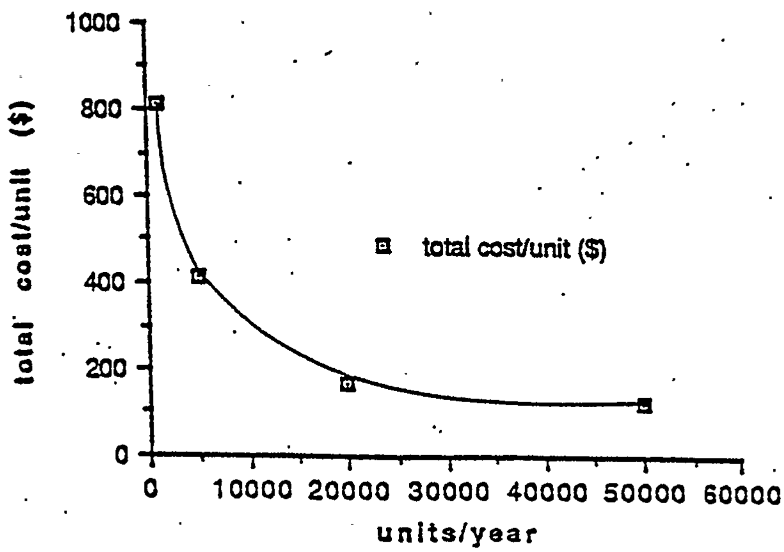
d. metal forming - roll and seam welded

- to produce the seat bracket and cable pathways

4. Costs (not including seating device and bracket) (Todd Parker 1991)

- glass reinforced polypropylene at $1.20/lb.
- **total tooling costs $630,000**
  - worksurface $80,000
  - computer/shelf support structure $250,000
  - seat support structure $300,000

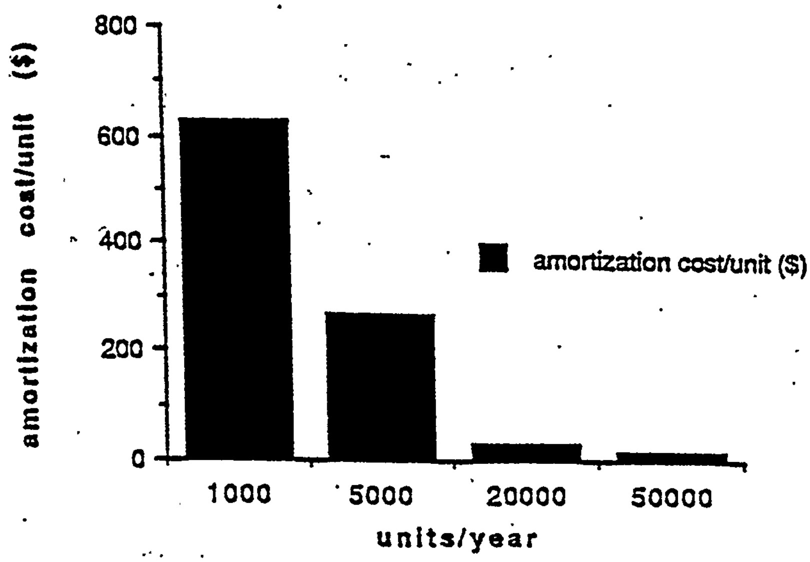
- **cost of work station $180.00/unit**
  - based on 1000 units
  - different wall thickness will affect price
  - price includes setup, running time, material, and overhead
- **amortization costs** (over one year)
    - 1000 units $630.00/unit
    - 5000 units $266.00/unit
    - 20,000 units $ 31.50/unit
    - 50,000 units $ 13.00/unit
  - **total cost of work station** (not including seat and seat bracket)
    - 1000 units/year $810.00/unit
    - 5000 units/year $410.00/unit
    - 20,000 units/year $166.50/unit
    - **50,000 units/year $121.00/unit**



Graph #3 Total Cost of Plastic Work Station

The above graph illustrates that total unit cost will decrease steadily as units produced increase. Because the production limit per tool is 50,000 units per year, another set of tools may need to be manufactured. Even with this additional cost the work station can still be manufactured economically.

The graph below demonstrates that, because of amortization costs, it is economically feasible to manufacture the work station at units above 20,000 per year. The more units produced the lower the amortization costs per unit.



Graph #4 Amortization Costs of Tools

Glass filled polypropylene was used in this production scenario for the following reasons:

1. structural properties
2. price

Glass filled polypropylene is an inexpensive and structurally stable thermoplastic. Polypropylene is as little as one third as expensive as Polycarbonate (Parker 1991). A concern with large molded panels is the risk of warpage. Polypropylene has good tensile strength, and high stiffness qualities (Parker 1991). These qualities are needed for the manufacturing of the work station. In addition to these qualities PP(polypropylene) is slow burning, possesses excellent machining qualities, and good colorability. Glass filled

PP (10%) will increase stiffness modulus twofold (Parker 1991).

The worksurface of the PP work station has a recessed area that houses a plywood laminate insert. This was chosen because it is difficult to repair a plastic worksurface. With a wood insert the worksurface can be easily replaced if vandalized or damaged.

Mild steel, high strength steel and spring steel were chosen to be used for all metal parts because of the varying strength conditions placed on the varying parts. Steel, in its varying forms, is very strong, and relatively inexpensive (Shorten 1991).

The plastic panels will be treated as wood panels and will be secured with appropriate screws. Fastening inserts are used in conjunction with the screws (Parker 1991).

Injection molding is the chosen production process for the following reasons.

1. ability to fulfill high production volumes
2. consistent quality
3. allows for complex molding
4. flexibility in material choice

Injection molding allows for high production volumes. The capacity of the tools for the work station is 50,000 units per year (Parker 1991). This will add approximately $13.00 to the total cost/unit. If demand warrants the production of 100,000 units a year, then additional tools would need be required. This would add to the total unit cost, but savings in material purchases and shipping may be realized, thus offsetting the amortization costs.

Initial research indicated different processes could have been used to fulfill the production quota. Injection molding was chosen because it was the best process for the entire design. Piecing together work station parts made from different processes would interfere with quality and fit. Shrinkage and warpage of plastic using other plastic forming techniques could inhibit joining one piece to another. Injection molding also allows flexibility in molding of complex forms. If blow molding is used to produce the support structure and storage shelves, the shelves would have had to be molded separately and joined to the support structure after production. This adds to the tooling costs of the final design. More importantly, the horizontal joining of the shelves to the vertical support is a poor option as joint failure may result. By using injection molding, however, the shelves can be molded directly into the support structure. This saves tooling costs and improves the overall strength of the form. Injection molding also saves after molding costs because there is less scrap or flash on the finished product as compared to RIM (Reaction Injection Molding) or blow molding (Shorten 1991).

The use of injection molding allows the designer to use materials ranging from thermoplastics to thermosets. While some materials are more difficult to mold than other materials (ie.polycarbonate) injection molding offers greater flexibility than blow molding, RIM, rotational molding, and hand lay-up processes (Shorten 1991).

The seat bracket and cable pathaways are produced through a metal forming process called roll and seam welding. A series of rolls gradually change the shape of the metal as it passes between them. It is then welded along the seam of the product as it continues through the production line. The finished product can be produced quickly to the desired cross-section.

2.5 Vandalism/Maintenance

Vandalism accounts for 20% of all repairs currently being done on school desks (Jensen 1989). It is one of the problems that should be addressed. Vandalism can take the following forms:

1. Scratching the work station surface.
2. Coloration of the worksurface.
3. Destruction of work station pieces.
4. Removal of work station pieces.

The proposed work station has a mar-proof laminate work surface. This is the best available deterrent to surface scratching, and destructive coloration. A type of laminate, manufactured by Nevamar, called 'ARP' is the latest and best abrasion resistant laminate surface. It is three times as durable as conventional laminates (Shuldiner 1989).

The ability to maintain the worksurface is very important. The laminate surface can be easily cleaned, is solvent resistant, and may not have to be repaired as often as in the past because of its durability (Shuldiner 1989). If the top needs to be repaired the laminate can be stripped off of the wood top or completely replaced. The wood top is secured by vandal proof screws and is easily replaceable. With the PP version, a laminate wood worksurface is recessed into a

PP frame and secured with screws. Again, this allows for quick replacement.

The actual destruction of the work station pieces is a concern. Destruction in this case means refers to the breaking of the shelves. There is not a great deal of concern regarding the destruction of the support structures and worksurface as they are solidly secured to each other and to the floor. The storage shelves could possibly be stood on and perhaps broken. Questionnaires returned by teachers indicated that students do not stand on seats or work surfaces. Designing for misuse is important, but the design would be compromised if a vertical support between the second and third shelves was added. Adding a vertical support would limit the ability for the student to access material and aesthetically ruin the left side of the work station.

All the pieces of the work station that potentially need repair are easily replaceable. The seat and seat bracket are replaceable only by the appropriate maintenance personnel. As mentioned earlier, the worksurface is replaceable. The electrical wiring guides are screwed to the worksurface and the bottom half of the computer support structure. This is done so the wiring may be repaired or replaced.

2.6 Safety

The overall concern regarding safety is that the student not injure him/herself while using the work station. The following are some areas of concern.

1. Sharp edges or corners.
2. Pinching of fingers or arm between the seat bracket and the seat bracket support.
3. Stability of the form.
4. Misuse of the form.
5. Fire resistance.

1. While the students are moving around the classroom there is the potential to bump into or fall onto the work station. The work station does not have any sharp corners or edges. The shelving edges are sufficiently rounded to prevent injury.

2. The movement of the hinging seat bracket is limited. The bracket(one surface) cannot rotate until it touches the bracket support(second surface). This not only prevents damage to the work station, but assures that students cannot injure themselves.

3. Because the seat is cantilevered from the work station, it is crucial that the unit remain stable. The

rotation of the seat bracket is limited to aid in this concern. The design is balanced by the shelves, shelf support structure, and the seat support structure.

4. Misuse of the form can be addressed, but extreme abuse should be controlled through classroom management. Data from the teacher questionnaires indicated that extreme abuse does not occur.

5. Under the right conditions any material will burn. The materials chosen help minimize this threat. Maple, because it is a hard wood, burns slower than softer woods. The Calgary Board of Education currently purchases desks made from hardwoods (Jensen 1989). Polypropylene burns slowly. Under real fire conditions any plastic will burn. Polypropylene is rated at a .75-.83 flame spread rate (ASTM D 635). This means that the flame will spread approximately one inch in one minute. The classroom should contain any fire (Nies 1991). This includes materials chosen for the manufacturing of classroom products.

2.7 Territoriality

"Territoriality is a pattern of behavior associated with the ownership or occupation of a place or geographic area by an individual or group, and may involve personalization and defense against intrusions."[1]

The work station design, according to the above definition, can influence behavior in the classroom. The following characteristics of the work station allow personalization of the work area and give the children a sense of importance and control.

1. Personal drawer
2. Organize shelving units
3. Seat is adjustable only to user requirements
4. Borders of the form
5. Organizing work stations into a creative environment

1. A personal drawer has not been offered to children in the past. There has been a common space for books and other utensils, but the children are forced to separate the pens, pencil, and other small articles into a pencil case. The drawer offered in the work station has enough room for small articles.

2. Prioritizing articles that are placed on the display shelves promotes organization. The student is choosing what occurs in his/her area.

3. The seat height can be adjusted to a student's needs. This deters students from using another person's work station.

4. The borders to the form create a spatial area that can be observed by other students. Elbows and work may not intrude onto other students' worksurfaces because students now have ample space to work.

5. The students can also have input as to how the classroom can be arranged. If they help create the classroom environment then they may feel as though they belong.

The word 'desk' is inappropriate to describe the proposed design. It is no longer a desk but an individual work station because it has been personalized. The student has permanent ownership of the work station for one academic year.

2.8 Educational Benefits

Computers are becoming a large part of the school system. Apart from the technology itself, the student must be able to use the computers efficiently.

The design of the work station fulfills the needs of the student ergonomically, socially, and aesthetically. Because these needs have been fulfilled a child will be able to work without being frustrated by a work station which is too small or large, not capable of storing materials, or insensitive to a child's territorial needs.

The physical durability of the work station (untested) is also a benefit to a student even if the students are not aware of this. The work station has been designed to minimize down time thus allowing a child to work without interruptions. The materials and the ability to maintain the work station are important factors as to whether the work station can be implemented effectively.

While the direct educational benefit of the work station can only be estimated, other work environments have benefitted from properly fitted and designed work stations. Other factors, such as lighting, noise, temperature and space planning would need to be taken into account to fully assess the benefits of this future work station and classroom.

2.9 Conclusion

The evolution of the classroom desk to a work station will rely on many factors. These factors should not only test the design for durability, usuability, and suitability but also develop the work station for eventual release into the market place.

The elementary school work station, as proposed in this document, has reached a point in its development that represents an initial prototype. The actual production of the work station may be as many as five years away. There are two areas in its development that need to be thoroughly explored.

1. Design Changes
2. Product Development

The final design would be a product of the above two issues. Design changes refer to physical changes to the work station as a result of factors which will affect the product's development. For instance, durability coupled with production may result in parts of the work station being manufactured in a way that balances product life with total cost.

Product development refers to issues such as marketing, distribution, funding, and production. As the final design solidifies its manufacturing funding must be in place. A marketing strategy must also be developed in order to ensure timely release into the market and to ensure proper promotion and distribution of the product.

The first step in its further evolution would be to do a more comprehensive breakdown of the production costs. This allows one to approach funding agencies, investors, or school furniture manufacturers to provide initial monies. The goal of finding funds or a manufacuturer to sponsor the project is to allow for a test market or in this case it may include a longitudinal study of the work station. The study may incorporate setting up computer labs and observing whether the current prototype is durable, usuable, ergonomically appropriate and perhaps most importantly whether the work station facilitates learning. From the study changes to the design would most likely occur.

Next final production drawings would be drawn and manufacturing tools would be produced. This would only occur if approximately one million dollars was in place and it was evident that the market would sustain 50,000 work stations. The tools themselves would take six months to one year to manufacture. An initial manufactured prototype would only be realized after the following occurred.

1. Completing the longitudinal study
2. Completing design changes
3. Assuring funds for higher production runs
4. Obtaining purchasing orders from users
5. Establishing a national marketing and distribution strategy

The computer will be a part of the elementary school system. Computers have been recognized as the tool of the future for elementary schools students, but there must be an acceptance and overall committment to improving individualized education. The concept of an individualized computer work station will most likely occur when there has been a committment to individualized education for elementary school students.

Appendix One - Research and Data Collection

3.1 The Learning Environment

3.1.1 Description

Traditionally, children have spent most of their elementary school years in formal classrooms (OECD 1981). They would sit at a single desk, with no other type of work place in the room. Displaying of work was confined to pinning surfaces. The storage and display of books was generally inadequate. Some rooms had single or dual tables arranged in groups. But without using this arrangement as a teaching and learning tool it was irrelevant. Some schools had no internal walls to separate grades of students, an indication of a more informal teaching approach. Though these spaces may have given the impression that a significant educational change had been taking place, it would, in reality, appear that only the range of group sizes had been extended. An extended range of educational opportunity had not really taken place (OECD 1981). The furniture in these classrooms has changed very little from what has been familar to previous generations and again represents no educational change.

3.1.2 Changes - Classroom of the future

A school is "an institution for teaching and learning".[2] Yet this traditional institution may no longer fit in our society (Hill 1984). The classroom need not have four walls and the desks do not have to be placed in six rows of six. The teacher no longer needs to be the main source of all knowledge for students (Hathaway 1989). Recent history reveals that there are trends which are effecting education positively.

By the end of the 1960's the computer had become a major information management tool. Today, personal computers are more powerful and several times less expensive than those of the 1960s. "Many see computers as being of great use in education."[3]

Society has become dissatisfied with educational results. "Educational costs (expressed in real dollars) have increased about four times over last 30 years but student achievement has changed very little."[4] This combination has created a greater interest in the educational well-being of young students. Experiments with different teaching techniques and different school classroom layouts have been attempted, (both) with variable success. What is "needed are capabilities for widespread individualized or customized educational programs".[5] The development of these programs raises the spectre of the need for an individual work station. An evolution towards a working environment in which the student is the focus of attention is presently occurring.

3.1.3 The Effects of the Computer on the Student

The children of our elementary schools are in the midst of a computer revolution. This revolution is affecting every aspect of their lives (Coburn 1985). These students are facing the reality of computers as being a part of their lives. They must be prepared to use computers.

1. Benefits of the Classroom Computer

The school of the 21 century could be a place where students all have personal computers that are linked to laser disc libraries, and networked to other schools, homes, and other cities all around the world. There is evidence that our present school system is already taking this view. A 1989 position paper titled "Growth and Improvement: Expectations for CBE Mission Fulfillment" has indicated that children should have "easy access to computers" and "ideally, one for each student" (Dickson 1989). Computers offer the following benefits:

a. The computer as a tutor, will make education more efficient and enriching (Lepper & Gurtner 1989). The computer provides immediate feedback, and offers new learning opportunities. In essence, the student can learn at his/her own pace and level.

b. The computer as an experimental learning tool. Areas in education that are not regularly taught can be addressed by computers. As an example, the acquisition of speech, and scientific simulations (Lepper & Gurtner 1989).

c. The computer can promote writing and communication skills. The students will have access to word processing programs which will aid in documenting work as well as encourage students to spell correctly and revise his/her own work (Lepper & Gurtner 1989, Coburn 1985).

d. Computers can help teachers make teaching time more effective (Lepper & Gurtner 1989). Computers can free teachers from time consuming tasks like marking and report writing.

e. Computers can enhance social and motivational skills (Lepper & Gurtner 1989). "Because it facilitates active learning, provides immediate feedback, and adjusts to match the capabilities and the pace of individual students, the computer may make learning more fun."[6] In addition to this, students are encouraged to help each other on the computer. Some students become teachers, enhancing the sense of accomplishment and self confidence.

f. Lastly, the computer may increase the equality of education (Lepper and Gurtner 1989). Because computers can minimize the "pernicious effects of teacher prejudices or favoritism",[7] students that normally do not perform well under traditional methods may perform much better if computers are used.

2. Negative Aspects

"Many teacher and school administrators-those on whom the implementation of the coming computer revolution in schools will ultimately depend-quietly harbor similar concerns"[8] to those who are unconvinced of the benefits of computer education. Some believe that the computer will have the same effect as educational television, that is, the inability to inspire the student. The following are some other potential problems stemming from computer use in the classroom.

a. The removal of the teacher and therefore the personal side of teaching. Some students depend heavily on social interaction, something that may not be available if every student had a computer. There is a question as to whether computers will deliver inequality as opposed to equality to the educational process. High-quality software and hardware may not be available to every school (Lepper & Gurtner 1989). Students from different social backgrounds may be assigned different programs to work with. It also remains to be proven that intellectually or economically advantaged or disadvantaged students benefit from computer (Lepper & Gurtner 1989).

b. Computers "may inadvertently and inappropriately shape the nature of the curriculum".[9] It is feared that subjects adopt easily to computers (ie. math). These may begin to dominate the curriculum eventually resulting in the decline of subjects like drama, art, or literature.

c. There are concerns with the transferability of learning and motivation outside of school (Lepper & Gurtner 1989). There is some question regarding child performance without the use or accessibility to a computer. Reading, writing and arithmetic are still the fundamentals of a curriculum. If the computer checks spelling for the child, or aids in performing simple mathematics, there is some question of how the students will perform when more advanced writing skills are needed or when more advanced mathematical problems need to be solved (White & Hubbard 1988).

"Despite sharp disagreements among educators concerning the revolutionary potential of computers use in schools, there would seem to be few who would dispute the assertion that computers will affect schools in some fashion and to some degree."[10]

3.1.4 Role of Teachers

With the addition of the computer to the school classroom the role of the teacher will change. Teachers have traditionally been the focus of classroom attention (White & Hubbard 1988).

"As a consequence of computers entering the schools, the traditional place of the teacher at the front of the classroom is likely to diminish. In fact, teachers will probably spend most of their time guiding, counseling, and leading instructional teams rather than lecturing to a room full of students."[11]The instructional team will consist of teachers, teachers aids, as well as those with specific technical knowledge. In fact, students will be offered more individual help than ever before but the computer and support equipment will provide most instruction (White and Hubbard 1988).

Future teachers or coordinators will combine electronic and human resources to ensure students are learning effectively (White & Hubbard 1988).

"Teachers will cease being the primary sources of knowledge in the classrooms and will become mentors to their students in the process of learning and applying information to solve problems."[12] Teachers will <u>facilitate</u> learning.

When educational data bases become available it is likely that the teaching profession, as a whole, will diversify not shrink, as many believe. Proceedings from a 1983 seminar called "The Impact of Technological Advance on Education" provides evidence that, with the increasing role of computers in the work place, the demand for teachers is expected to increase. Teachers may choose many avenues. Some may develop software specially suited for a particular group of children or alter existing software to make better local use of it.

Some teachers will act as contacts to other teaching centers. This will enable students to compare ideas and knowledge with other students.

In sum, the idea of the 'front' of the classroom will no longer exist. The student-teacher relationship will be enhanced because the teacher will be freed from time consuming tasks via the use of computer instruction.

3.1.5 The Classroom of the Future

For over a century the traditional classroom has not changed (White & Hubbard 1988). With the advance of computers every aspect of the school will need to be reconsidered. It is unlikely that new schools will be built due to the declining birthrate (White and Hubbard 1988). It is more likely that our present schools will be remodelled. "The focus of classrooms in the future will almost certainly be on electronics work stations, with each student having immediate access to a terminal."[13] Obvious changes in schools will be control in temperature, lighting, and dust. These factors all affect the performance of the computer and its operator.

3.1.6 Design Philosophy

By reviewing how the computer can affect the elementary school environment, one can develop a philosophy of how education is evolving.

Education will become more individualized.

The above statement can be applied to all aspects of the classroom environment. Teachers, students, the desk or work station, and aesthetics are all factors that are affected by this philosophy.

Now, however, the student is becoming the focal point. An open classroom atmosphere and the encouragement of group work has contributed to individualized education. The involvement of the computer in the class curriculum will induce further changes. The computer encourages self development and individualization and may also be used in groups. One can visualize a teacher walking through a working environment helping students who are working individually while linked physically and electronically by the work stations. The work station should reflect the evolving roles of teachers and students as well as the evolution from hard to electronic information.

The aesthetics of the classroom should reflect the changes that will occur to the teachers and the students. With the addition of the computer and its peripherals, the students' desks will evolve into computer educational work stations.

3.2 Related Working Environments

3.2.1 Seated Work

Seated work, in many conditions, is subject to many problems. The following are some of those problems.

- Maintaining lumbar lordosis
- Strain on neck & shoulders
- Static postures
- No support for areas of the body (forearms, feet)
- Lack of ergonomic factors
- Suitability of workspace to tasks at hand

These problems are common to the school work environment, computerized offices, and office work stations, some to a greater degree than others. Research into solving the above problems has been done in adult work settings. It may be possible to transfer some solutions to other work environments.

The concept of 'correct sitting posture' must be discussed. Correct sitting posture in this case refers to the best sitting posture for the task at hand.

There are two positions which ergonomists, doctors, and designers believe to be the most suitable for seated work.

1. Sitting Postures

a. Forward inclined

Mandal A.C., The Seated Man, p. 49, 1985.

Figure #7 Forward Inclined Sitting Posture

b. Right angled or upright

Mandal A.C., The Seated Man, p. 16, 1985.

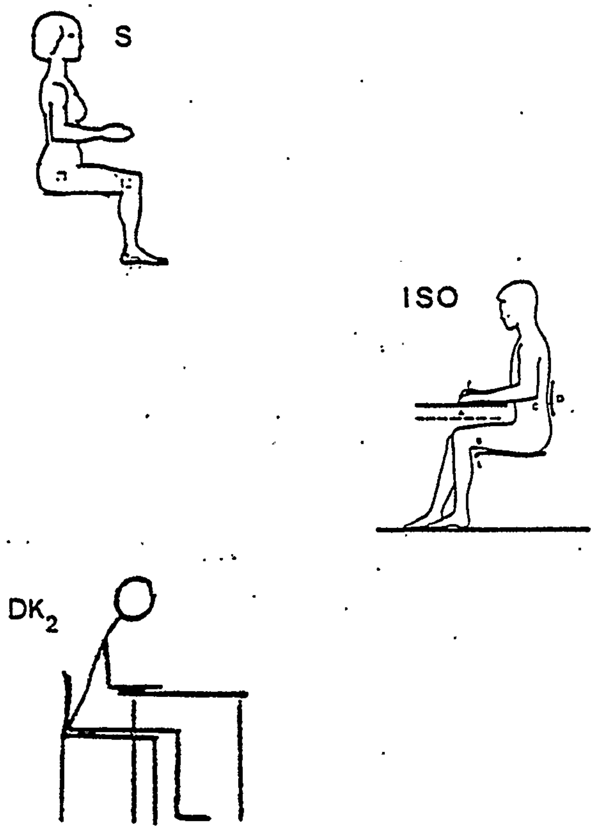


Figure #8 Upright Seated Posture

a. Mandal, the main advocate of the forward inclined seated position, contends that the right-angled or upright sitting position is ruining childrens' posture and, subsequently, as they grow older they will continue poor habitual sitting techniques. Dr. Mandal's research is supported by observational experiments. His solution to a slumped sitting posture consists of the following factors.

i. Higher work surfaces

ii. Sloped work surfaces

iii. Forward sloping seats between an angle of 15-25^{o}

iv. Higher chairs

v. Larger script (Mandal 1981)

In order to understand how these factors solve a slumped sitting posture, a description of what happens to the body (particularily spine and hips) in a right-angled seated position is needed.

When a person sits down many erroneously believe that the hip joint rotates through 90^{o}. The hip bends 60^{o} while 30^{o} comes from the flattening of the lumbar curve (Mandal 1981). Mandal's observation has been confirmed by Gunner B.J. Andersson. Andersson studied radiographic data which indicated that lumbar lordosis (proper curvature of the spine) decreased by an average of 38^{o} when sitting in an upright posture (Corlett, Wilson, Manenica 1986). Others, such as, Akerblom, Burandt, Carlsoo, Keegan, Rosemayer, Schoberth and Umezarwa all agree that the pelvis rotates backward and the lumbar spine flattens when sitting (Corlett, Wilson, Manenica 1986).

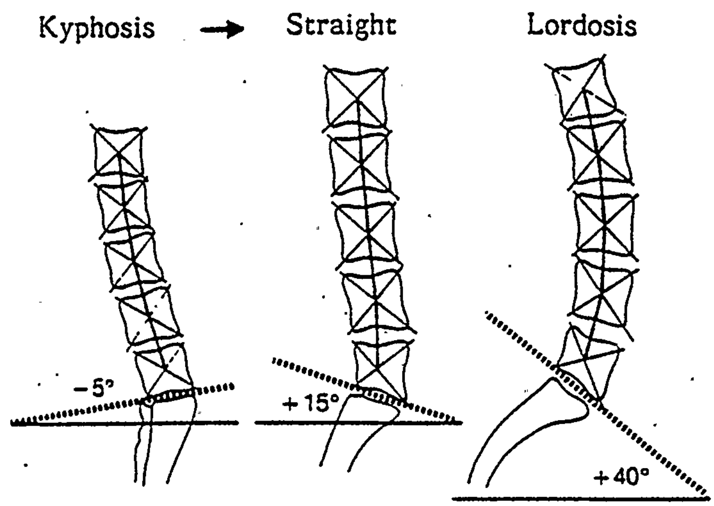


Figure #9 The Lumbar Curve

Mandal A.C., The Seated Man, p. 50, 1985.

Mandal believes that lordosis cannot be maintained because in most types of seated work the body is bent forward (Edwards June 1982). Increasing the height of the worksurface, sloping the worksurface 15°, raising the seat height 20 cm and sloping the seat 15° reduces the flexion of the back (Corlett, Wilson, Manenica 1986). This was demonstrated in an experiment conducted by Mandal in which a seated person read at a desk. The chair had a 5° backward sloped seat, and a horizontal table height of 72 cm. The experiment continued with table heights of 82cm and 92cm, each sloping 15°. The seats also increased in height to 53 and 63 cm, each sloping 15° forward. By doing this Mandal claims that flexion of the lumbar decreased by 17° when increasing to a table height of 82 cm. In addition to this the hip flexion decreased by 7^{o} (Mandal 1985).

Tom Bendix, who has studied seated postures in relation to Mandal theories, has also found that lumbar lordosis is increased as seat inclination increases. But a seat inclination of 15^{o} only decreased lumbar flexion (kyphosis) by 4^{o} (Scandinavian Journal of Rehabilitation Medicine vl. 15 1983). Bendix, in another article called "Chair and Table Adjustments for Seated Work", found that the lumbar curve changed towards lordosis with increased height and forward inclination of the seating device. It was his conclusion that lordosis is best achieved by having a desk at a 45^{o} angle, with a table height 4-6 cm above elbow level (Corlett, Wilson, and Manenica 1986). This is inconsistent with Mandal's findings. It should be noted that "varying the seat inclination and height, at identical seat-to-table height differences, do not influence the position of the head and cervical spine."[14] This issue is not addressed by Mandal. Figure 10 demonstrates the above quote.

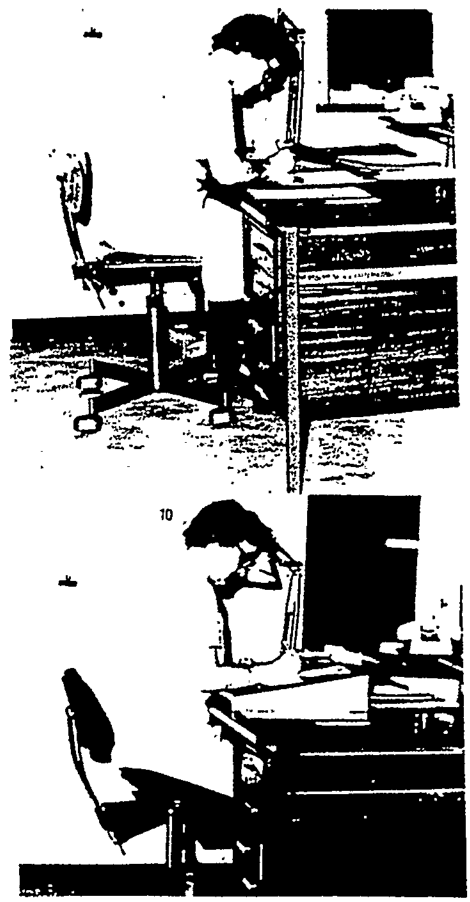


Figure #10 Head Posture

Mandal A.C., The Seated Man, p. 39, 1985.

Discrepancies in conclusions between Bendix and his colleagues, and Mandal's followers are listed below.

- Bendix recommends a desk slope of 35-45°.
  Mandal believes 15° is suitable.
- Bendix recommends a seat height of 3-5 cm above the popliteal while Mandal recommends 10-20 cm above the popliteal.
- Bendix recommends a forward seat slope of 5°.
  Mandal recommends a forward seat slope of 15°.

A decision regarding which seated posture is best suited for an elementary student is premature at this point because the right angled posture should be discussed.

b. The ideal right-angled seated posture can be described as arising from a horizontal or slightly negative sloping chair, the back supported with a lumbar support, feet flat on the floor or footrest, and a backrest inclination between 90-110^{o}.

This posture, or seated position, is based on 4 factors:

i. The body weight is distributed over the seat surface- main weight borne by ischial tuberosities.

ii. No substantial pressure exerted on the bottom of the thighs.

iii. The lumbar portion of the back needs support if static contractions of trunk muscles are to be minimized.

iv. An opportunity is available for postural changes.

Number one and two above "dictates an approximately horizontal position of the thighs and a further requirement is that the feet shall be capable of being placed fully on the floor."[15] It has been proven (Bendix & Biering Sorenson 1983, Bendix 1986, Anon 1976, Drury &

Francher 1985, Andersson 1986, Bendix & Hagberg 1984) that a lumbar support maintains lumbar lordosis. The opportunity to make postural changes allows muscles to act as a blood circulation pump (Grandjean 1987). With proper work and seat surface adjustment this type of seated posture can maintain lumbar lordosis, minimize strain on the cervical spine, and allow for postural changes.

3.2.2 The Office Work Station

A discussion of ergonomics in the office will aid the final design of the work station for school students because the following similarities exist:

- The use of computer technology
- Seated working position
- Ergonomic similarities
    - reach
    - clearance
    - viewing angles
    - near point
    - posture
- Anatomically, childrens' bodies react the same as adults, except muscles tire more quickly with children.

- Environmental constraints
  - noise
  - lighting
  - temperature
  - color

Research into the office working environment illustrates that there are many areas of concern regarding the well-being of the worker. The following issues will be considered.

1. Backrest Research and the Office

Research done by Bendix, Grandjean, Burandt, and Kleeman demonstrates that an upright or right-angled posture is suitable for an office working environment. Observations of office employees performing tasks such as reading, writing, and typing can give some clues to how similar problems can be solved in a school environment. Burandt and Grandjean found that 42% of office employees leaned against a backrest while working (Zacharchow 1988). A survey done by Kleeman of air traffic controllers found that:

15.1% always used the backrest

36.8% use the backrest more than half the time

30.4% use the backrest approximately half the time (Zacharkow 1988)

What these two observations demonstrate is that employees do use a backrest while in a seated position. If the observation had shown that the employees sat on the edge of their seat, or tilted forward on their chair, these would give support to Mandal's forward inclined sitting posture. Historically, individuals have been taught to 'sit up straight'. This could have influenced Burandt and Grandjean, and Kleemans' observations. This means that Mandal's position cannot be determined as a totally inappropriate seated position.

In addition to finding that a backrest was used, a backrest as high as the shoulders was preferred by air traffic controllers. These findings are supported by a 1977 study done by Grandjean and Hunting (Grandjean and Hunting 1977).

2. Decreasing disc pressure

A high backrest allows the worker to lean back and stretch. From a medical point of view "an occasional change of posture from bent to erect or from leaning back to an upright position and vice versa must be beneficial".[16] It is beneficial because when disc pressure is reduced and increased the intervertibal discs are nourished with blood due to the resulting "pumping" action (Grandjean 1987).

Upon analysis of backrest and disc pressure research two important points are to be recognized;

a. Evidence that workers in seated positions use a backrest lends support to the conclusion that an upright posture is one position that appears to be suitable for tasks which require writing, reading, and typing.

b. Research demonstrates that a high backrest is needed to allow employees to lean back.

Two other points should also be mentioned as contributing factors in reducing disc pressure;

c. Increasing seat angle reduces disc load (Grandjean 1987). Andersson and Ortergren measured the static load of the disc by observing electrical activity." The results reveal that leaning back as well as bending forward with supported upper limbs (writing posture) are favorable conditions for the disc pressure."[17]

d. A proper lumbar support also decreases disc pressure (Grandjean 1987).

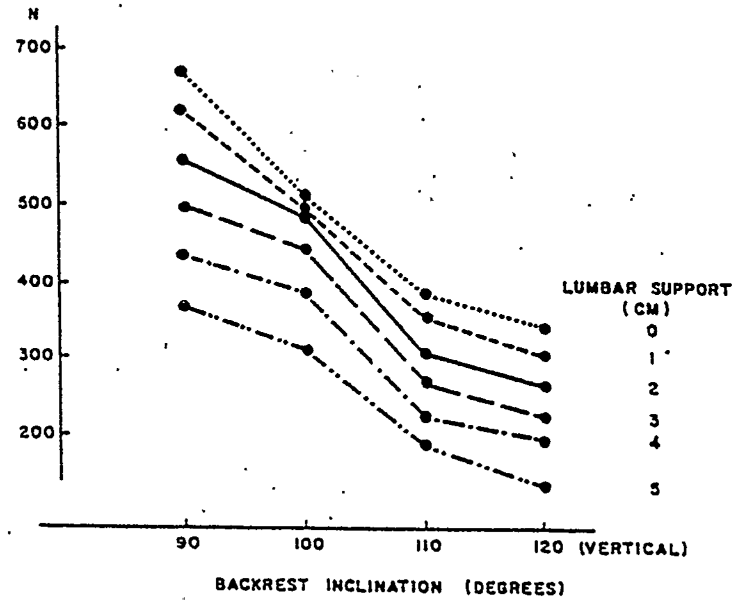


Figure #11 Lumbar Support & Backrest Angle

Grandjean Etienne, Ergonomics in Computerized Offices, p. 126, 1987

The above diagram illustrates that if the distance between the front of the lumbar support and the plane of the backrest is increased and the backrest inclination is increased then disc pressure is decreased.

3. The Stooping Posture

Mandal, as mentioned before, advocates a forward sloping seat. It is generally agreed that a forward sloping seat will reduce kyphosis to some degree. But criticism of the forward sloping seat is also evident. A constant effort is required not to slide off of the chair.

Discomfort arising from the drag on clothing, the inability to move into different postures, increased pressure on feet, and amount of pressure on the backrest are all factors which must be considered when designing a seating device (Zacharkow 1988).

A chair without a backrest, and the addition of a kneeling pad to keep the buttocks from sliding forward is another style of chair based on the forward sloping seated position.

Figure #12 Kneeling Chair

Zacharkow p. 214 1988.

Disadvantages of the kneeling chair are as follows:

a. sitting is limited to forward leaning and upright posture.
b. constant pressure on the shins.
c. feet are cramped.
d. discomfort in knees (Zacharkow 1988).

Drury and Francher (1985) reported that there was great discomfort involving the legs and knees while using this style of chair. This extensive study including the kneeling chair also indicated that terminal group users (seated for 2.5 hrs) showed great discomfort. Typists found the chair to be unsuitable due to the difficulties getting in and out easily and the lack of chair swivel (Zacharkow 1988).

The above evidence indicates that a right-angled or upright posture is an appropriate position for seated work. Design considerations for this type of chair are as follows:

a. Chair should support lumbar spine from the backrest in both a forward and backward sitting posture.
b. Backrest should have an adjustable inclination.
c. A high backrest should be used.
d. Backrest should have lumbar support.
e. Seat should fit the user anthropometrically.

4. Other factors affecting Seated Posture

a. Use of a VDT(Video Display Terminal)

"The most frequent musculoskeletal complaints of VDT operators have been found to involve the neck, neck-shoulder region, and the back."[18] It is important to note that these complaints are from those who are in ergonomically poor work settings. Non-detachable keyboards, bent head posture, lack of wrist, arm, and back support are all contributing factors to musculoskeletal complaints. "Several studies have already demonstrated a reduction in musculoskeletal complaints or stress, along with an increase in productivity, as a result of a properly designed workstation."[19]

The use of a visual screen will determine the visual demands of the work station. Computer use may be classified three ways.

i. Data entry
ii. Data acquisition
iii. Dialogue

i. With data entry tasks the main job is to enter information into the computer. The operator will look at the 'source documents' more often than the computer screen. This means that the computer screen should be off to one side with the source documents in direct view of the operator.

ii. Data acquisition tasks make the operator look at the screen more than any other source. Therefore, the screen should be directly in front of the user or be in the direct line of sight.

iii. A dialogue with the computer implies that the operators will alternate between looking at the computer screen and source documents.

Depending on the task, the operators head and neck posture will be determined by the location of the computer screen and source documents. Poor ergonomic placement of the screen and source documents will result in a forward inclination of the head resulting in neck pain, headache and even low back pain (Zacharkow 1988).

Other Causes of Poor Head Posture

- Non-Detachable keyboard.
- No document holder.
- Lack of Arm Support.

A Non-detachable keyboard- The inability of the operator to move or adjust the keyboard height independently of the screen height may result in the need for an increased viewing angle (Zacharkow 1988). Most authors believe that a head angle of 15 degrees is an acceptable viewing angle (Grandjean 1987).

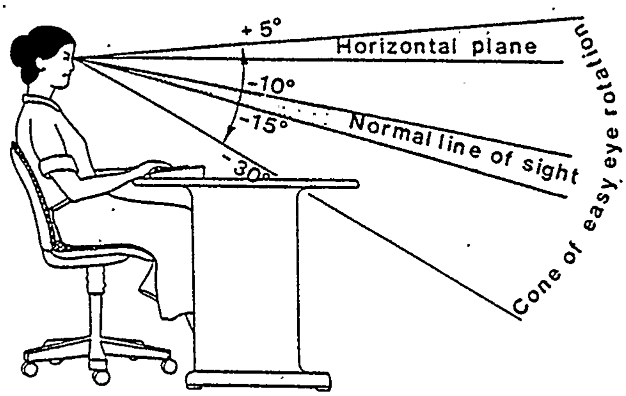


Figure #13 Viewing Angles

Grandjean Etienne, Ergonomics in Computerized Offices, p. 128, 1987.

An assessment of the 'normal line of sight', the combination of eye movement and head and neck posture indicates that eye movement 15° above and below the normal line of sight is acceptable (Grandjean 1987). A display or other visual target should be "placed within a viewing angle of 5° above and 30° below the horizontal plane."[20]

No document holder - If a VDT is used, a document holder should be used in conjunction with it. The placement of the document holder is based upon the tasks of the operator. "Having source documents lying flat on the desk rather than on an adjustable, inclined document holder can be one of the greatest sources of musculoskeletal stress for VDT operators, typists and other office machine operators."[21] By viewing documents on the writing surface the viewing angle is greater than the operator can sustain comfortably. Bendix and Hagberg (1984) and Bendix (1986) found that strain on the cervical spine was reduced as desk slope is increased. Sloping a worksurface is equivalent to having a document holder. A document holder allows an operator to sit up straight to see source documents thereby also reducing strain on the lumbar area. Bendix and Hagberg (1984) also found that it was more "acceptable" for people to use a sloped working surface for reading and a horizontal desk for writing. This means that a document holder should be supplanted by a horizontal writing surface if the task warrants this situation. When used for writing a sloped work surface beyond 10° results in papers and pencils sliding off the worksurface. If writing is part of a VDT work station then a horizontal worksurface is preferred.

Lack of Arm Support - When using a keyboard, the arms and hands should be supported.

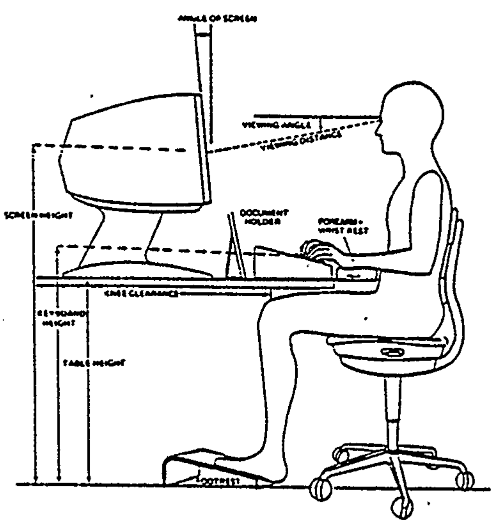


Figure #14 Arm Support

Zacharkow Dennis, Posture, p. 178, 1988.

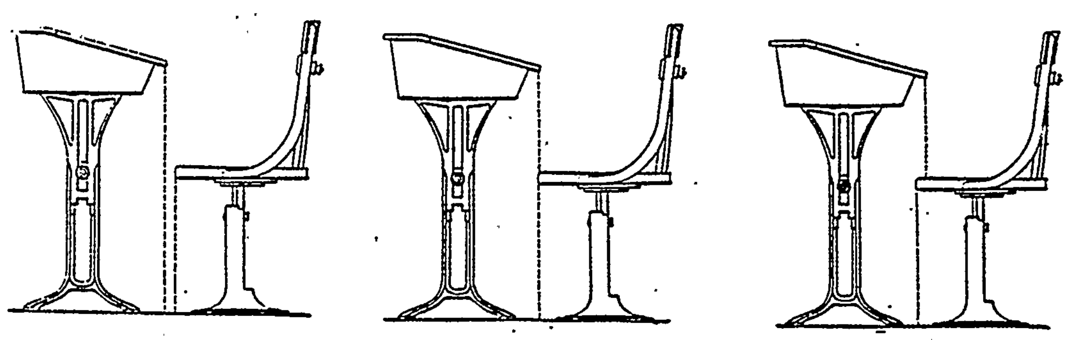
Transmission of the weight of the arms to the posterior neck and shoulder musculature will occur if arm support is not used while using a keyboard. The arm support induces a backward leaning trunk posture, thus the operator can receive support from the backrest (Zacharkow 1988).

b. Worksurface height and angle

Improper worksurface height can lead to many postural problems. If the worksurface height is too high then the shoulders or arms will be raised in order to compensate. This may lead to pain in the neck and shoulders (Grandjean 1987). If a work height is too low, a stooping posture may result because the worker cannot see, or properly reach, the worksurface. This will cause kyphosis.

c. Horizontal distance from the worksurface

Kyphosis is also caused by improper horizontal distance from the worksurface to the seat.



Positive Distance Zero Distance Negative Distance

Figure #15 Distance

Zacharkow Dennis, Posture, p. 132-133, 1988.

Illustrated above is the difference in distance from the seat edge to the worksurface edge. The inability of the worker to get close to the work surface will result in kyphosis of the spine. If the chair is too far away from the work surface then the worker will not be able to reach or see his/her work.

d. Keyboard posture

The addition of a computer to the classroom presents the designer of a work station with more variables than those discussed in the previous section. A position of keeping the arms at the same angle as the keyboard and leaning backwards (driver position) is a new concept. This concept contrasts the viewpoint that the trunk should maintain a vertical position while the forearms remain in a horizontal posture. The keyboard for this working posture should be as thin as possible and be sloped no more than 5^{o} (Zacharkow 1988). Observed postures of VDT operators reveals that operators prefer to lean back in their chairs with the shoulders flexed from 0 to 30^{o} and the forearms are elevated from 5 to 30^{o} (Zacharkow 1988). It must be noted that this posture was observed in those who work for long periods of time at a VDT station. The diagram below demonstrates this position.

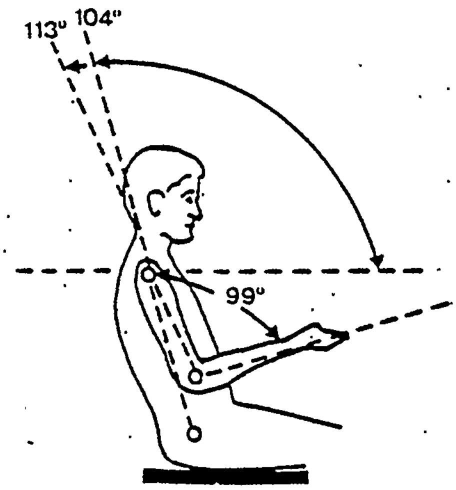


Figure #16 VDT Operators' Posture

Zacharkow Dennis, Posture, p. 190, 1988.

In the above diagram the keyboard slope would correspond to the arm angle that the user prefers to maintain by adjusting the worksurface and by tilting the chair backwards. Support is crucial if the forearms are elevated. If no support is available the operator will lean forward to reduce torque on the shoulder joints resulting in kyphosis (Zacharkow 1988). "One restriction must be made here: some special work situations (such as manual work requiring freedom of movement or physical effort) might call for an upright trunk position with elbows down and forearms horizontal."[22] If a person sits continuously in front of a screen performing data acquisition or data entry tasks then the backward leaning (driving) posture would be preferable to the upright posture.

3.2.3 The School Work Station

Most often it is in school where permanent habits of posture and sitting are formed. If problems of posture are not corrected or addressed early in life they may become counter productive in later years.

There is evidence that approximately 23% of elementary school students (ages 6-12) have low back pain and approximately 20% have neck pain (Zacharkow 1988). These percentages closely correspond to adult figures. A study by Grandjean and Burandt (1962) showed the incidence of body pain was prominent in the neck, shoulders and back, and the knees and feet (Grandjean 1987). The diagram below shows the results.

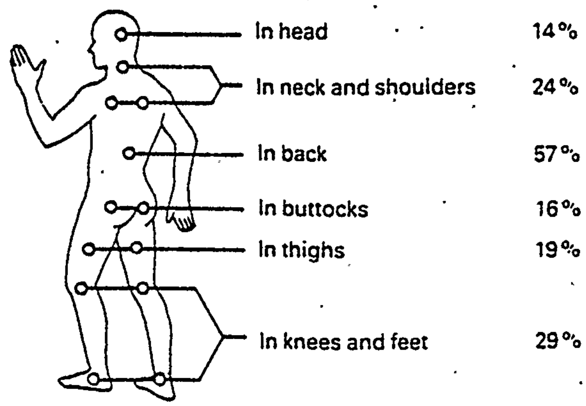


Figure #17 Incidence of Bodily Aches

Grandjean Etienne, Ergonomics in Computerized Offices, p. 103, 1987.

Studies of children's postures are scarce. Mandal (1985), however, has observed children and subsequently made recommendations for a new style of chair and desk. Mandal has observed students in exam settings only, where students tend to stoop over his/her work. In addition to this the students are seated in desks that do not 'fit' them. Karvonen, Koskela and Noro (1952) observed postures of 100 students during three theoretical subjects, one exam and one health education subject. A theoretical subject combines reading, writing, and listening. An exam only addresses writing.

The health education class could involve reading and a discussion. The results of the observation are as follows:

1. A backrest is used for about 50% of the time.
2. A stooping posture is most popular.
3. Posture during theoretical subjects is twisted.
4. During an exam a straight body position is common.
5. Leg position varies-no regularity.
6. Students often lean on their forearms or on one forearm during theoretical subjects but less often during exams.
7. The shoulder of the writing hand is raised.

Comparing these results to the sitting position of office employees reveals many similarities. Grandjean reports that adults used a backrest 42% of the time. Karvonen, Koskela and Noro (1952) reported that children used a backrest approximately 50%. Adults lean on the worksurface for support 40% of the time; children just over half of the time. These comparisons indicate that similarities exist between adult and student sitting postures. Video analysis of childrens' postures was done by Armbruster (1989) to confirm the above results.

3.3 Video Taped Analysis

3.3.1 Problem

The role of the video analysis was to help confirm problems discovered while performing interviews with children and reviewing questionnaires from teachers. It was also used to discover other problems not addressed or established by students and teachers. The problems discovered during the interviews and questionnaires were the following:

1. comfort
2. storage/organization of materials
3. sizing or dimensional fit
4. mobility/moving desks into communal spaces
5. posture
6. safety

The video analysis confirmed that most of these problems existed. One problem that was not discovered through interviews and questionnaires, was related to worksurface size.

3.3.2 Definitions

1. Comfort represents any pain or discomfort the students may have had using his/her desk.

2. Storage is the facility that the student places his/her books and other related articles.

3. Sizing or dimensional fit refers to whether the physical size of the desk is suitable for the student. Suitable in this case refers to the <u>individuality</u> of the desk or work station.

4. Mobility is the ability of the teacher and or students to move the desks into communal workspaces.

5. An upright posture was considered to be the preferred posture. Results from the video taped analysis are based on this assumption.

6. Safety is a concern with fire hazards and general factors of the product, like rounded corners and edges.

7. Worksurface size is the physical configurations of the desk top. In the study the worksurface tops were 18" X 24".

3.3.3 Procedure

Video Analysis of seven Grade 6 students was done in December of 1989. Approximately 90 minutes of video tape was taken. Three subjects including journal writing, talk time, and math were observed, each for 10 minutes. It should be noted that the students were seated around the perimeters of the classroom in a "U" shape.

3.3.4 Limitations

There were many difficulties with the video observation such as:

1. Angle at which the camera faced the students.
2. Impossibility of recording every posture change done by the students.
3. Distinguishing whether a student did not move or change a posture because he or she was comfortable or uncomfortable.
4. The amount of different postures the students illustrated was underestimated.

To address the above problems the following actions were taken.

1. Because the angle of the camera did not allow the clear observation of the back or backrest of every student, especially those that faced the camera, extreme postures were observed. For example it was difficult to see whether a student was using his or her backrest properly. An extreme bending of the back was recorded as a 'bent' posture while a less severe bending of the back was recorded as a 'slumping' posture. This same problem occurred with recording leg position. Viewing angles made it difficult to see whether a leg was at 90^{o} or bent slightly in a different angle.

2. Some students moved multiple parts of his/her body at the same time making it very difficult to record these changes. Therefore the 10 minute time intervals were divided into 5 second intervals. At the end of every 5 seconds the camera was stopped and the child was observed to see whether his or her posture had changed. There was the possibility that a student moved many times during a 5 second span and then returned to the same posture of the previous 5 second recording.

3. Every child's movements were different therefore it would be necessary to observe this issue in a separate analysis.

4. The amount of different postures that the students assume are impossible to imagine. Therefore if a student did not assume a position that was on the recording table, his/her posture was written down in the appropriate time slot.

3.3.5 Data and Findings

1. Comfort - Several times during the video observation students could not keep his/her knees bent at a 90^{o} angle because the desk was too small. Their knees rubbed under the storage device. The implication of this is that a more suitable location for storage should be found.

2. Storage - The storage problem was confirmed not only with the above information but also with two general postures or positions which students assumed while looking into his/her desk.

a. The child would kneel down on the floor and look into the storage device.

b. When the child looked in the desk he/she generally slouched by leaning back against the backrest, the buttock moved forward, the back and head were twisted and the legs moved forward.

The video analysis has proven that the storage, under the writing surface, is in an unacceptable location.

3. Sizing or dimensional fit - In general, when students could not bend his/her legs at a 90° angle, this was taken as a sign that his/her desk was undersized. Four out of the seven students observed had this problem. In addition students had difficulty just getting in and out of the desk. All students stooped over his/her work lending evidence to the fact that a sizing problem is prevalent. There is also the possibility that some of the students needed glasses.

4. Mobility - Teachers move the desks into many configurations. Often students do not move the desks,

instead using a different writing surface such as a table. There is simply not enough room for all students to do this, thus movement of desks may be necessary.

Mobility of the desk was not a confirmed problem. It was noticed that in a "U" shape it was very difficult for the students to move freely within the desk.

5. Posture - This was the most obvious problem. Children very rarely used his/her backrest (see 3.3.6 for explanation).

Ideally the backrest and writing surface should be used in conjunction with each other. This did not happen thus causing the students to stoop, sit on the edge of the seat, and or place themselves in awkward positions.

6. Safety - Accidents did not occurr during the video observations. General issues like bumping arms, knees and legs occurred, but nothing which constituted a safety problem.

7. Worksurface Size - During math it was noticed that the students did not have enough room for books. This is clearly illustrated by the students having to stack books on top of each other to make room. In addition to this, books and papers intruded onto other students'

workspace. Physical intrusion (elbow overlapping) also occurred during the three subjects (journal, talk time, math).

3.3.6 Numerical Summary of Findings
(averages over 10 minute periods)

	Journals	Talk time	Math
Unsupported back posture	73%	90%	94%
Back posture changes	28	33	28
Head movement changes	16	17	21
Arm posture changes	6	11	12
Leg posture changes	6	7	7

Back posture changes			
undersized desk	18	18	23
appropriate size	13	16	18.5
Arm posture changes			
undersized desk	6	11	12.5
appropriate size	7	11	12
Leg posture changes			
undersized desk	7	9.5	8
appropriate size	4	4	5

The results illustrate general trends in the classroom. One can say that unsupported posture is a problem because of the high percentages. If a student changed posture more often for one subject as compared to another this did not necessarily mean that the child was uncomfortable as a result of the work station. Perhaps it meant that the child participated in class discussions more than others. To achieve a better understanding of the results more detailed explanations follow.

3.3.7 Video Taped Results and Explanations

UNSUPPORTED BACK

	JOURNALS	TALK TIME	MATH
CHILD 1.	63%	100%	100%
2.	52%	69%	99%
3.	55%	87%	100%
4.	83%	93%	99%
5.	86%	96%	95%
6.	89%	88%	88%
7.	85%	96%	80%
AVERAGE	73%	90%	94%

A possible explanation why the students used backrests more during journal time was because they had to think about what they did over the weekend. They would lean back (supported) then move forward (stoop) to write about what they did.

The most popular resting position for the students was putting their arms on the desk and leaning forward. This was considered to be an unsupported posture because of the strain on the shoulders and on the back as a result of not being able to use the seat and desk together.

CHANGES IN BACK POSTURE OVER THE 10 MINUTE INTERVAL JOURNAL (this does not include legs, arms, and head)

	FIRST 5 MINUTES	SECOND 5 MINUTES
1.	19	10
2.	25	23
3.	33	19
4.	32	40
5.	36	28
6.	41	24
7.	35	27
AVERAGE	32	24

TALK TIME

	FIRST 5 MINUTES	SECOND 5 MINUTES
1.	16	19
2.	45	22
3.	33	52
4.	46	19
5.	36	28
6.	32	47
7.	36	28
AVERAGE	35	31

MATH

	FIRST 5 MINUTES	SECOND 5 MINUTES
1.	25	19
2.	23	32
3.	20	28
4.	20	45
5.	20	23
6.	29	26
7.	47	39
AVERAGE	26	30

There are no major differences between the subjects. The averages for journal writing are different because journal writing was the first subject of the day and the students were excitable. The averages for math are reversed as compared to journal and talk time because the children had to listen to the teacher explain a technique first, then questions were asked, thus causing more movement in the second half of the analysis.

HEAD MOVEMENT CHANGES DURING THE 10 MINUTE INTERVAL

JOURNAL

	FIRST 5 MINUTES	SECOND 5 MINUTES
1.	10	5
2.	22	15
3.	20	22
4.	15	16
5.	12	10
6.	22	18
7.	18	21
AVERAGE	17	15

TALK TIME

	FIRST 5 MINUTES	SECOND 5 MINUTES
1.	14	13
2.	21	23
3.	17	24
4.	17	5
5.	14	12
6.	21	13
7.	29	18
AVERAGE	19	15

MATH

	FIRST 5 MINUTES	SECOND 5 MINUTES
1.	11	22
2.	10	20
3.	15	18
4.	27	21
5.	22	23
6.	21	23
7.	32	27
AVERAGE	20	22

These results are very consistent. The students would randomly move his/her head. A fixed pattern was not noticed.

ARM POSTURE CHANGES DURING THE 10 MINUTE INTERVAL

JOURNAL

	FIRST 5 MINUTES	SECOND 5 MINUTES
1.	7	4
2.	5	5
3.	13	9
4.	4	6
5.	7	1
6.	14	2
7.	7	4
AVERAGE	8	4.5

TALK TIME

	FIRST 5 MINUTES	SECOND 5 MINUTES
1.	7	9
2.	19	8
3.	13	22
4.	10	3
5.	6	8
6.	13	19
7.	5	9
AVERAGE	10.5	11

MATH

	FIRST 5 MINUTES	SECOND 5 MINUTES
1.	18	9
2.	15	18
3.	13	17
4.	00	12
5.	8	5
6.	15	8
7.	18	14
AVERAGE	12.5	12

Arm posture changes were greater for talk time and math because during talk time the students would raise an arm to be noticed so they had a chance to talk. This could occur several times with one student. During math students had to ask questions therefore more arm movement was prevalent.

LEG POSTURE CHANGES DURING THE 10 MINUTE INTERVAL

JOURNAL

	FIRST 5 MINUTES	SECOND 5 MINUTES
1.	4	4
2.	7	5
3.	4	2
4.	10	15
5.	6	3
6.	1	3
7.	9	6
AVERAGE	6	6

TALK TIME

	FIRST 5 MINUTES	SECOND 5 MINUTES
1.	0	0
2.	7	7
3.	3	8
4.	18	8
5.	7	6
6.	6	9
7.	11	10
AVERAGE	7.5	7

MATH

	FIRST 5 MINUTES	SECOND 5 MINUTES
1.	4	4
2.	4	7
3.	4	6
4.	4	20
5.	8	6
6.	3	9
7.	8	12
AVERAGE	5	9

These results are very consistent and suggests that the students assumed consistently different leg postures. Generally students had a leg position that they would try to maintain. They would divert from this position many times but return to it in a short period of time.

UNCOMFORTABLE OR COMFORTABLE?

To help determine whether student's posture changes were a result of being uncomfortable or comfortable the video was observed to determine which students had a desk that was too small. In this particular class it was concluded that #2, #4, #6, and #7 all had desks that were undersized. The number of posture changes for the above categories were averaged for the undersized and proper sized desks. The results are as follows:

Back movement changes

(not including head,arms,and legs)

	Journal	Talk time	Math
Undersized	31	34	33
Proper sized	24	31	22.5

Head movement changes

Undersized	18	18	23
Proper sized	13	16	18.5

Arm movement changes

Undersized	6	11	12.5
Proper sized	7	11	12

Leg movement changes

Undersized	7	9.5	8
Proper sized	4	4	5

On average posture changes for students which had undersized desks (2,4,6,7) were greater than those which had desks which seemed to 'fit' the student.

3.4 Ergonomic Needs Analysis

3.4.1 Teacher Questionnaire and Student Interview

1. Objectives

General - To obtain information about school desks which may aid in the design of a new work station.

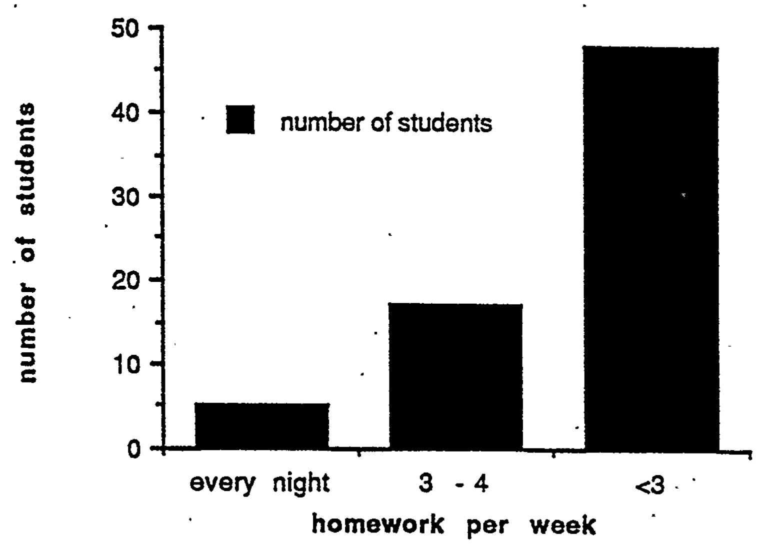
Specific - To obtain information regarding the students' tasks, attitudes of the student and teacher towards existing desks, and uses of the desks. This will help identify potential problems, develop constraints and to collect criteria pertinent to the future design. The information obtained will also give the designer an idea about how the teachers' attitudes differ, if at all, from the students'.

3.4.2 Results - Student Interview

The students interviewed were in grades 4,5, and 6. They use desks more than lower grades and could best respond to my questions. In total there were 71 students interviewed; 37 boys and 34 girls.

I will now briefly discuss each question and the relevance of it as it relates to the design of a new school work station.

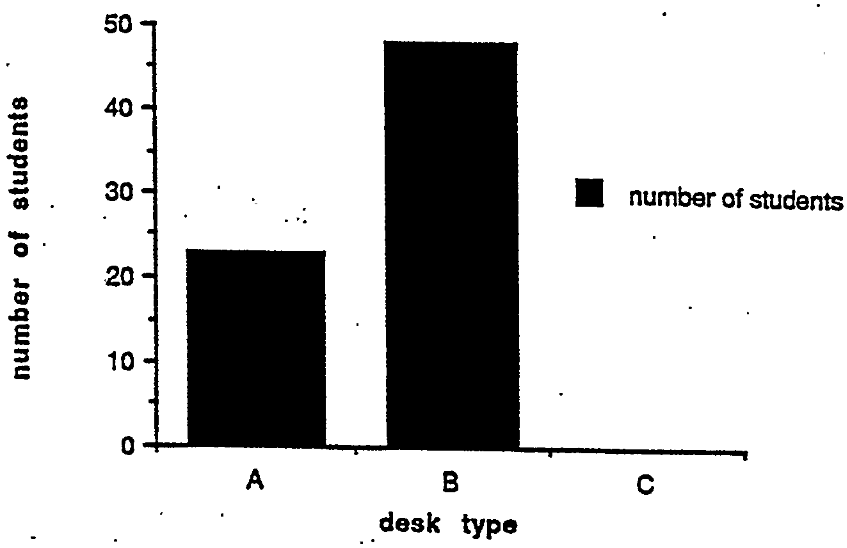
Question 1. This question, "how many times a week do you have homework?", was placed in the questionnaire to get the child thinking about how many books he/ she had. It also gave an indication of how important it may be to have adequate and suitable storage space.



Graph #5 Homework per Week

From the above graph one can see that most of the students have homework less that three times a week.

Question 2. At the school which I performed the interview most children had a desk that had a chair connected to it. It should be noted that some of the desks had baskets under the seat.



Graph #6 Desk Type

Each desk had a table top and chair. 'A' and 'B' had a connected chair where 'C' did not. Storage was under the seat for 'A' and under the top for 'B'.A relatively good cross-section of desk type is evident. This allows one to look at the problems of one desk as compared to another.

Question 3. An inventory of what the children stored in his/her desk was taken. On average children had the following articles in his/her desk.

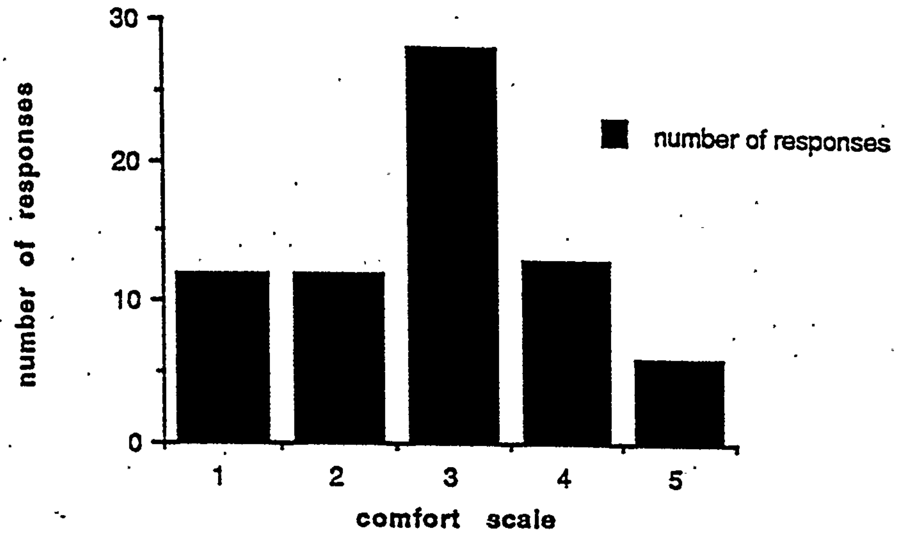
	responses	average / child	maximum
text books	75	2	5
booklets	63	4	7
binders	42	1	no grade 4
duotang	8	2	
note pad	20	1	3
eraser	69	2	11
scissor	7		
pencil	71	2	10
pen	35	2-3	12
crayons	49		
toys	7		
comb or brush	11		
calculator	4		
money	22		
glue	12		
dictionary	6		
glasses	5		
shoes	66		
tissues	8		
knap sack	37		

A considerable amount of storage is needed by the student. There should be room for text books, writing booklets, a binder, erasers, pencils, pens, and crayons. All students needed a separate pair of "indoor" shoes.

When not in use they were either placed near the coat rack, on the seat, under the seat, or on top of the desk. There is evidence that a student needs a place for shoes. Out of the 71 children interviewed, 37 hadk knap sacks. These were usually located with the coats or hung on the back of the chair. Again there is evidence that a student could perhaps utilize a place to hang a knap sack at his/her desk.

Question 4. Responses to this question varied. Most the students either painted in groups, on the desks, floor, or on a table. The existence of group work could be the biggest deterrent in making sloped writing surfaces because they are not adaptable for group work. It is therefore necessary to recognize the need to group the desks.

Question 5. A rating scale (1-5 where 5 was most comfortable) was used to achieve some idea of how comfortable the students thought his/her chair was. The results are as follows:



Graph #7 Comfort Rating

Children felt discomfort with his/her chair. Seventy two percent either were indifferent or felt that the chair was uncomfortable. Reasons for this discomfort will be discussed in greater detail in the next two questions.

Question 6. From the results given by the students it is apparent that there were four areas which could best be described as the problems. They are listed below.

Storage problems	**17**
difficult to open top	
more storage	
tray instead of box	
stopper for tray	
get rid of tray	
Comfort	**26**
separate desk and chair	
cushion seat	
curved back on chair	
arm rests	
straighten backrest	
tilting backrest	
Fit	**13**
bigger size	
smaller size	
box too close to body	
spinning seat	
Writing surface	**3**
horizontal top	
vandal proof top	
bigger writing surface	

Out of the 59 responses 44 percent expressed comfort problems. This figure is similar to the percentage given in question 5. It is evident that the students wish to be more comfortable. This problem cannot be solved by just cushioning the seat, but by taking into account other major problems. For instance, if a child hit his/her knees on the storage tray then this presents two problems. Is the storage in an appropriate location or should the desk be made bigger to better 'fit' the student? Each of these above problems affects the other to some degree, but for the designer it clearly shows that problems are evident concerning comfort, storage, and fit.

Question 7. This question was used to confirm some of the responses in 5 and 6. By visually showing "where they hurt when they used the desk", it helped to clarify and expand responses such as "cushion seat". The student was asked to point or put an 'X' beside the place where he/she hurt while sitting.

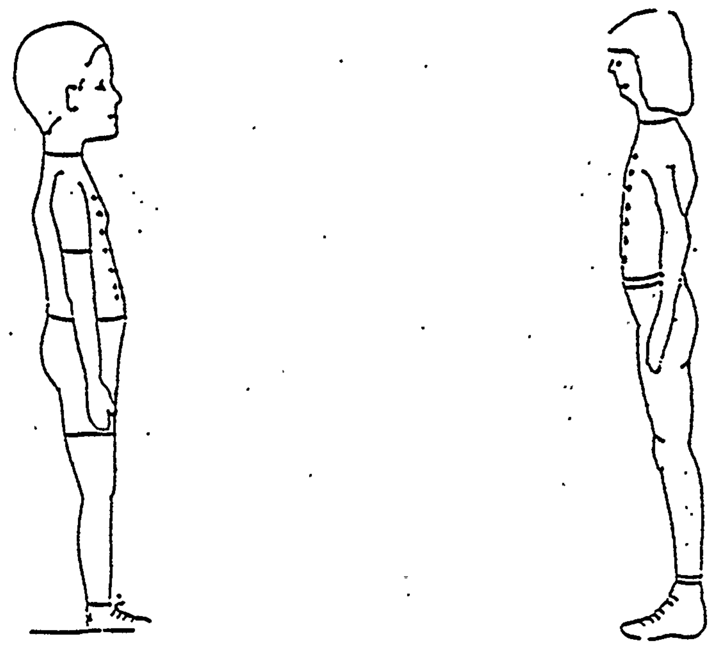


Figure #18 Models

The above pictures were used during the interview. If a child put an 'X' beside the buttocks then this confirmed a seat comfort problem. Some children responded to this question and not to the previous one. Perhaps it was easier to visually express discomfort. In contrast, children that responded to question 6 did not necessarily respond to the visual question. For instance, some students which felt the seat needed a cushion did not necessarily express a problem in question 7, the visual question. These students may have been intimidated by the question. Out of 71 interviewed only 23 did not respond.

The models or pictures shown to the students were broken down into segments making it easier to classify problems.

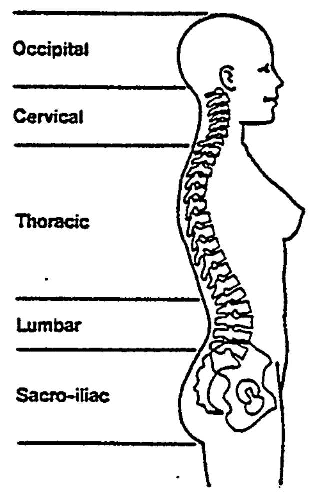


Figure #19 Vertebrae

Source: Pheasant 1986 p. 123

The results of those who answered question 7 are as follows:

back	18
buttock	12
top of knee	6
behind knee	5
neck	4
chest	2
wrist	1
outside of thigh	1
top of thigh	1
back of thigh	1
heel	1
calf	1

Based on these results the following generalizations can be made:

1. Back problems could be caused by poor posture or improper size (fit) of desk.

2. Buttock problems can be attributed to lack of comfort (cushion) or improper fit.

3. Top of knee problems indicate that the desk may be too small. Thus when a child sits in his/her desk his/her knees hit under the storage tray.

4. Behind the knee complaints are due to a seat depth which is too large. The edge of the seat is cutting into the back of the student's knee.
5. Neck problems could be attributed to posture. The near point (distance to the work surface from the eyes) is an inadequate distance thus making the child stoop the neck to properly see the material on the desk.
6. The rest of the problems are either very child specific or their numbers do not allow for a generalization.

A generalization can be made confirming problems indicated in earlier questions. Comfort and sizing (fit) are major problems which should be addressed in any future design of a work station.

Question 8. This was included to determine whether children sat in certain positions. Position A was the physically best posture. Only 17 children indicated that he/she ever sat in this position. Posture two, the most common seated position (59) is the stooped position. A prevalence of this position solidifies that postural problems occur, that sizing may be an issue, and current child desk design is in question. The third position, perhaps a product of boredom, is the slouch position. Sizing of the desk may also be a problem because the child slouches to try and obtain a 45^{o} reading angle.

Thirty seven children indicated that he/she has sat in this position. It should be noted that if a child indicated that he/she did not sit in a certain position, the reason why, was not asked by the interviewer. It was felt that only an indication was needed.

3.4.3 Results - Teacher Questionnaire

Questionnaires regarding the students' desk, were given to nine grade 4, 5, or 6 teachers. These teachers are seen as experts, therefore a large sample of teachers is not needed. On average the teachers had 11 years experience at various grade levels, the lowest being 2 years and the maximum being 20 years. On average, the teachers had 26 students in their class, 18 being the minimum and 30 being the maximum.

Question 1. Teachers indicated that students received homework either 3-4 times a week (4 out of 9) or less than three times a week. Because this question was used to get the teacher thinking about the students' subjects (leading question) it is only seen as an informative question.

Question 2. Most teachers indicated that their students have approximately 7-10 text, writing booklets, and binders. This figure confirmed how many books students said they had. The storage space of the future work station should accommodate at least 10 books.

Question 3. The materials listed in this matrix were surprisingly used for many other subjects than originally thought. Text books were traditionally used for language arts, math, social studies, and French. A general trend is that upper grades used more text books. Pencils and erasers were used most often. Pens are used in upper grades or in more specialized subjects such as art. Crayons, glue, scissors, and dictionaries on average were used in most subjects, depending of course on the teacher. Crayons are usually kept at the students' desk but materials such as glue, scissors, and dictionaries are usually kept in a separate common location. If students use these articles to a greater degree then it may be easier to keep them at his/her desk. There is a question as to whether storage should be made available at the desk for these materials.

Question 4. Almost all teachers indicated that if the student had school articles, such as text books, listed on the matrix, that the most common place for students to store them would be in his/her desk. This may be misleading because teachers tell their students where to keep his/her things. Because the student is storing so many different things in the desk, gives support for a storage organizer, that is a separate place for binders, text books, smaller books, and erasers, pens and pencils. Children sometimes use or store scissors, glue, paint, and crayons at their desk. These articles could have a separate storage place as well.

Question 5,6,7,&16. Most (7) of the teachers surveyed indicated that the students had a desk and separate chair. Four believed the storage to be inadequate and three believed that it was adequate. The other two teachers were split on their opinions on available storage, one being dissatisfied and one being generally satisfied. In general, storage is unsatisfactory. It could be improved. Out of nine teachers, seven expressed that if they could change one thing about the desks, it would some how be related to increasing storage, or organizing storage. Teachers and students agree that storage should be improved.

Question 16 asked whether the students' chair and desk should be attached. An advantage of a desk with a chair separate is that they are highly mobile. The students can put these desks into groups quite easily. But there are more disadvantages. Firstly, students cannot organize or keep their desks orderly(straight lines). Secondly, they are very noisy because of where the storage tray is located. The student must push the desk away from the chair to pull out the tray. Once the article is retrieved the desk is pulled towards the student making more noise. Lastly, the chairs must be placed on top of the desk in order to sweep the floor. By separating the desk and chair there are twice as many legs to sweep around. Seven teachers responded to question 16, four indicating that they thought the desk and chair should be separated and three indicated they should not. Mobility seems to be the major component of a desk that has a chair separate. Therefore in order to satisfy the teachers, a mobile school desk that has a chair connected would one solution.

Question 8. Comfort was a major problem indicated by the students. Yet teachers do not feel as strongly about this as the students. Out of nine, four teachers believed that the desks used by students were generally comfortable. It should be noted that these four all had a desk and chair separate. Three others indicated that separated units were generally uncomfortable and the last two indicated that a desk and chair connected is equally uncomfortable. What this means is that there is a trend that teachers believe that students' desks are uncomfortable but a chair and writing surface separate are more comfortable. This may in fact be true because all new desks currently being purchased by the Calgary Board of Education are separate. Also the newest seating devices are more forgiving (flexible), that is, the material is more flexible. The sturdy fiberglass seats are no longer being purchased and are slowly being replaced by a thinner more flexible plastic (Jensen 1989).

Question 9 & 10. There is evidence that the students of ages 9-13 spend approximately 60 percent of hsi/her time at a desk (OECD 1981). To confirm this figure to some degree teachers were asked "how much time does the student spend in his/her desk"?

On average 85 percent of the students' time is spent working at his/her desk. Questionnaires were purposely distributed to teachers who taught in a more traditional, structured atmosphere because these teachers and the students could give more information about desks, as they use the desks to a larger degree than that of a school which encourages "island" teaching or open classrooms. The figure of 85 percent indicates that because the students spend so much time in his/her desk that it should fit the student.

Question 10 merely asked how often children go to other classes for instruction. If this figure was high then it would be apparent that desks would be less personal and in essence more common. If students' desks were less personal this could change the appearance or function of a desk drastically. Results indicated that on average students went to other classrooms once a day. This figure is favorable, meaning that a more personal desk is appropriate.

Question 11. This question, was asked in order to obtain an idea about teachers attitudes towards the posture of students. From the three positions illustrated to the teachers, each position was chosen three times. The results indicate that teachers realize that posture is important to the student and indicated which are better for the students.

Question 12. On average, based on questionnaire results, students worked in groups 3-4 times a week and when they did, they always pushed the desks together, usually ranging in size from 2-6. Based on this information alone one might conclude that a sloped writing surface would not be a major inconvenience, but other factors such as the ability of children to organize articles on a sloped work surface may change this observation.

Question 13. Children sit on the edge of the seat usually because he/she cannot get close enough to his/her work thus facilitating a stooped position. Questionnaire results indicated that 6 teachers felt students sat in this stooped position, two did not, and one did not respond. Out of the six teachers the responses were as follows:

1. "The chair/desk combination isn't suitable for sitting further back in the chair!"
2. "To get closer to the work."
3. "Usually when individual work, high concentration times are required."
4. "Closer to writing area. More comfortable."
5. "If their chair is too high, it probably is uncomfortable on their legs."
6. "They have trouble reaching the desk (height,size) or have uncomfortable chairs."

These responses, to some degree, are correct. They illustrate that many problems exist, many of which have already been illustrated.

Question 14 & 15. These questions ask whether students stand on the seat pans, or on the writing surface of the desk. Potential hazards involving the desk is useful. A decision is needed regarding whether to make a desk support a standing individual. If, for instance, a tilting seat is incorporated into the design of the desk, then if a child stands on the seat it becomes very unstable and hazardous. This can be applied to the writing surface as well. Only two teachers believed that students stand on the seat pan. According to these nine teachers children do not stand on the writing surface. No matter what these results indicate design safety is of major concern.

The teacher questionnaire results indicate that students and teachers both believe that similar problems exist. Both teachers and students have reinforced their responses throughout the interview and questionnaire. The questionnaire and interview have proven to be reliable.

3.5 Personal Interviews - Production Technology

3.5.1 Personal Interview, Allan Trenouth - Woodsworth design

- "should have guides for personal drawer due to expansion of the wood....
- fasteners for vertical and horizontal panels are called figure 8 fasteners....
- wiring guides cannot be made out of maple wood....
- $40 per hr. charge out rate....
- maple wood is a good material but may be difficult to work with....
- 20% - 50% wastage....
- costs
  - 1 unit is $2400.00....
  - 100 units $1500.00....
  - 1000 units $800.00....
- glueing pieces is an important factor....
- one can glue with or against the wood grain....
- recommend that shelves be screwed and glued...."

3.5.2 Telephone Interview, Eric Jensen - CBE

- "repairs to furniture in 1989....
  - 180 wooden desks
  - 1457 metal desks (usually the desk box at a cost or $20)
  - 284 upohlstered chairs ($50 to repair)
  - 2404 chrome upohlstered chairs

- 219 wooden chairs
- 581 tables
- 29 couches
- 142 stools
- 20% of all repairs occur because of vandalism....
- 100,000 plastic chairs in CBE....
- 8 out of 10 are vandalized...."

3.5.3 Telephone Interview, Todd Parker - Eimco Molded Products

- "worksurface should not be made from plastic....
- material should be glass filled PP....
  - PC is too expensive....
  - PE experiences warpage....
- mold shelves directly to support.....
- tooling costs.....
  - left panel $250,000....
  - right side $300,000....
  - worksurface $80,000....
- $180 /unit based on 1000 units....
- weight is 60lbs depending on the thickness of material....
- connections made with inserts....
- limit per mold is 50,000 units/year...."

3.5.4 Telephone Interview, John Nies - Fire Prevention Officer

- "the classroom is called a rated assembly....
- the classroom should contain any fire....
- there are no regulations regarding furniture....
- non burning furniture is preferable....
- plastics are being used already...."

3.5.5 Telephone Interview, Andy Grimson - G. E. Plastics

- "recommend injection molding....
- Xenoy alloy....
  - polyester / polycarbonate....
  - better abrasion resistance....
- ribs can be slots or grooves....
- ribs be at most 50 - 60% of wall thickness....
- blow molding has too much trim...."

3.5.6 Telephone Interview, Mark Nicholas - D&M Plastics

- "rotational molding not suited but could be done....
- molding flat panel done with double molds and then cut in half....
- surface quality is suspect...
- fit is not easily predictable because of shrinkage....
- mold inserts cannot be used because the surface distorts around the inserts....
- multiple molds needed for production....

- rotational molding tooling costs are approximately $10,000-$20,000 for entire form....
- 25 units per day based on 10-12 cycles a day...."

3.5.7 Personal Interview, Geoff Shorten - Amptech

- "injection molding....
  - assembly advantage....
  - use a polycarbonate....
  - injection mold costs totalling $500,000+....
  - shelves may be done this way....

- RIM....
  - a lot of trim....
  - thermoset urethane....
  - must paint afterwards....
  - long cycle time....
  - no hardness of skin....
  - parts may be too flexible....

- Blow molding....
  - supports may be done this way....
  - PP or PE....
  - no rigidity....
  - no true flat surfaces....
  - no sharp detailing....

- Rotational molding....
  - large radii....
  - detailing bad....
  - difficult to mold flat panels....

- SMC....
  - treat this like steel....
  - light weight....
  - need fasteners....
  - any color....

- Sheet steel....
  - costs for tools expensive....
  - steel is inexpensive....
  - weight is a problem...."

3.5.8 Personal Interview, Robert Pogue - Acti-Plast FRP

- "FRP is very labor intensive....
- double molds are needed because only one side of the surface is smooth....
- very strong....
- part complexity is minimal....
- my opinion is that FRP is not a good process....
- shipping cost a problem....

3.5.9 Personal Interview, Karl Fu - Pacific Technologies Research

- "recommend injection molding....
- material should be PP....
- did not think top should be make from plastic....
- joining pieces done with "L" brackets....
- tooling costs are approximately $150,000 - $200,000....
- based on manufacturing overseas in Hong Kong...."

3.6 Testing

3.6.1 Design Strategy

5th percentile boys age 8 compared to 5th percentile girls age 8 generally have longer upper limbs by approximately 20mm (Pheasant 1986). Therefore girls measurements should be used for reach concerns. Girls and boys at this age generally have same measurements elsewhere (within 5mm) (Pheasant 1986).

95th percentile girls age 12 compared to 95th percentile boys age 12 are generally taller, have longer limbs (buttock popliteal, length of upper limbs), are wider (shoulder breadth), and are deeper (abdominal depth) (Pheasant 1986). Therefore clearances should be guided by these measurements.

Using the above information a design strategy of the 5th percentile girl age 8 to 95th percentile girl age 12 will be used as the design range. These extremes allow for using the small individual for reach measurements and the larger individual for clearance measurements.

3.6.2 Measurements Needed

Seating

- popliteal height
- popliteal to buttock length
- hip width
- thigh width

Worksurface seating

- thigh thickness
- sitting elbow height
- reach zone
- abdominal depth

Seating (backrest)

- sitting shoulder height
- hip width
- shoulder blade height (unavailable)

Footrest

- leg envelopes
- buttock to knee length
- foot size

These above measurements are guides to aid in the design of the work station. The use of these measurements do not guarantee that every student will 'fit' to the work station.

3.6.3 The Back

The back is made up of 24 vertebrae (Pheasant 1986). The vertebrae rest on the sacrum which is attached to the hip at the sacro-iliac joints. The back can be grouped into three flexible sections; the cervical spine (seven vertebrae), thoracic spine (twelve vertebrae), and the lumbar (5 vertebrae) (Pheasant 1986).

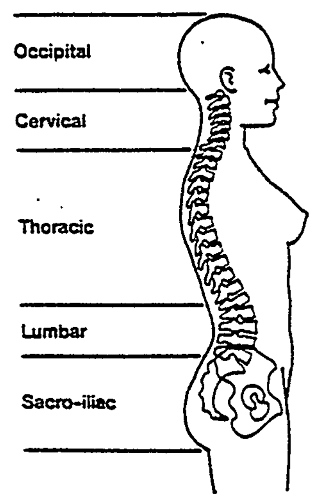


Figure #20 Vertebrae

Pheasant 1986, p. 123

It is important to the designer of a child's chair to estimate lumbar sitting height because this support must be movable in the vertical plane to accommodate the different users. Because there is no child data pertaining to this measurement it must be estimated using adult measurements and using a percentage. This means that each section of the spine is proportionally the same as compared to an adult.

The two measurements needed to estimate a percentage are adult sitting lumbar height and C7 sitting height (Pheasant 1986). By dividing the lumbar height of the 95th percentile male and 5th percentile female by the C7 height one will get a percentage range. This range illustrates what percentage of the sitting shoulder height is lumbar height.

	Men				Women			
Dimension	5th %ile	50th %ile	95th %ile	SD	5th %ile	50th %ile	95th %ile	SD
1. Sitting height[a]	850	910	965	36	795	850	910	35
2. Occipital height (sitting)[b]	765	830	900	38	710	770	825	35
3. Nape height (sitting)[c]	660	725	785	38	605	660	720	35
4. C7 height (sitting)[d]	605	660	710	33	565	615	665	31
5. Scapular height (sitting)[e]	405	445	480	22	380	415	450	21
6. Lumbar height (sitting)[f]	195	240	285	26	195	230	265	22
7. Sacral height (sitting)[g]	125	165	200	23	130	165	200	21
8. Shoulder breadth (bideltoid)[a]	420	465	510	28	355	395	435	24
9. Chest breadth[h]	275	310	345	21	235	265	295	18
10. Elbow–elbow breadth	370	450	530	49	320	385	455	41
11. Waist breadth	250	290	330	24	200	230	260	18
12. Hip breadth[a]	310	360	405	29	310	370	435	38

Table #2 Lumbar Height & C7 Height

Pheasant 1986, p. 124

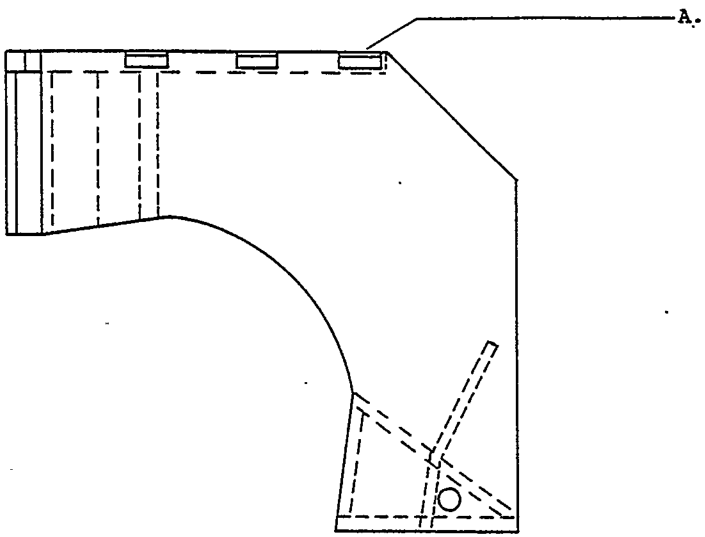
From the table above a range of 30 - 40% is obtained. The sitting shoulder height of the 5th percentile girl and 95th percentile girl is 37 and 54.5 centimetres respectively (Pheasant 1986). The lumbar height range for these children is 11 to 22 centimetres. What this means is that the tangent point on the curved lumbar support must be adjustable from a height of 11 centimetres from the seat pan to 22 centimetres from the seat pan.

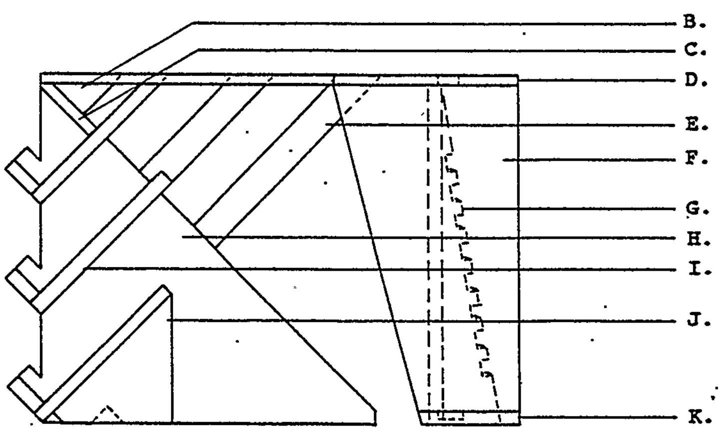
		8-year-olds Boys				8-year-olds Girls				12-year-olds Boys				12-year-olds Girls			
	Dimension	5th %ile	50th %ile	95th %ile	SD	5th %ile	50th %ile	95th %ile	SD	5th %ile	50th %ile	95th %ile	SD	5th %ile	50th %ile	95th %ile	SD
1.	Stature	1180	1280	1380	60	1185	1280	1375	59	1360	1490	1620	78	1370	1500	1630	79
2.	Eye height	1070	1165	1260	59	1070	1165	1260	58	1245	1375	1505	78	1255	1385	1515	80
3.	Shoulder height	930	1020	1110	54	930	1015	1100	53	1095	1215	1335	72	1100	1215	1330	69
4.	Elbow height	705	780	855	45	705	775	845	42	840	930	1020	55	840	940	1040	60
5.	Hip height	605	665	725	35	585	650	715	38	720	805	890	53	705	780	855	47
6.	Knuckle height	480	535	590	32	495	555	615	37	580	645	710	40	590	665	740	46
7.	Fingertip height	390	445	495	32	405	465	525	37	470	540	605	40	480	560	635	46
8.	Sitting height	630	680	730	31	640	685	730	28	700	765	830	39	700	775	850	45
9.	Sitting eye height	520	570	620	31	525	580	635	32	590	650	710	37	600	665	730	40
10.	Sitting shoulder height	380	425	470	27	370	410	450	25	440	490	540	30	435	490	545	32
11.	Sitting elbow height	145	180	215	21	145	175	205	19	160	205	250	27	155	205	255	31
12.	Thigh thickness	85	110	135	14	90	110	130	13	105	125	145	13	100	130	160	17
13.	Buttock–knee length	375	415	455	25	375	420	465	26	445	500	555	32	450	510	570	36
14.	Buttock–popliteal length	305	340	375	22	310	355	400	27	375	415	455	23	380	435	490	33
15.	Knee height	360	400	440	25	355	395	435	24	430	480	530	30	420	470	520	29
16.	Popliteal height	295	325	355	18	295	330	365	20	350	390	430	23	345	385	425	24
17.	Shoulder breadth (bideltoid)	275	310	345	21	270	310	350	24	315	355	395	25	305	355	405	29
18.	Shoulder breadth (biacromial)	265	285	305	13	255	280	305	16	290	325	360	21	290	325	360	21
19.	Hip breadth	200	235	270	20	205	245	285	23	230	275	320	26	235	295	355	35
20.	Chest (bust) depth	115	150	185	20	120	150	180	20	135	175	215	24	135	190	240	33
21.	Abdominal depth	135	170	205	20	140	180	220	24	165	200	235	22	155	200	245	27
22.	Shoulder–elbow length	240	265	290	15	240	260	285	14	280	310	340	18	280	315	345	20
23.	Elbow–fingertip length	310	340	370	19	305	335	365	19	360	400	440	25	355	400	445	27
24.	Upper limb length	515	565	615	30	495	555	615	35	600	665	730	41	575	660	745	52
25.	Shoulder–grip length	425	475	525	30	405	465	520	35	490	560	625	41	465	555	640	52
26.	Head length	170	185	200	8	165	175	185	5	170	185	200	8	165	175	185	7
27.	Head breadth	130	140	150	5	125	135	145	5	135	145	155	5	130	140	150	6
28.	Hand length	125	140	155	9	125	140	155	8	150	165	180	10	145	165	185	11
29.	Hand breadth	60	65	70	4	60	65	70	4	65	75	85	5	60	70	80	5
30.	Foot length	180	200	220	12	180	200	220	12	215	235	255	13	205	230	255	14
31.	Foot breadth	70	80	90	5	65	75	85	5	80	90	100	7	75	85	95	7
32.	Span	1165	1280	1395	69	1150	1250	1350	60	1355	1510	1665	93	1320	1480	1640	96
33.	Elbow span	610	675	740	39	600	660	720	36	710	795	885	53	685	780	880	58
34.	Vertical grip reach (standing)	1425	1550	1675	75	1405	1535	1665	78	1655	1835	2015	110	1650	1835	2020	112
35.	Vertical grip reach (sitting)	805	890	975	52	785	870	955	52	925	1035	1145	67	925	1035	1145	67
36.	Forward grip reach	475	535	595	35	475	530	585	34	550	620	690	42	550	625	700	45

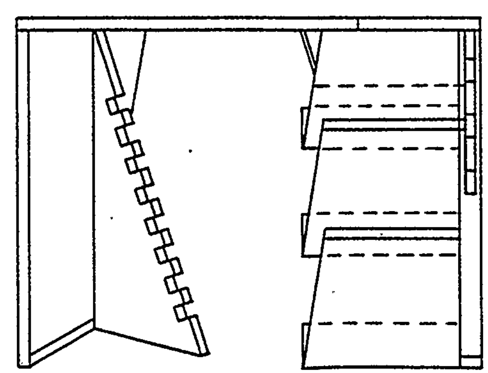
Table #3 Female & Male Age 8-12 Anthropometry

3.7 Technical Drawings

Drawing	Title
133	Element Description
134	Seat Support Structure-Triangle
135	Shelf Triangle
136	Shelf to Worksurface Attachment
137	Worksurface-Wooden Version
138	Cable Pathway Guide
139	Seat Support Structure
140	Computer and Shelf Support
141	Computer and Shelf Support
142	Shelf Structure
143	Personal Drawer
144	Seating & Footrest Device
145	Worksurface-Plastic Version
146	Shelves & Computer Support
147	Seat Support Structure
148	Bracket Collar
149	Seat Pan Pivot Insert
150	Seat Bracket Hinge
151	Screw Mechanism
152	Cable Securing Device
153	Reach Envelope







A. Extrusion Cover

B. Triangle Cover

C. Worksurface to shelf attachment

D. Worksurface

E. Cable Pathway Guide

F. Seat Support Structure

G. Seat Support Structure - triangle

H. Computer and Shelf Support Structure

I. Shelf Structure

J. Shelf Structure - triangle

K. Seat Support Structure - base plate

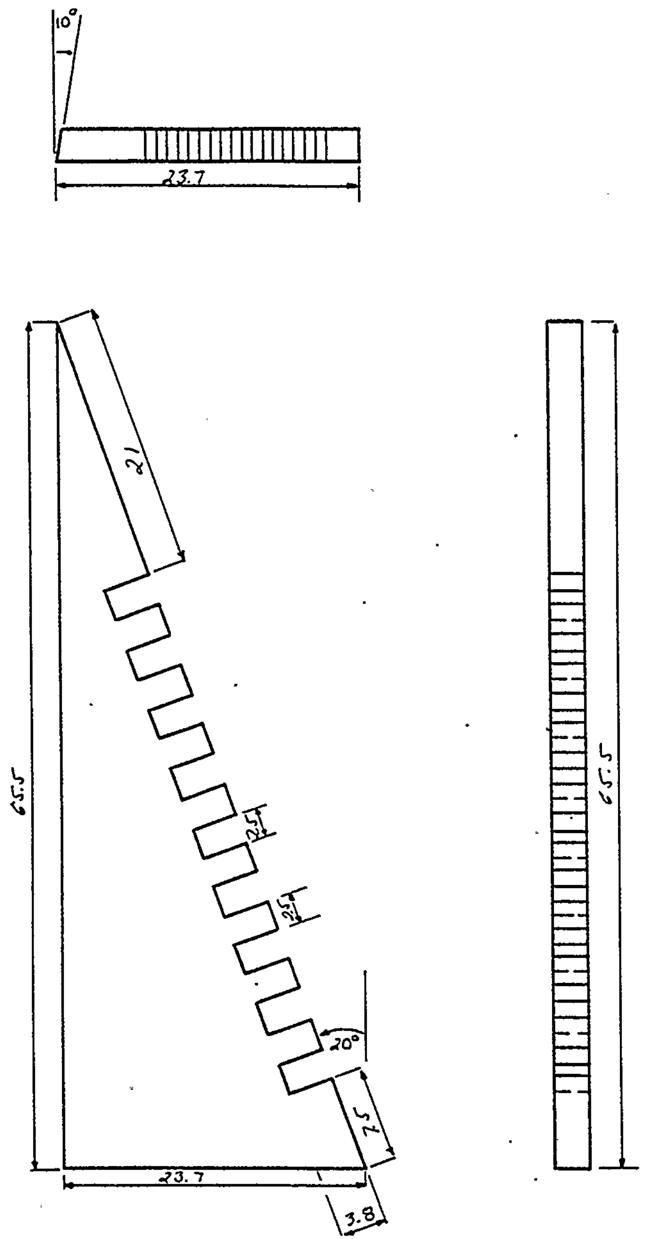
Project: Elementary School Students' Work Station

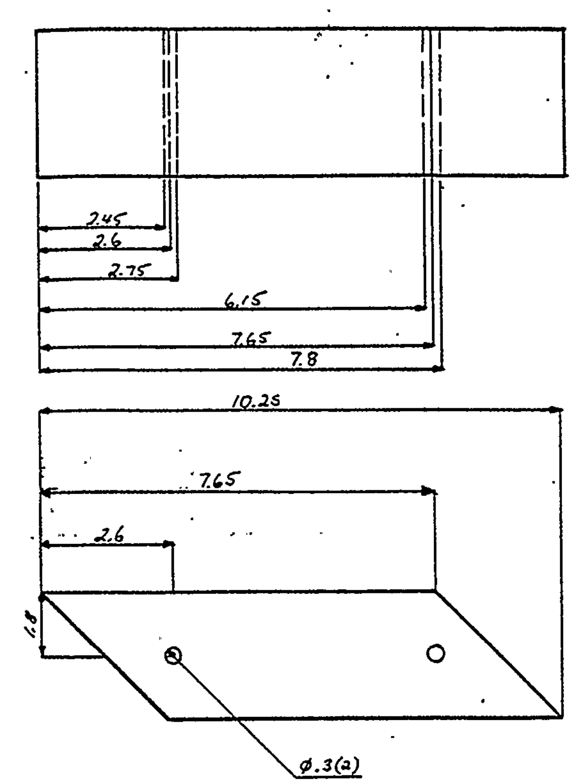
Drawing: Element Description

Scale: 1:10

Drawn by: Eugene Armbruster

Drawing No. 133





SEAT SUPPORT
STRUCTURE-TRIANGLE

EXTRUSION COVER

NOTES:

MATERIAL: Wooden version - maple
Plastic version - PP

FINISHING: Wooden version - polyurethane coating

TOLERANCE: +/- .1 cm

Project: Elementary School Students' Work Station

Drawing: General Arrangement

Scale: 1:4

Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 134

SHELF TRIANGLE

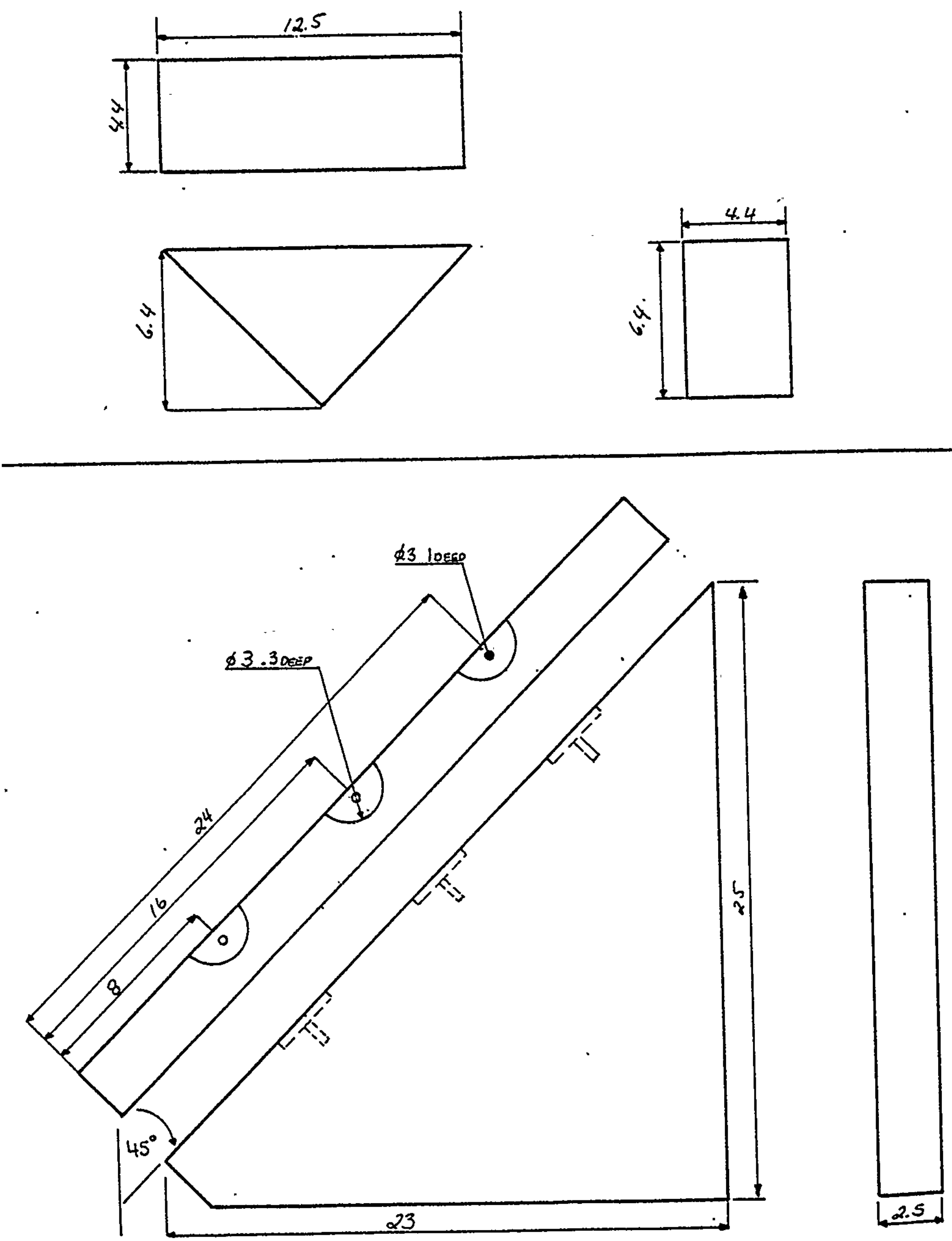
WORKSURFACE PLUG

NOTES:

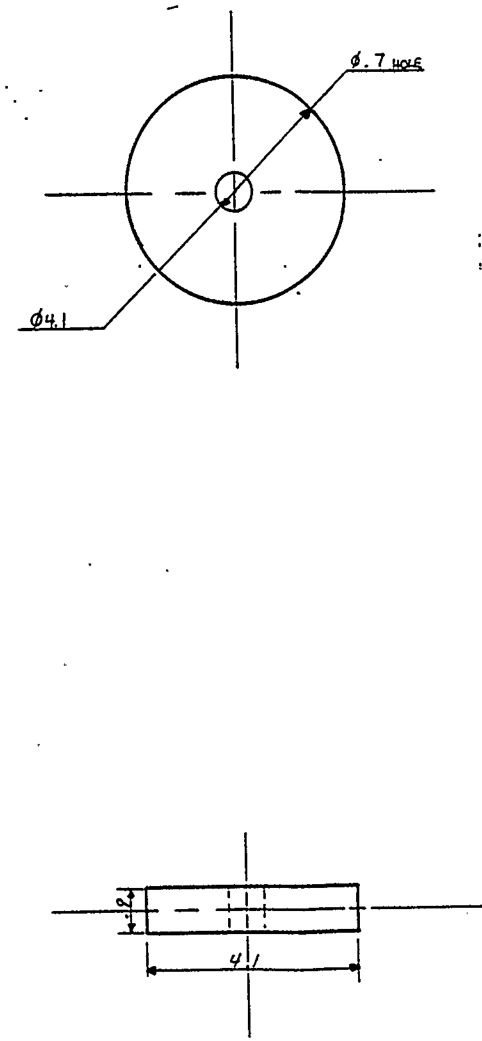
MATERIAL: Wooden version - maple
Plastic version - PP

FINISHING: Wooden version - polyurethane coating

TOLERANCE: +/- .1 cm



SCALE 1:2



SCALE 1:1

Project: Elementary School Students' Work Station

Drawing: General Arrangement

Scale: as shown

Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 135

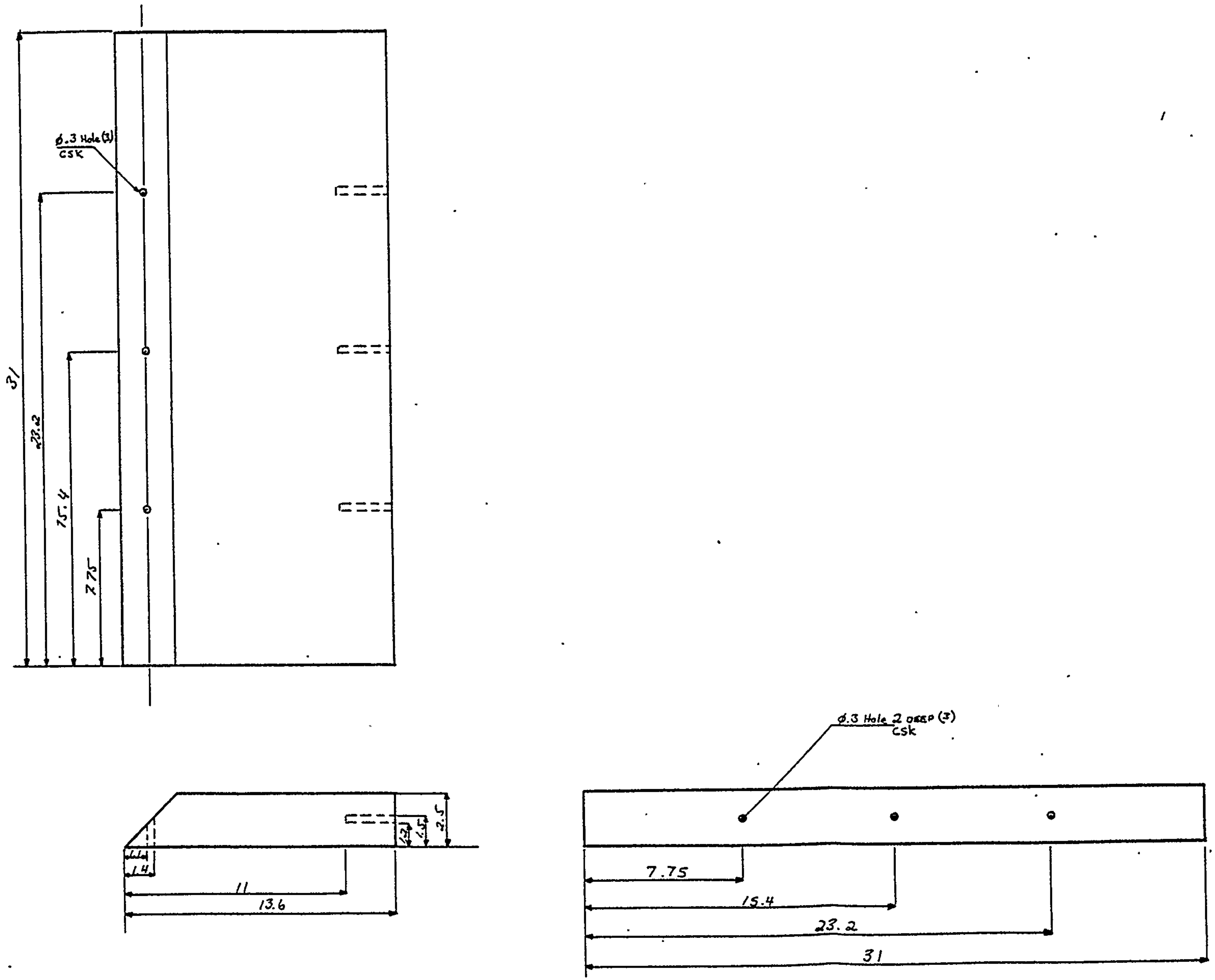
SHELF TO WORKSURFACE ATTACHMENT

NOTES:

MATERIAL: Wooden version - maple
Plastic version - PP

FINISHING: Wooden version - polyurethane coating

TOLERANCE: +/- .1 cm



Project: Elementary School Students' Work Station

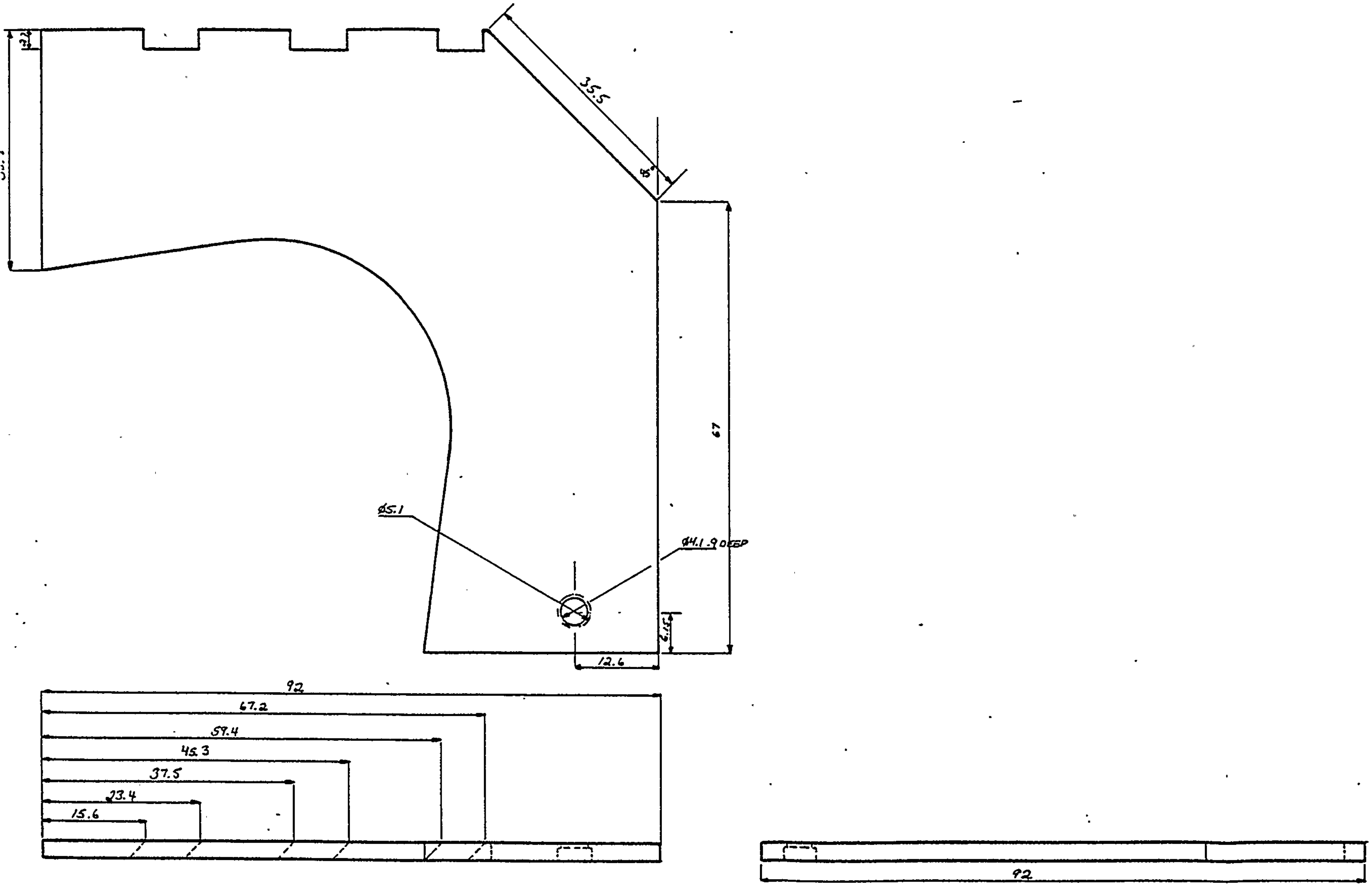
Drawing: General Arrangement

Scale: 1:2

Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 136



WORKSURFACE
NOTES:

MATERIAL: Wooden version - birch plywood.

FINISHING: Laminate top. Polyurethane coating to edges.

TOLERANCE: general tolerance is +/-.1cm. Angle tolerance is .5 degree.

Project: Elementary School Students' Work Station

Drawing: General Arrangement

Scale: 1:6

Drawn by: Eugene Armbruster

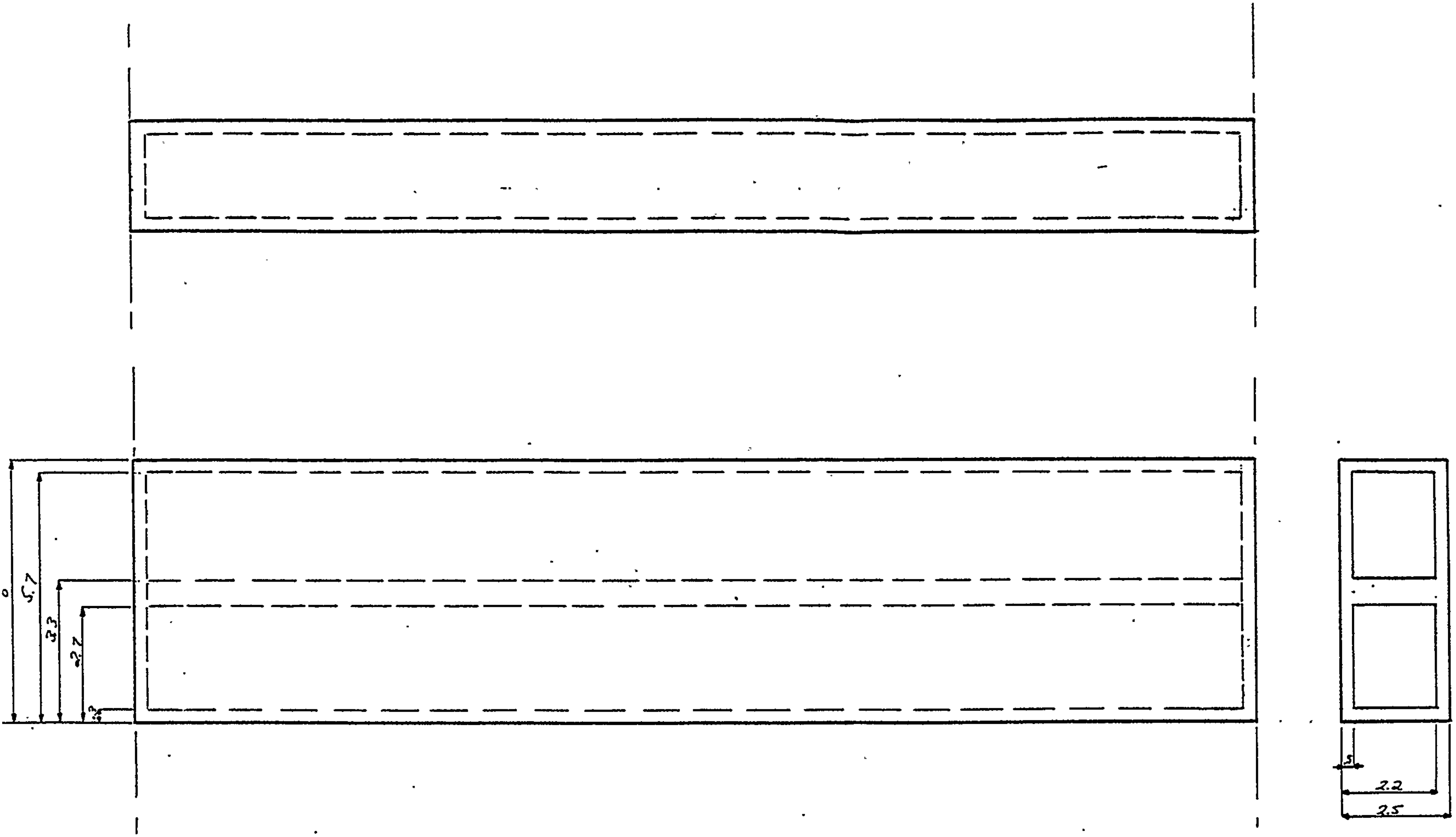
Dimensions in: cm

Drawing No. 137

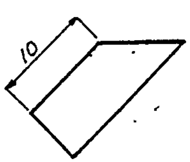
CABLE PATHWAY GUIDE
NOTES:

MATERIAL: Cold rolled steel

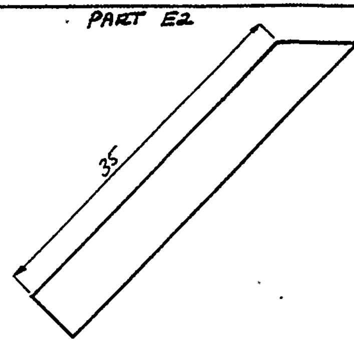
TOLERANCE: +/- .025cm



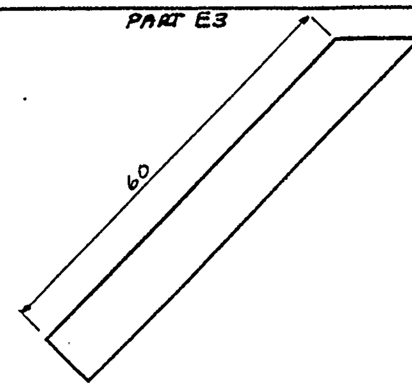
PART E1



PART E2



PART E3



EACH PIECE IS CUT TO FIT

Project: Elementary School Students' Work Station

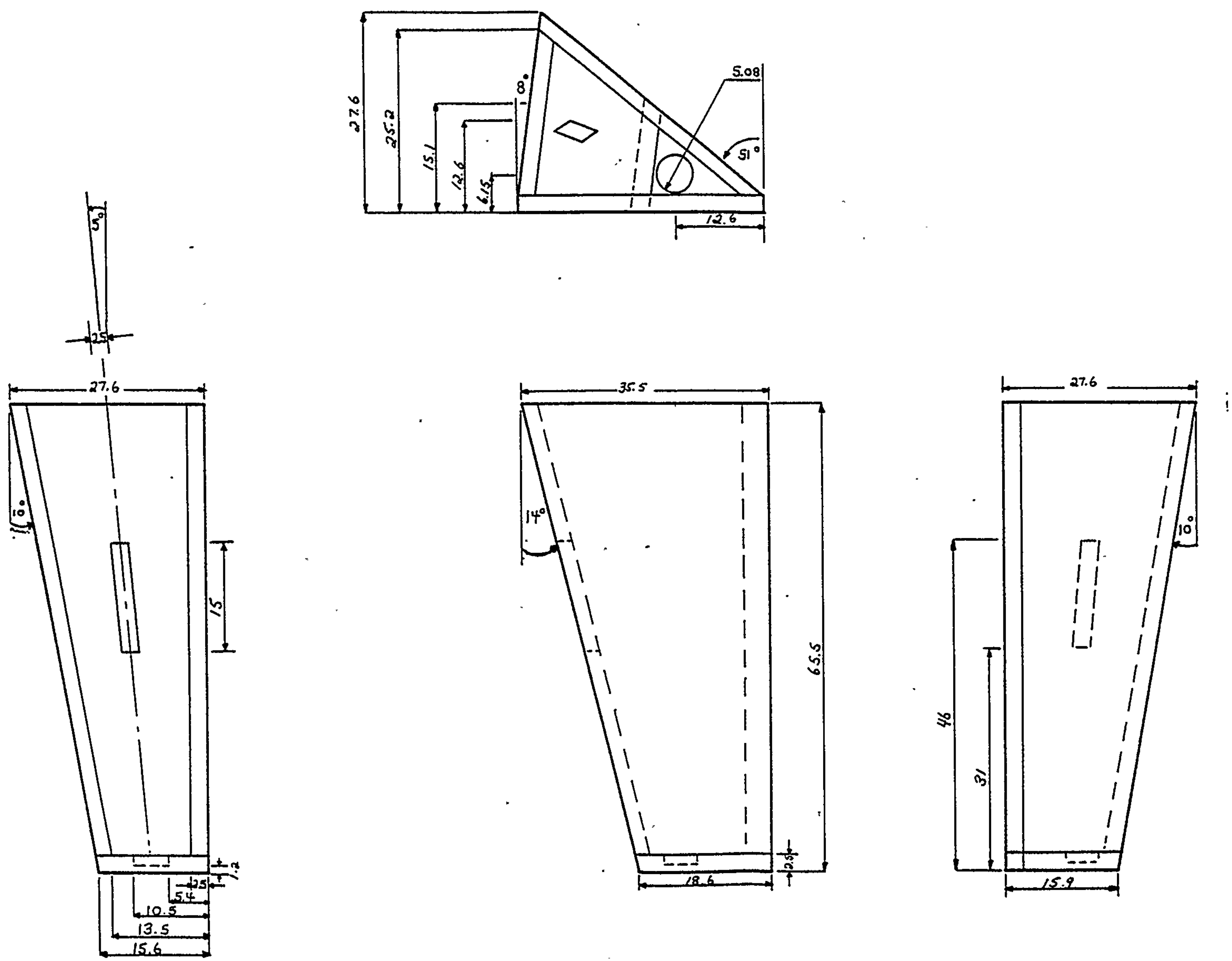
Drawing: General Arrangement

Scale: 1:4

Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 138



SEAT SUPPORT STRUCTURE
NOTES:

MATERIAL: Wooden version: maple

Plastic version: polypropylene

FINISHING: Wooden version: polyurethane coating on wooden pieces.

TOLERANCE: general tolerance is +/-.1cm on wooden pieces. Angle tolerance is .5 degree.

Project: Elementary School Students' Work Station

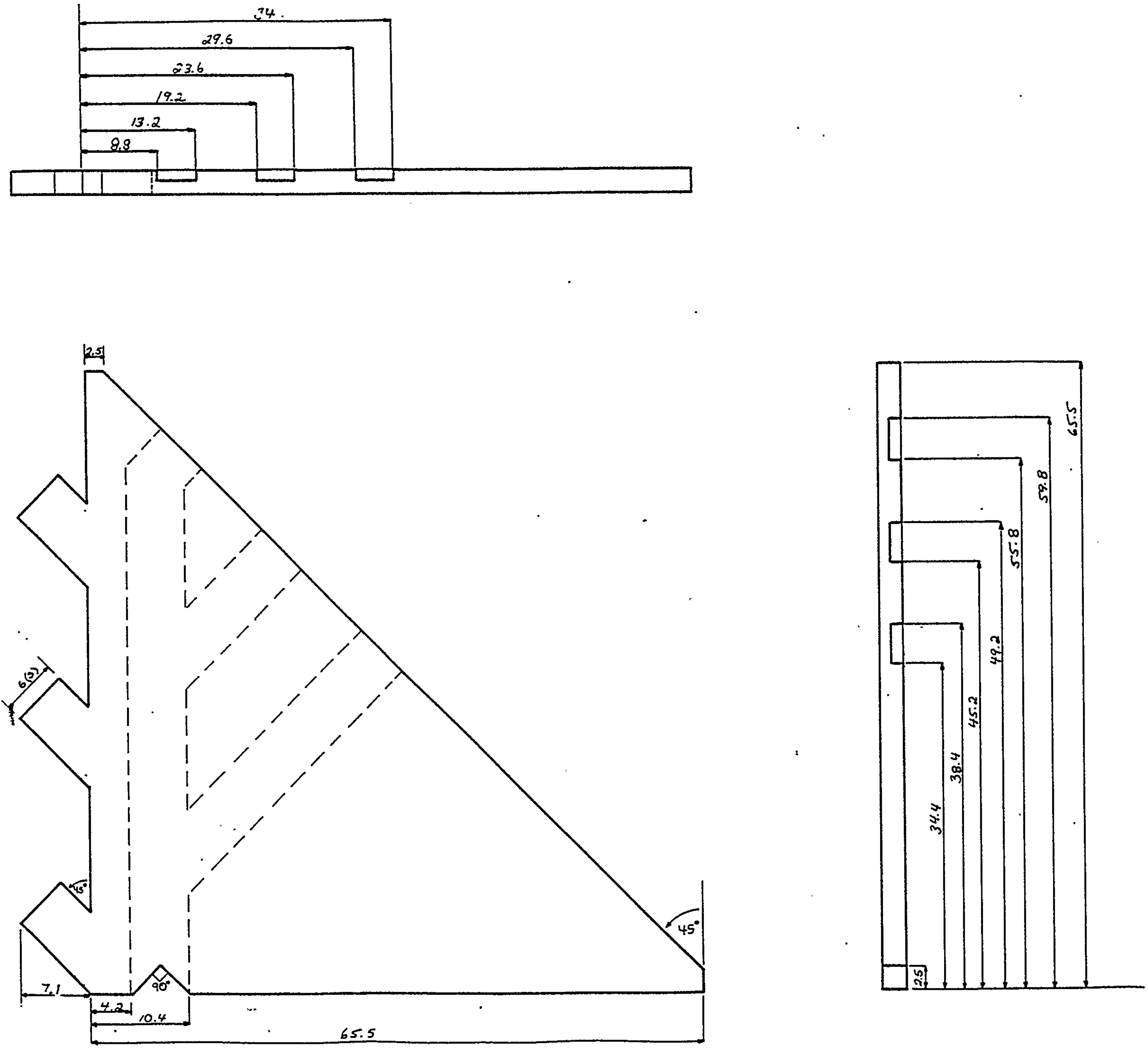
Drawing: General Arrangement

Scale: 1:6

Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 139



COMPUTER & SHELF SUPPORT
NOTES:

MATERIAL: Wooden version - maple.

FINISHING: Polyurethane coating to surfaces.

TOLERANCE: general tolerance is +/-.1cm. Angle tolerance is .5 degree.

Project: Elementary School Students' Work Station

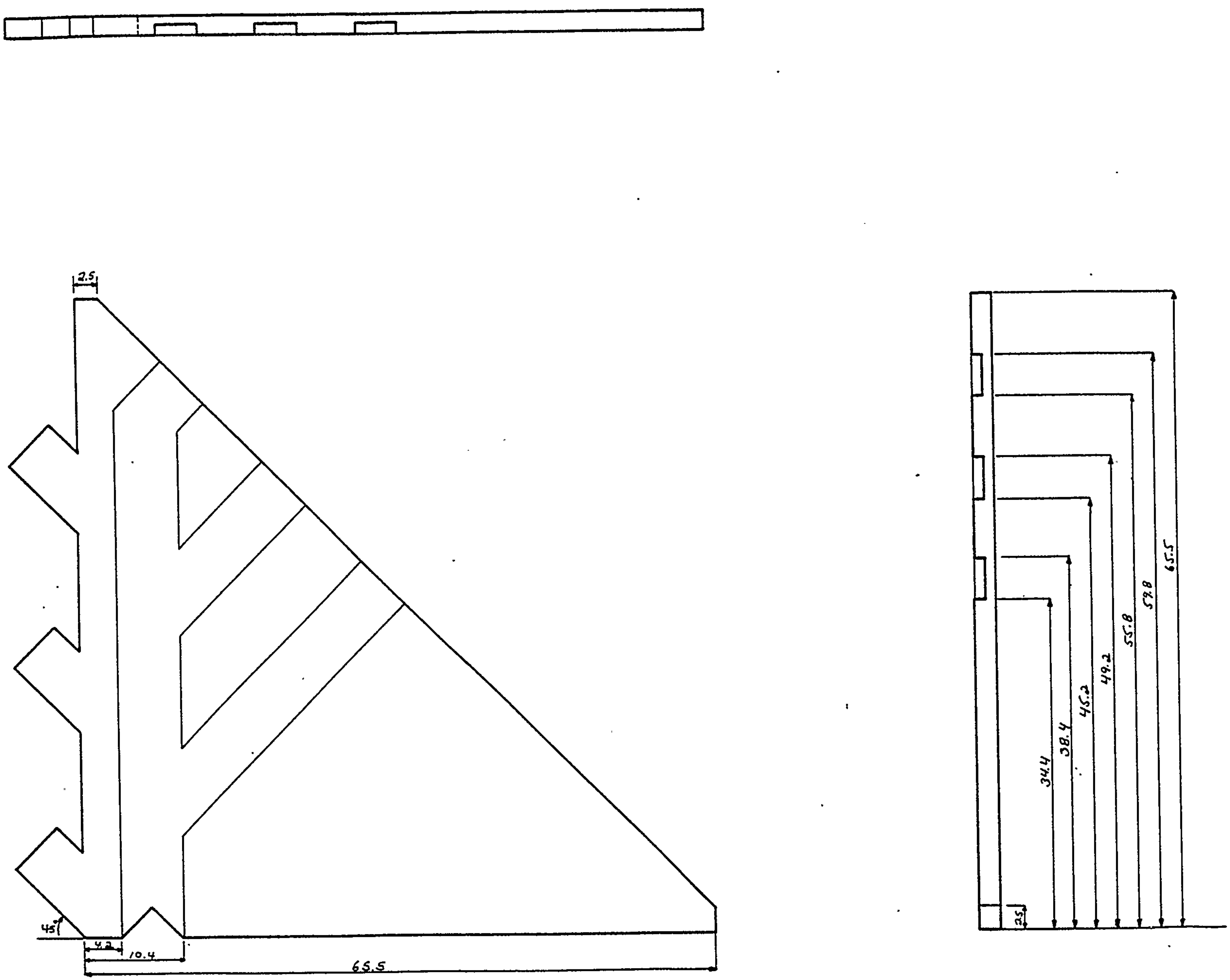
Drawing: General Arrangement

Scale: 1:4

Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 140



COMPUTER & SHELF SUPPORT
NOTES:

MATERIAL: Wooden version - maple.

FINISHING: Polyurethane coating to surfaces.

TOLERANCE: general tolerance is +/-.1cm. Angle tolerance is .5 degree.

Project: Elementary School Students' Work Station

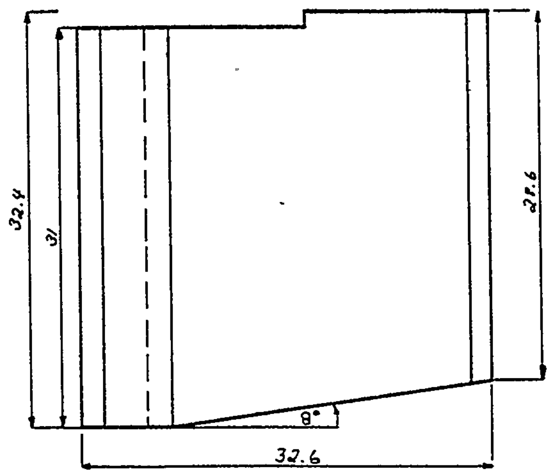
Drawing: General Arrangement

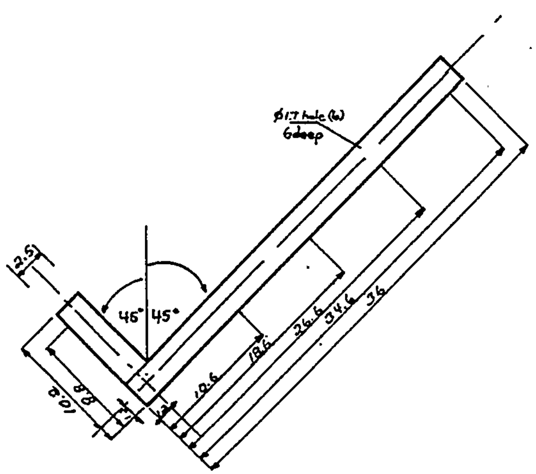
Scale: 1:4

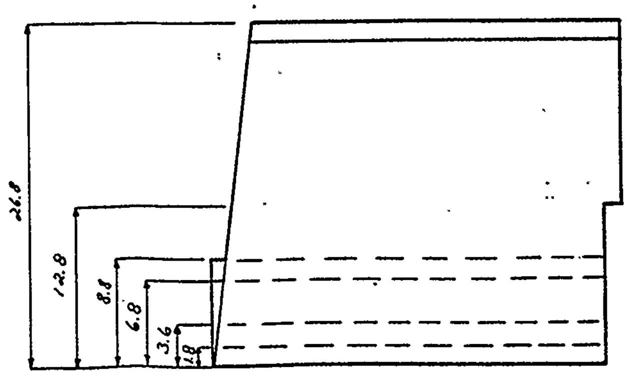
Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 141







SHELF STRUCTURE
NOTES:

MATERIAL: Wooden version - maple.

FINISHING: Polyurethane coating to surfaces.

TOLERANCE: general tolerance is +/-.1cm. Angle tolerance is .5 degree.

Project: Elementary School Students' Work Station

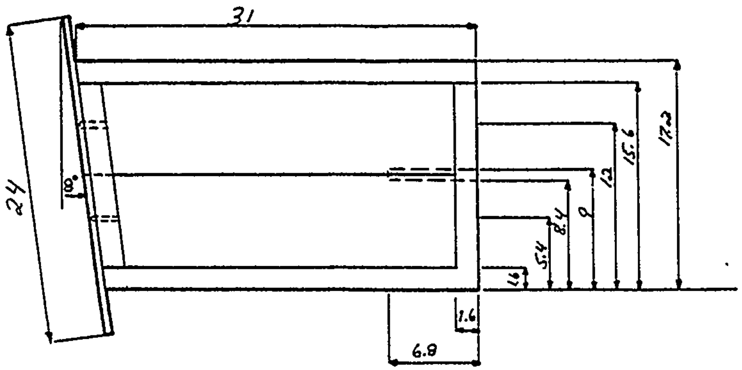
Drawing: General Arrangement

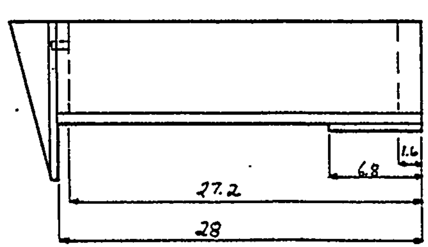
Scale: 1:4

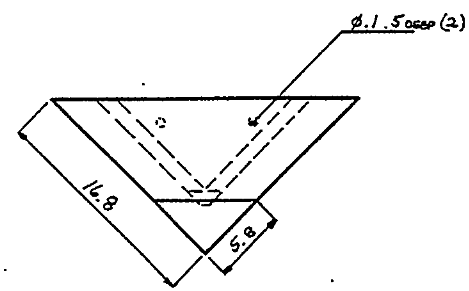
Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 142







PERSONAL DRAWER

NOTES:

MATERIAL: Wooden version - maple
Plastic version - PP

FINISHING: Wooden version - polyurethane coating

TOLERANCE: +/- .1 cm

Project: Elementary School Students' Work Station

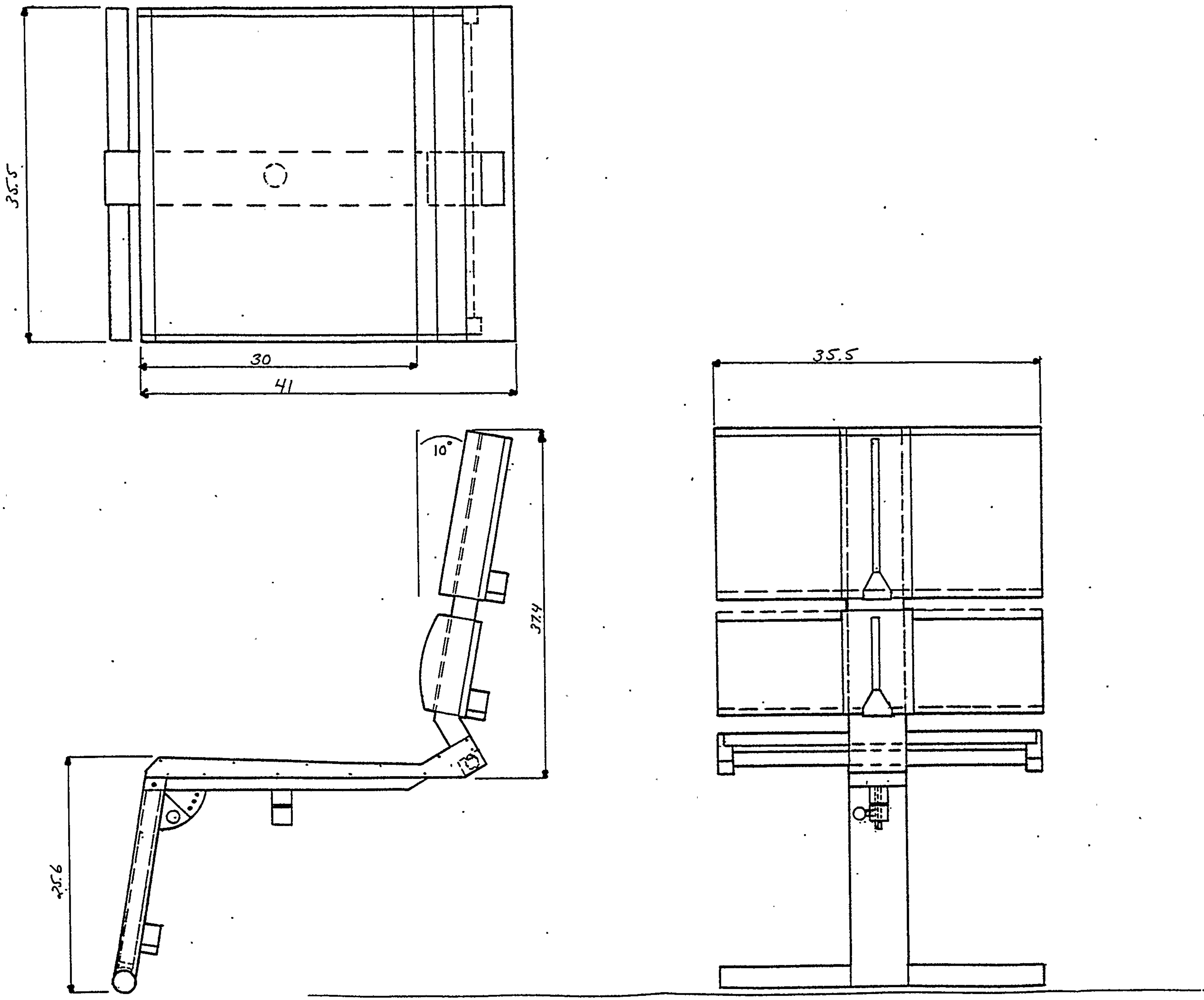
Drawing: General Arrangement

Scale: 1:4

Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 143



SEATING & FOOTREST DEVICE

NOTES:

MATERIAL: Wooden version:maple, cold rolled steel.

Plastic version: polypropylene, cold rolled steel.

FINISHING: Wooden version: polyurethane coating on wooden pieces. Powder coating on metal pieces.

Plastic version: Powder coating on metal pieces.

TOLERANCE: general tolerance is +/- .025cm on metal pieces and +/- .1cm on wooden pieces.

Project: Elementary School Students' Work Station

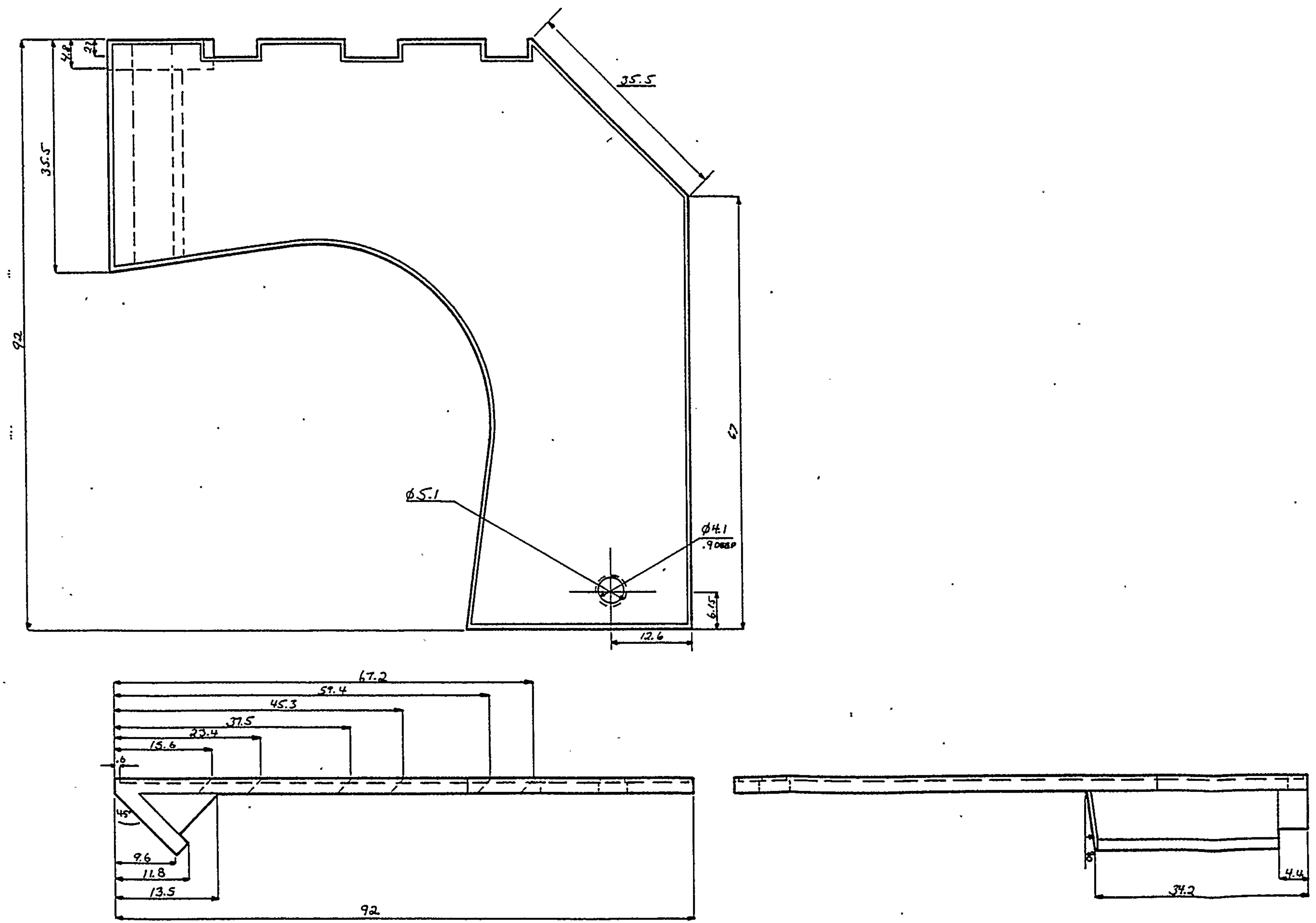
Drawing: General Arrangement

Scale: 1:4

Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 144



WORKSURFACE NOTES:

MATERIAL: Plastic version: polypropylene (glass reinforced) Recessed worksurface is made from birch plywood.

FINISHING: scrap removed.

TOLERANCE: general tolerance is +/-.025cm. Angle tolerance is .5 degree.

Project: Elementary School Students' Work Station

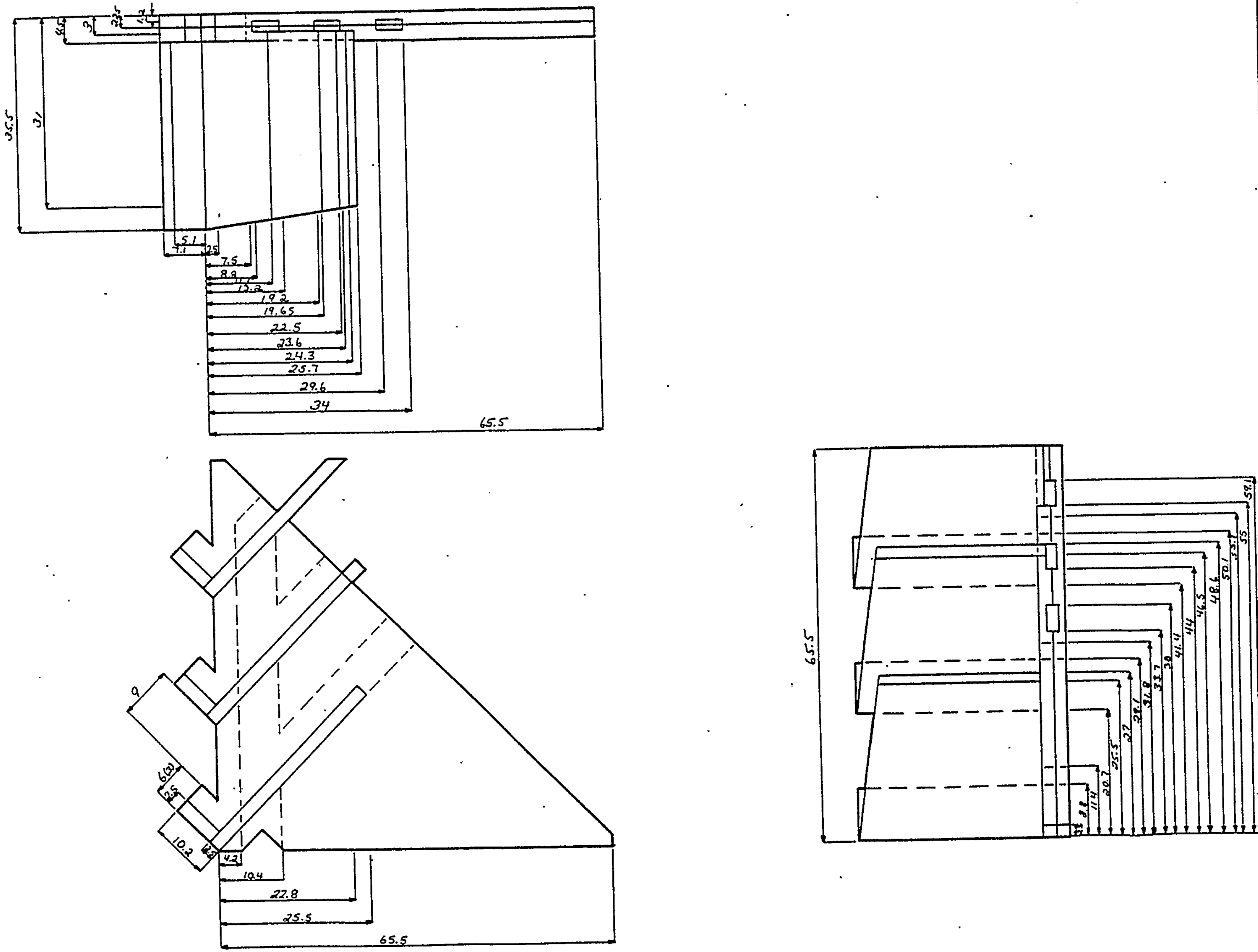
Drawing: General Arrangement

Scale: 1:6

Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 145



SHELVES & COMPUTER SUPPORT STRUCTURE

NOTES:

MATERIAL: Plastic version: polypropylene (glass reinforced)

FINISHING: scrap removed.

TOLERANCE: general tolerance is +/-.025cm. Angle tolerance is .5 degree.

Project: Elementary School Students' Work Station

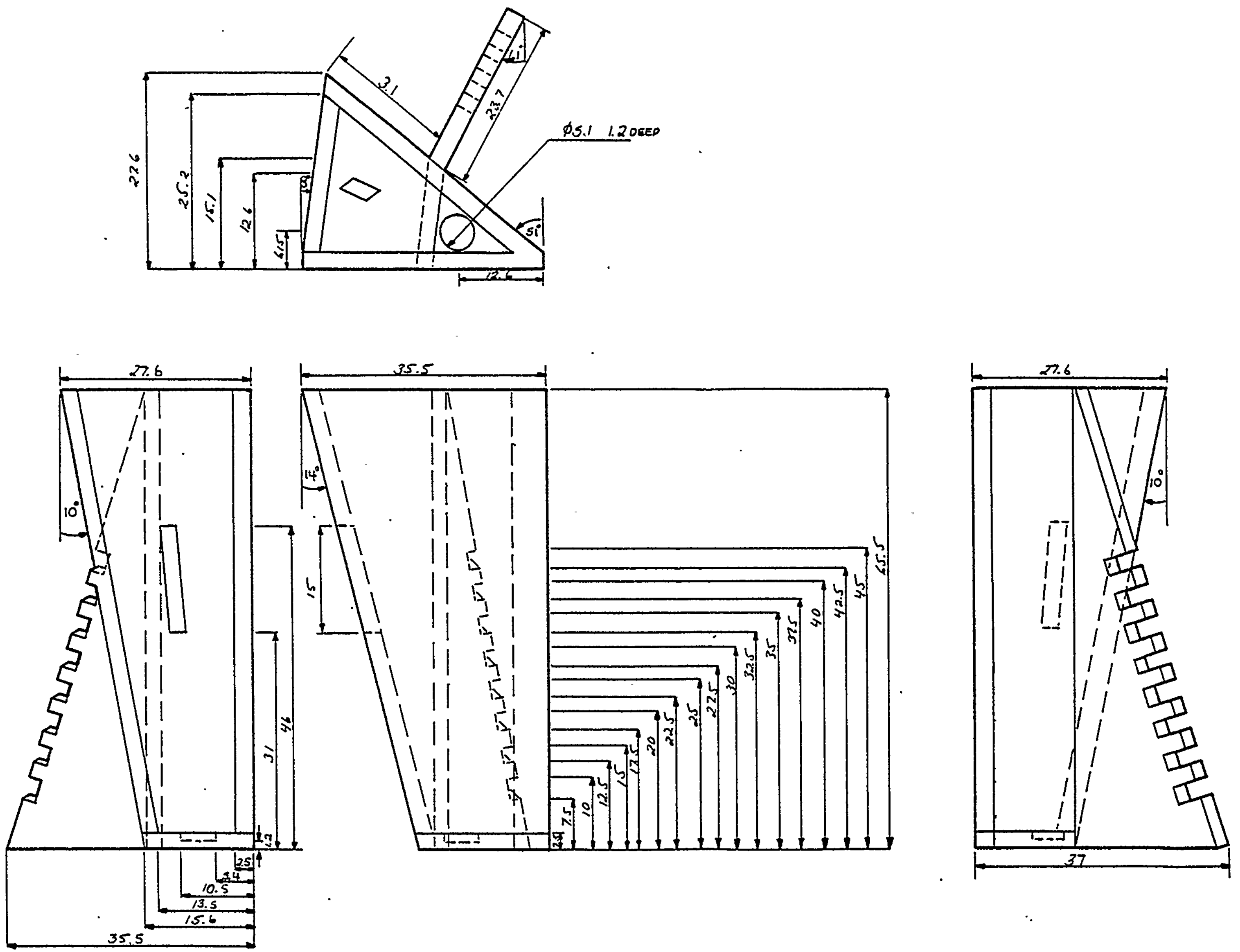
Drawing: General Arrangement

Scale: 1:6

Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 146



SEAT SUPPORT STRUCTURE NOTES:

MATERIAL: Plastic version: polypropylene (glass reinforced)

FINISHING: scrap removed.

TOLERANCE: general tolerance is +/-.025cm. Angle tolerance is .5 degree.

Project: Elementary School Students' Work Station

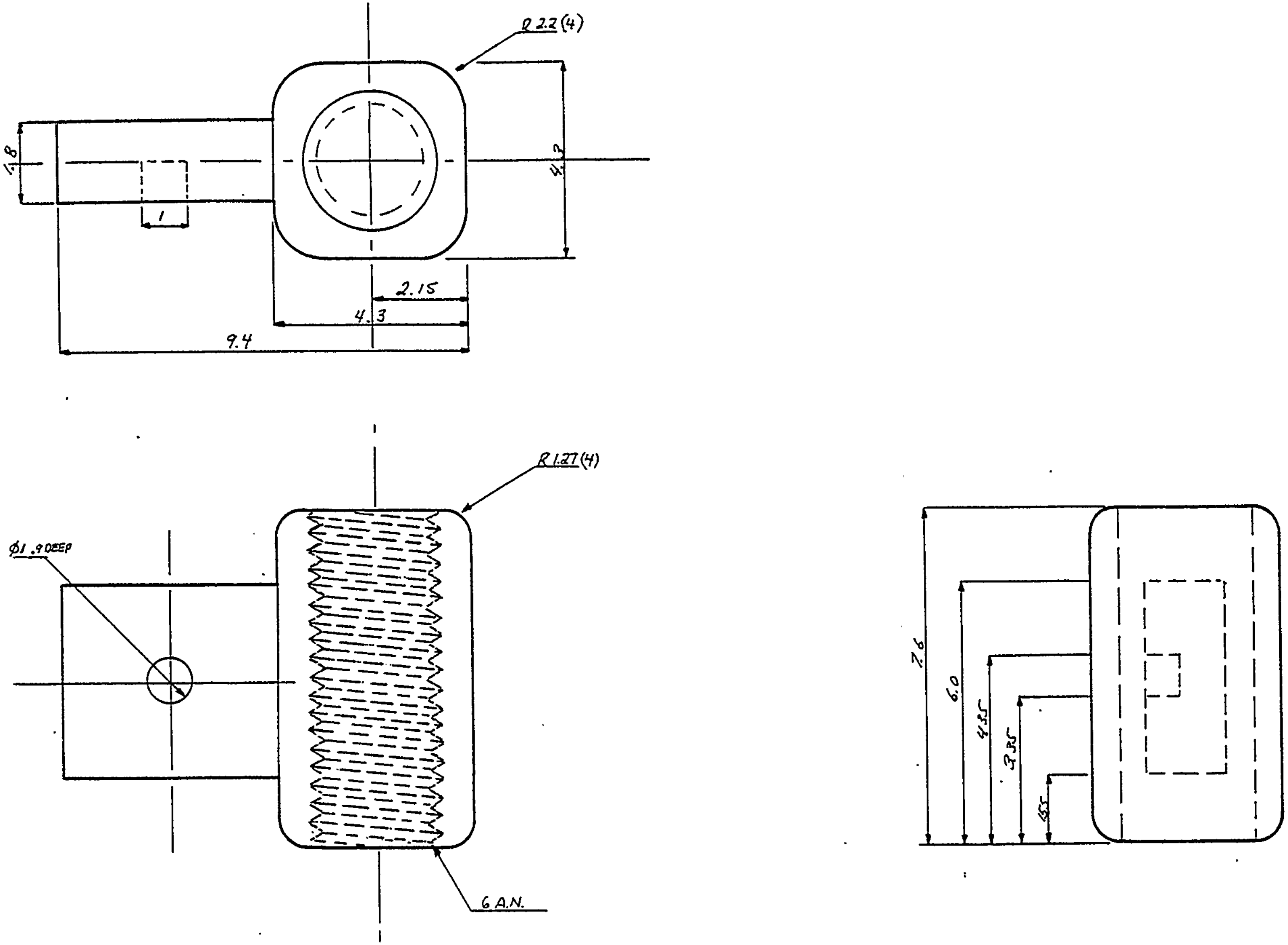
Drawing: General Arrangement

Scale: 1:6

Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 147



SEAT BRACKET COLLAR

NOTES:

MATERIAL: Cold rolled steel

TOLERANCE: +/- .025cm

Project: Elementar School Students' Work Station

Drawing: General Arrangement

Scale: 1:1

Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 148

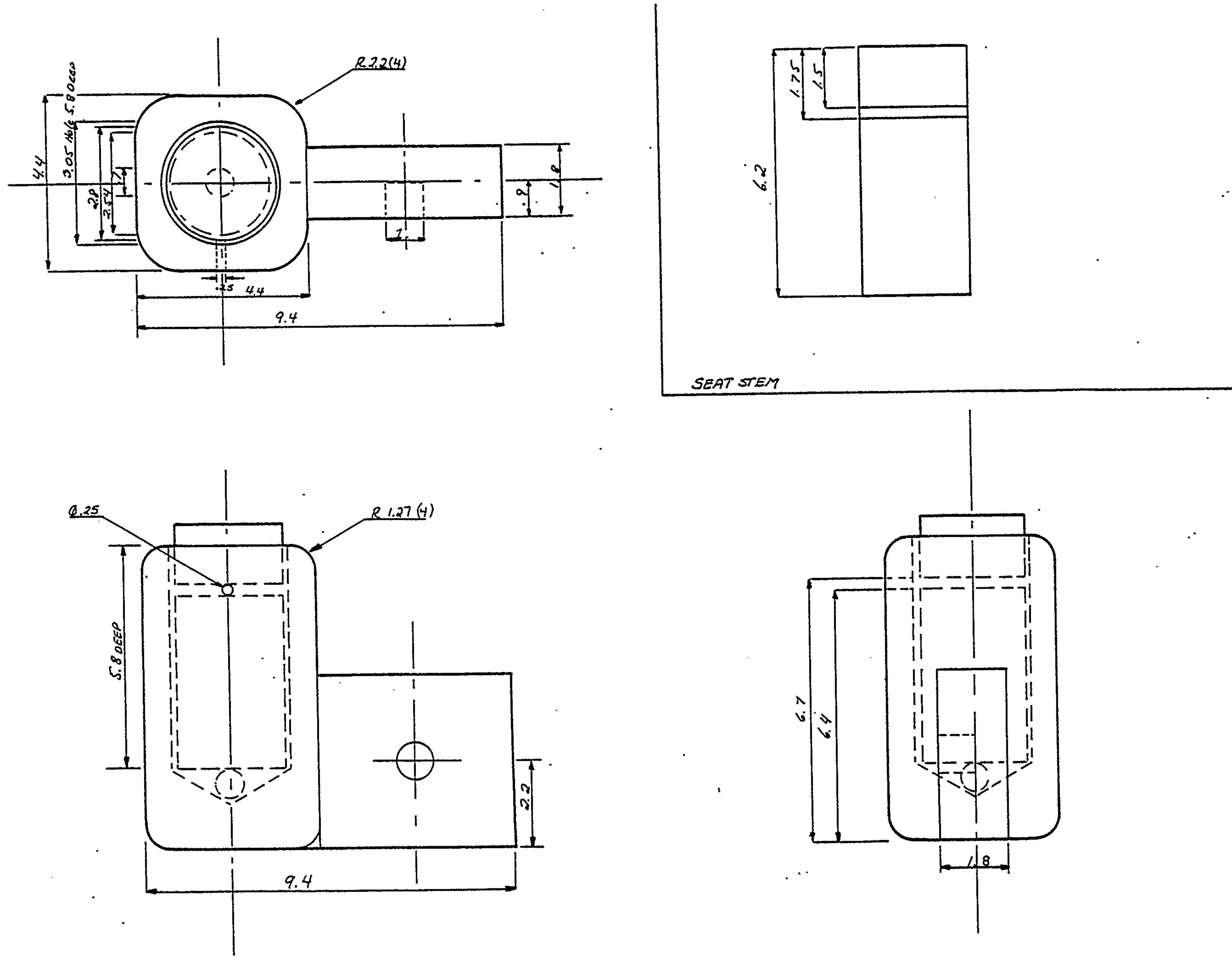
SEAT PAN PIVOT
INSERT

NOTES:

MATERIAL: Wooden and Plastic version - cold rolled steel

FINISHING: powder coating.

TOLERANCE: +/- .025 cm. Angle tolerance is .5 degree.



Project: Elementary School Students' Work Station

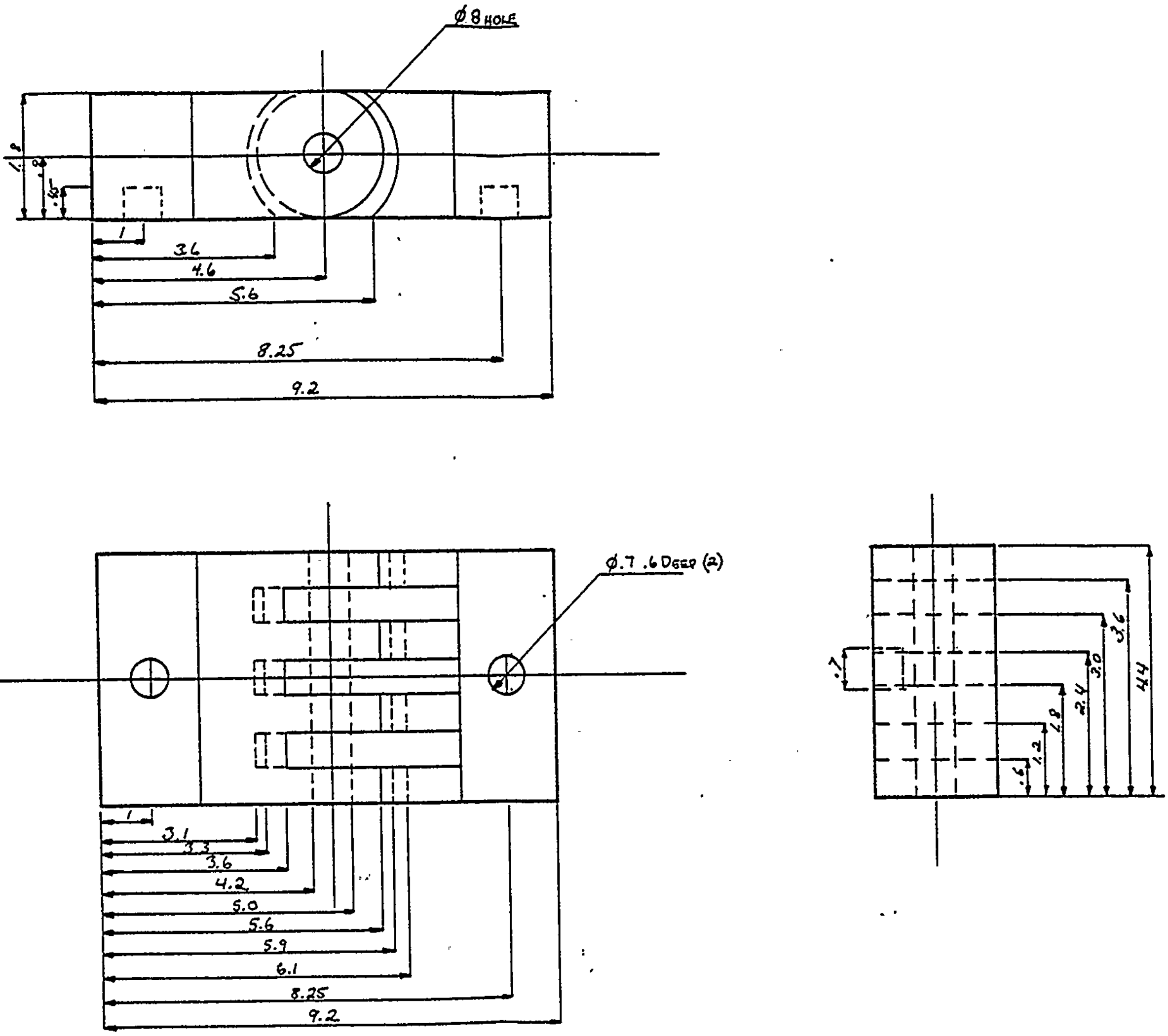
Drawing: General Arrangement

Scale: 1:1

Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 149



SEAT BRACKET HINGE

NOTES:

MATERIAL: Wooden and Plastic version - cold rolled steel

FINISHING: powder coating.

TOLERANCE: +/- .025 cm. Angle tolerance is .5 degree.

Project: Elementary School Students' Work Station

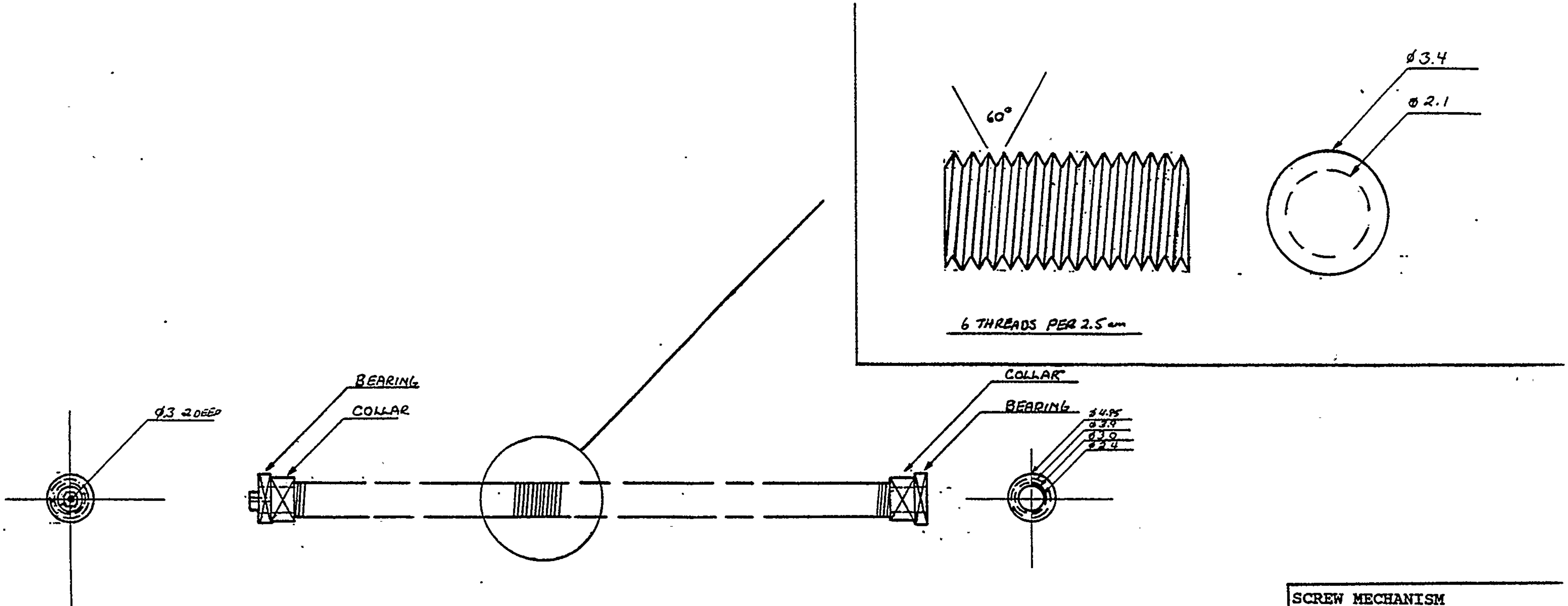
Drawing: General Arrangement

Scale: 1:1

Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 150



SCREW MECHANISM

NOTES:

MATERIAL: Cold rolled steel

TOLERANCE: +/- .025cm

Project: Elementary School Students' Work Station

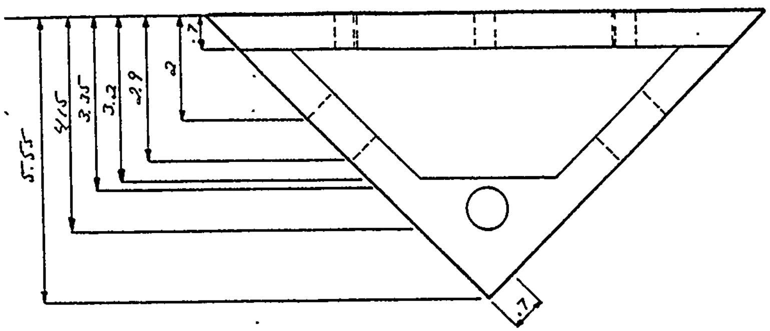
Drawing: General Arrangement

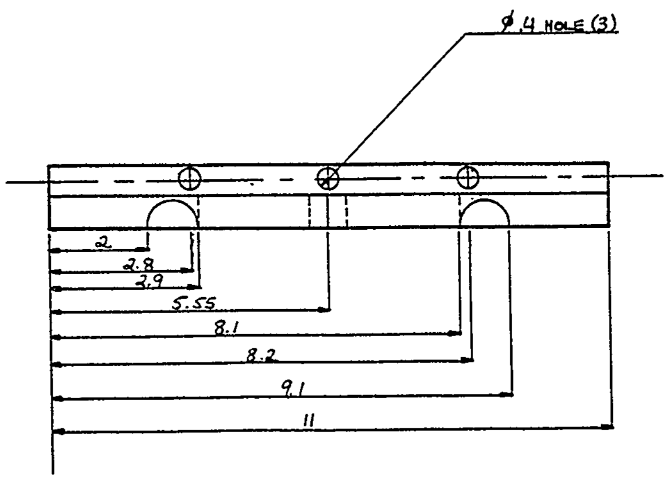
Scale: 1:4

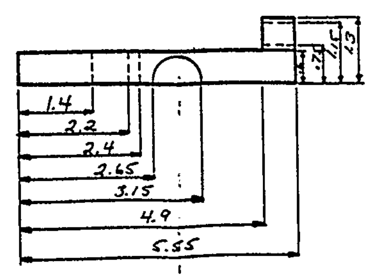
Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 151







CABLE SECURING DEVICE

NOTES:

MATERIAL: Wooden and Plastic version - cold rolled steel

FINISHING: powder coating.

TOLERANCE: +/- .025 cm. Angle tolerance is .5 degree.

Project: Elementary School Students' Work Station

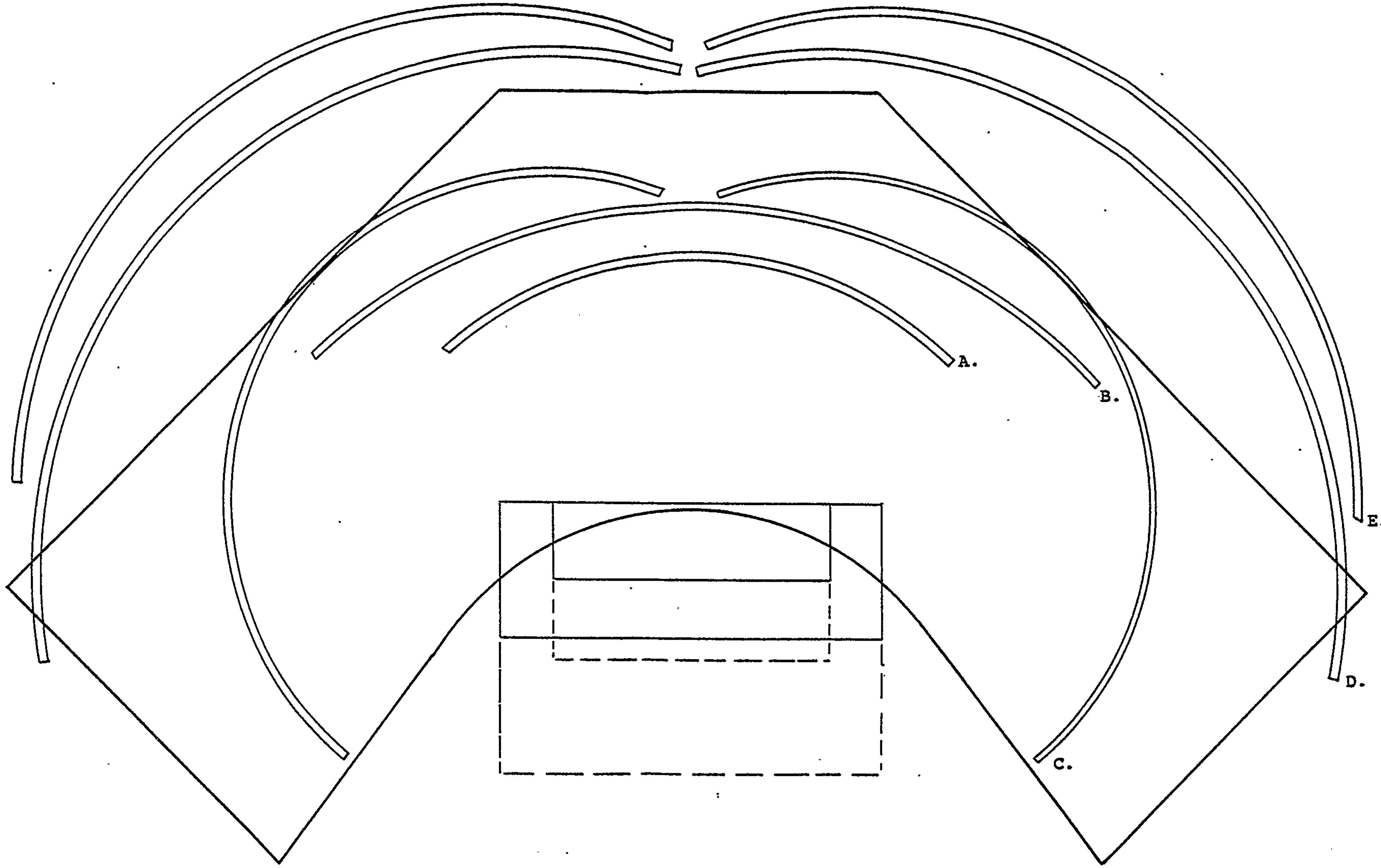
Drawing: General Arrangement

Scale: 1:1

Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 152



Reach Envelope Diagram

5th percentile 8 year old female
95th percentile 12 year old female

A. 8 year old female buttock to knee envelope
B. 12 year old female buttock to knee envelope
C. Working area of 8 year old female
D. Working area of 12 year old female
E. Zone of comfortable reach of 8 year old femal

Drawing No. 153

Source: Pheasant (1986)

Appendix Two - Glossary

Anthropometry - the collection of numerical data concerning the physical characteristics of human beings.

Blow molding - is a plastic molding process where a parison(a tube like plastic shape) is inserted into a closed mold. Next air is injected into the parison to blow it out against the mold cavity where it sets up into the final product.

Cervical spine - this is the spine of the neck which consists of seven vertebrae.

Ergonomics - the application of scientific information concerning human beings to the problem of design.

Extrusion - a process by which a material, in a plastic form, is forced through a die to achieve a desired cross-section.

Fabrication - to construct or to manufacture something, usually labor intensive, offers small production volumes and is tool intensive.

Flexible manufacturing - the ability to produce any part from a selected family of parts on a random basis without incurring downtime for changeover.

Glass reinforced polypropylene - glass is added to polypropylene resin to enhance impact strength and improve toughness.

Ischial tuberosities - are two narrow curved bones which help support the body in a seated position.

Injection molding - is a closed molding process in which granular thermoplastic material is fed into the end of a heated cylinder and then forced out the end of the cylinder through a nozzle into a relatively cool mold held under pressure. The plastic cools and cures. The mold opens and the molded part is ejected.

Lumbar spine - is an area of five vertebrae located above the sacrum(tail bone).

Lumbar kyphosis - a curve of the lumbar spine which is convex to the rear.

Lumbar lordosis - a curve of the lumbar spine which is concave to the rear.

Modulus strength - in general it refers to the overall cross-sectional strength of a material while being tested under certain applications.

Numerically controlled machine - a machine which accepts programming instructions to produce a product or part of a product. This machine can also be controlled by a computer.

Plunge router - a tool with a high speed rotating bit which is used to cut or gouge a material. The term plunge refers to the router being lowered to a certain depth to cut or gouge.

Polycarbonate - is a thermoplastic that is characterized by high clarity, high hear resistance, and high impact strength.

Polyester - is a thermoplastic that possesses liquid crystal polymers, which exhibit a highly ordered crystalline structure, thus producing extraordinary combinations of properties.

Polypropylene - is a thermoplastic polymer that has good resistance to chemicals and fatigue.

Polyurethane coating - is a thermoplastic liquid which is applied to another material, such as wood, to enhance its abrasion resistance.

Popliteal - is the hollow at the back of the knee where the underside of the thigh meets the back of the lower leg.

Powder coating - is a technique where metal is sprayed with powder and then baked at high temperatures to cure the powder coat.

Radiographic - a photograph made by some form of radiation other than light.

Reaction injection molding - is a process in which two or more liquids are mixed under high pressure. Under pressure the liquids flow into a mold where they polymerize to form a molded part.

Rotational molding - is a process where plastic resin or liquid is placed into a mold. The mold is then rotated three dimensionally in a huge oven until the resin is forced against the walls of the mold where it cures to form a molded part.

Sedentary - a term used to describe a task that requires a lot of sitting.

Tensile strength - a measurement of a materials ability to withstand tensile conditions.

Thermoplastic - a plastic where the crosslinking of polymer chains is weak. Heat can break these crosslinks causing the material to soften and melt.

Thermoset - a plastic where the crosslinking of polymer chains in permanent.

Tooling - a term used to describe the fabrication of molds for a molding process. The material can range from aluminium to stainless steel.

Vulcanisation - rubber is hardened by the use of chemicals, temperature, and pressure.

Endnotes

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8. Ibid. p. 172.

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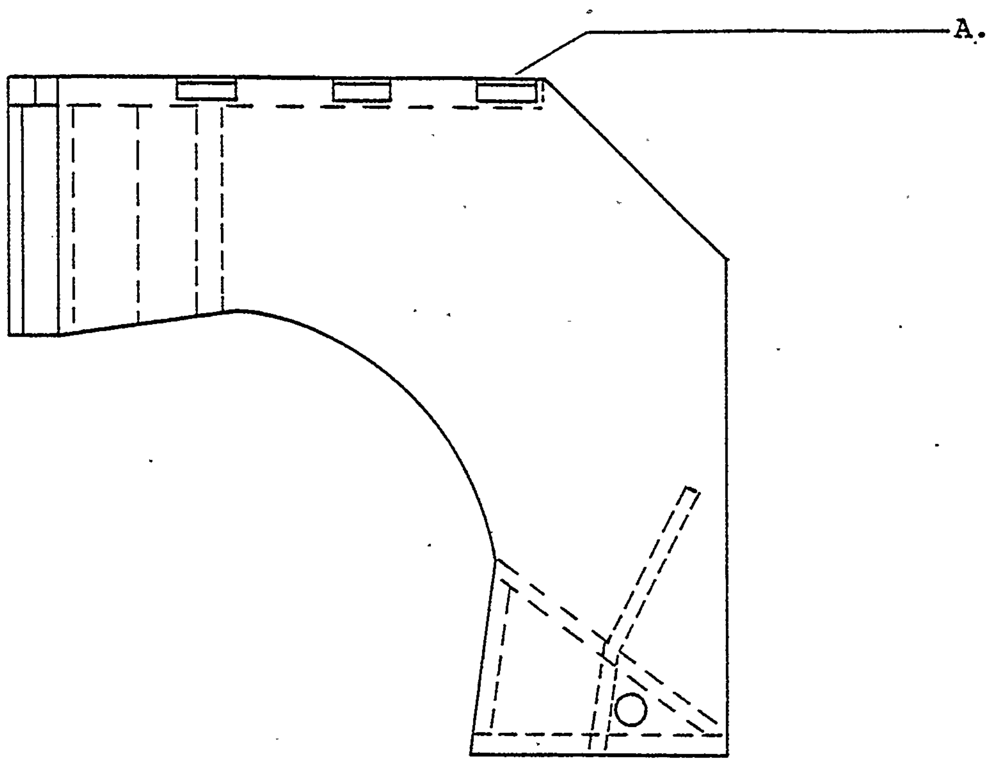
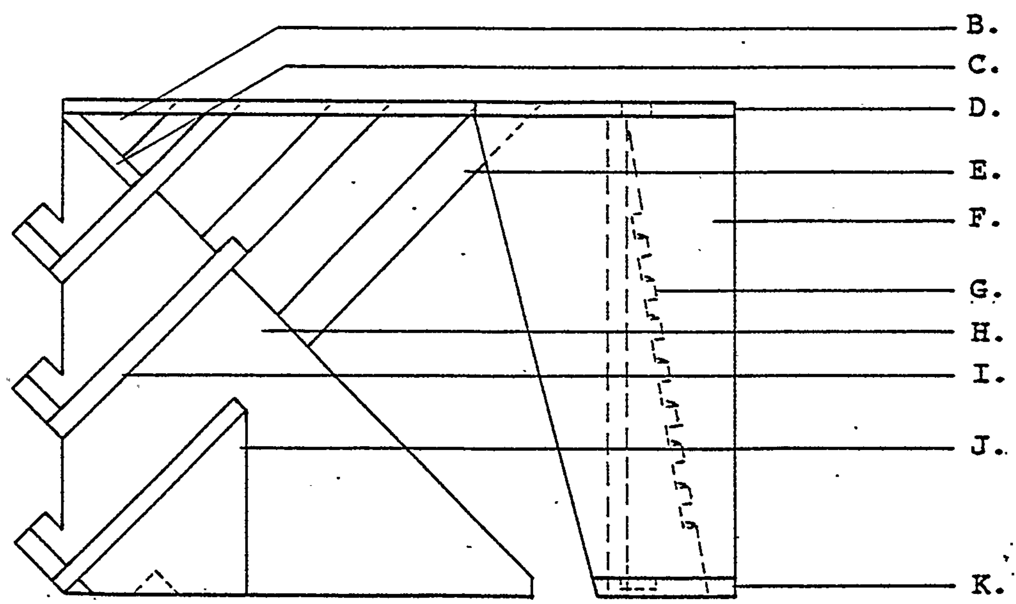
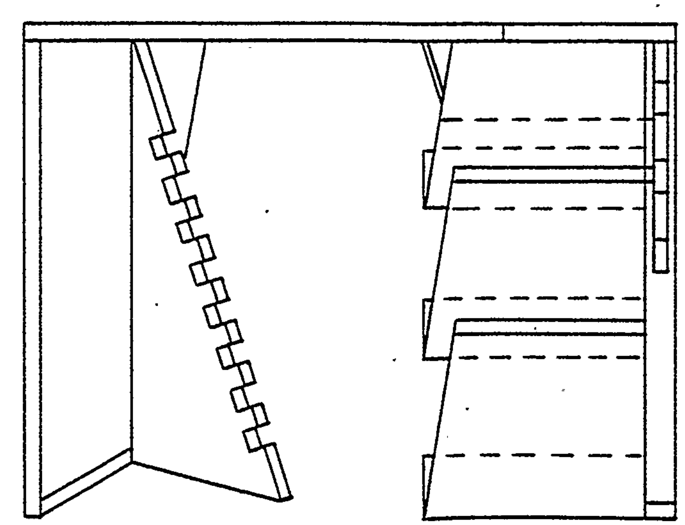
FACTORS		CRITERIA															
		Aesthetics	Vandalism	Maintenance	Costs	Materials	Production	Worksurface	Cultural	Environmental	Ed. Benefits	Adjustability	Safety	Posture	Anthropometry	Seating	Storage
individuality of education		x														x	
materials		x			x			x	x		x	x	x			x	
color		x				x										x	
texture		x				x											
grouping of forms		x										x					
entry/exit to form		x														x	
mar-proof worksurface		x	x		x	x											
sustain weight			x			x										x	
sustain impact			x			x											
replaceability of parts			x	x	x											x	
access to clean				x													
production					x	x					x					x	
shipping					x	x	x										
durability			x	x	x	x					x					x	
fire resistant			x			x							x				
mass production					x	x	x										
territoriality		x						x		x							
envelopes - leg and arm								x		x					x		x
square desk cultural bias									x	x							
glare/dust										x							
heat/cold						x				x							
ability to fulfill tasks											x						
footrest												x		x	x		
seating device												x					
height adjust												x					
body support												x					
document holder								x				x					
monitor								x				x					
keyboard								x				x					
protrusions/rounded edges													x				
ergonomics								x					x	x			x
lordosis														x			
strain on different body part														x			
arm/feet														x			
suitability to tasks at hand														x			
head posture														x	x		
adolescence															x		
clearance															x		
backrest															x	x	
anthropometry								x						x		x	x
lumbar																x	
books																	x
drawer																	x
location of element		x															x
sheives																	x
stability of form													x			x	

Table #1. Work Station Criteria







A. Extrusion Cover

B. Triangle Cover

C. Worksurface to shelf attachment

D. Worksurface

E. Cable Pathway Guide

F. Seat Support Structure

G. Seat Support Structure - triangle

H. Computer and Shelf Support Structure

I. Shelf Structure

J. Shelf Structure - triangle

K. Seat Support Structure - base plate

Project: Elementary School Students' Work Station

Drawing: Element Description

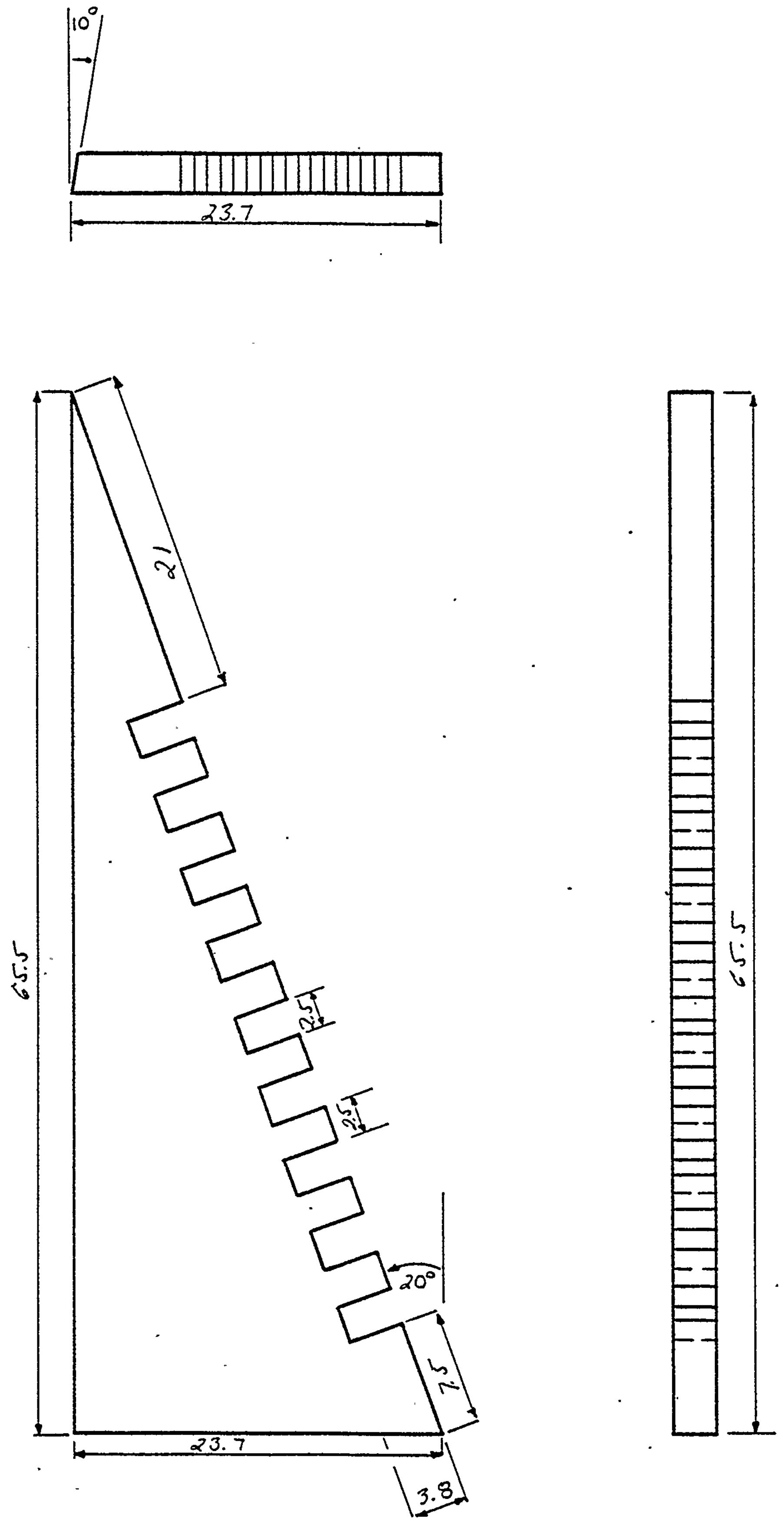
Scale: 1:10

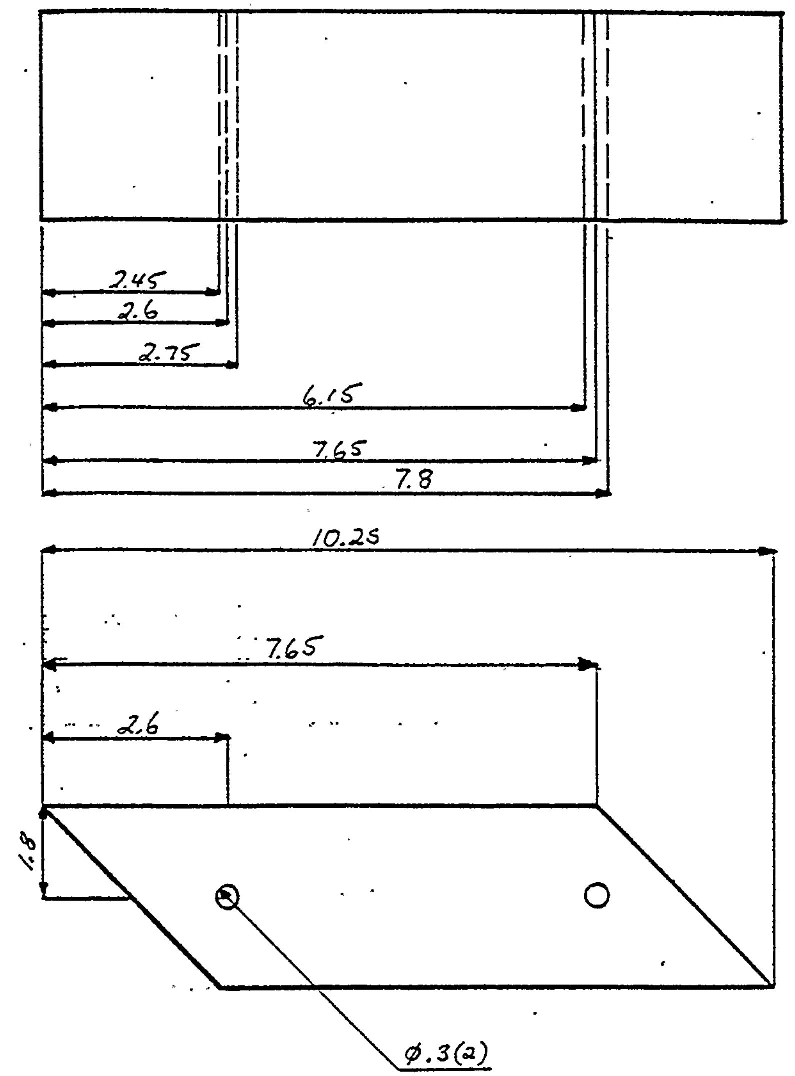
Drawn by: Eugene Armbruster

Drawing No. 133

SEAT SUPPORT
STRUCTURE-TRIANGLE

EXTRUSION COVER





NOTES:

MATERIAL: Wooden version - maple
Plastic version - PP

FINISHING: Wooden version - polyurethane coating

TOLERANCE: +/- .1 cm

Project: Elementary School Students' Work Station

Drawing: General Arrangement

Scale: 1:4

Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 134

SHELF TRIANGLE

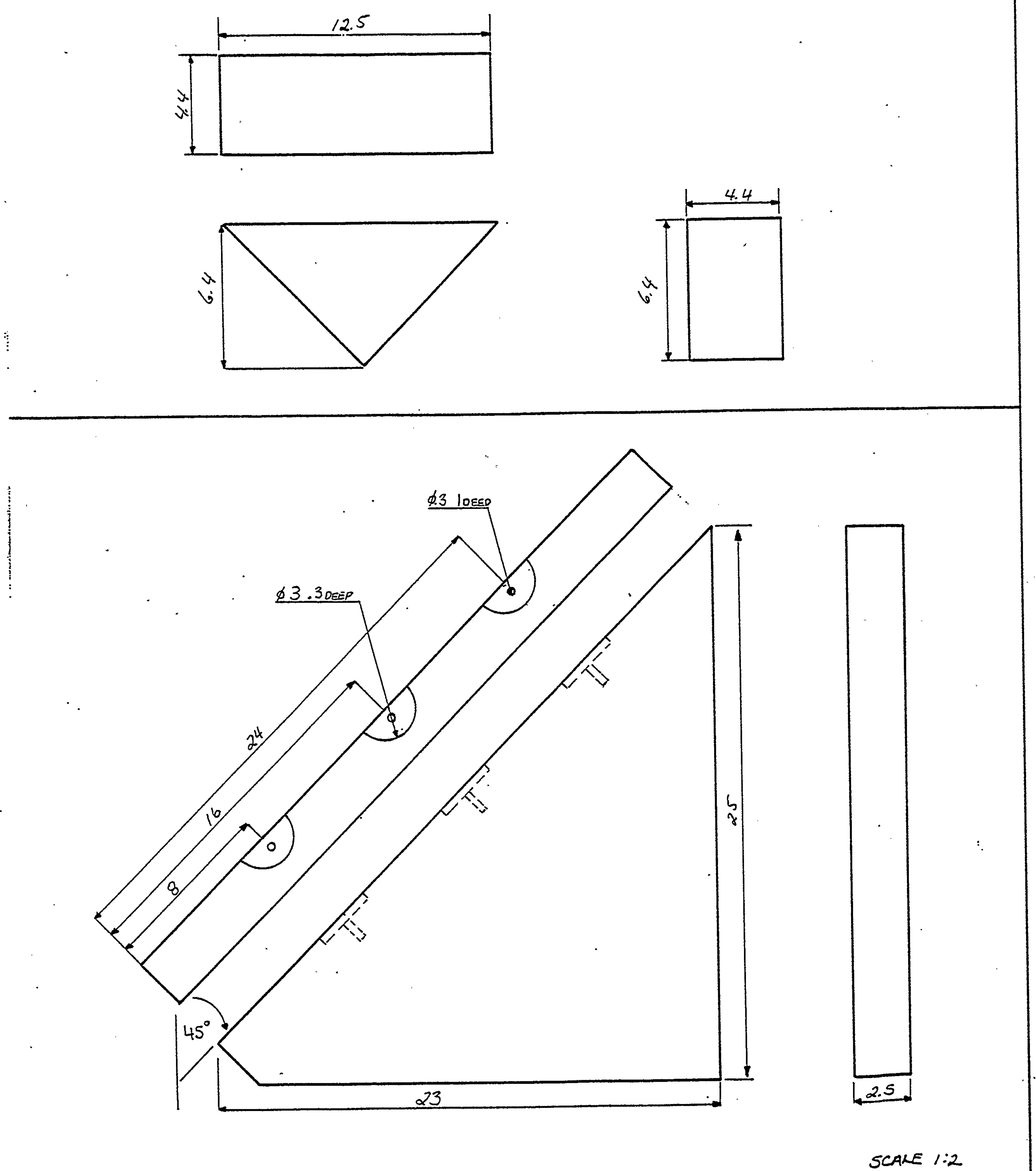
WORKSURFACE PLUG

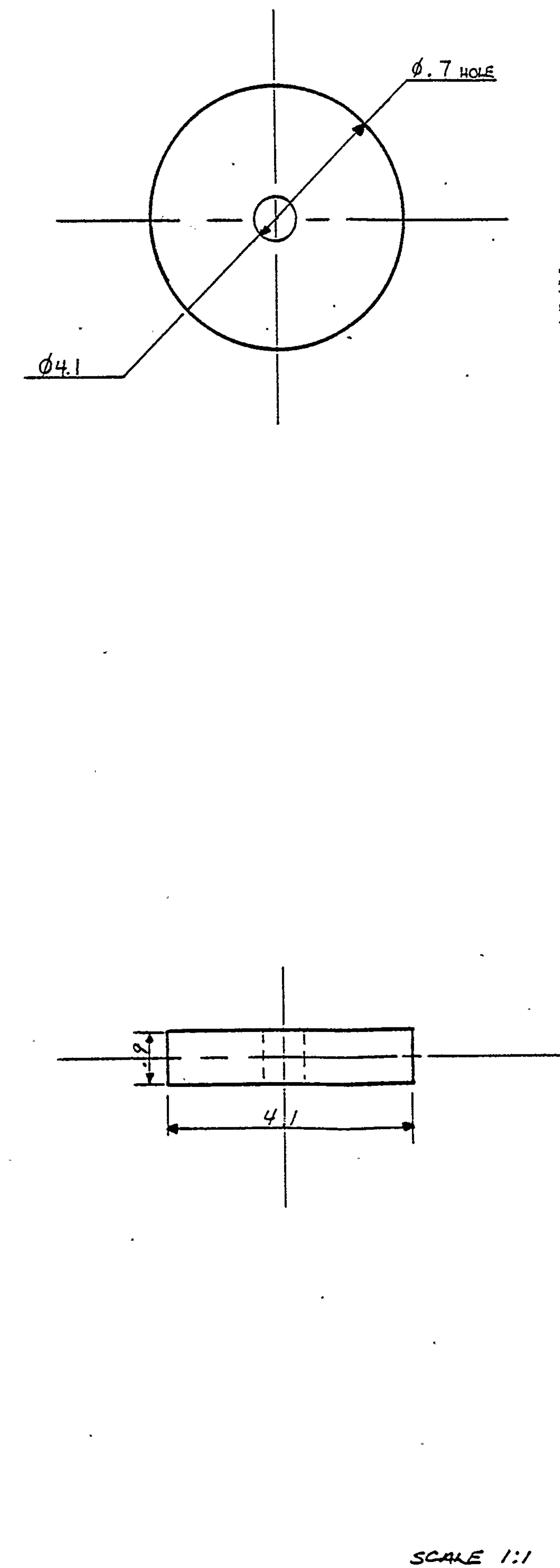
NOTES:

MATERIAL: Wooden version - maple
Plastic version - PP

FINISHING: Wooden version - polyurethane coating

TOLERANCE: +/- .1 cm





Project: Elementary School Students' Work Station

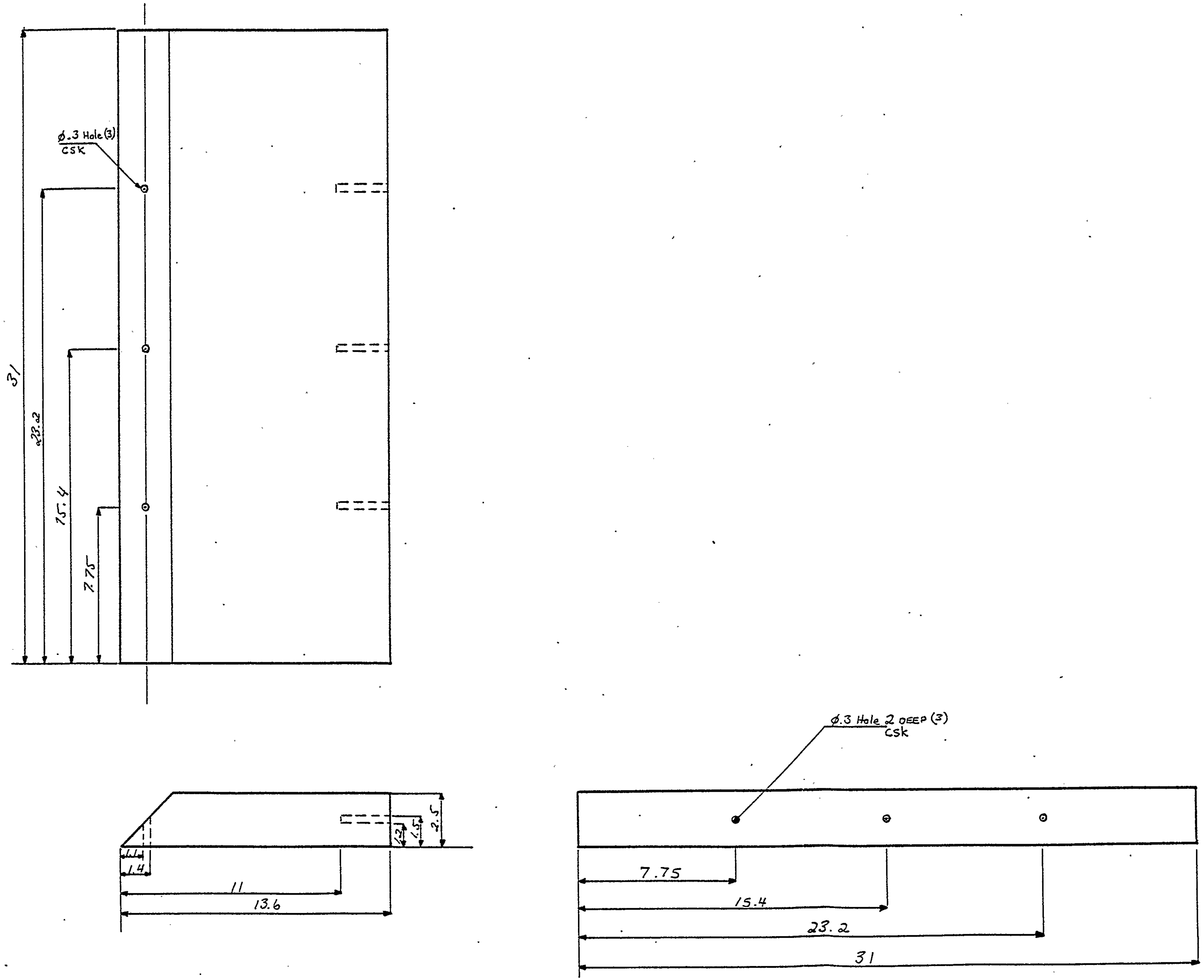
Drawing: General Arrangement

Scale: as shown

Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 135



SHELF TO WORKSURFACE ATTACHMENT

NOTES:

MATERIAL: Wooden version - maple
Plastic version - PP

FINISHING: Wooden version - polyurethane coating

TOLERANCE: +/- .1 cm

Project: Elementary School Students' Work Station

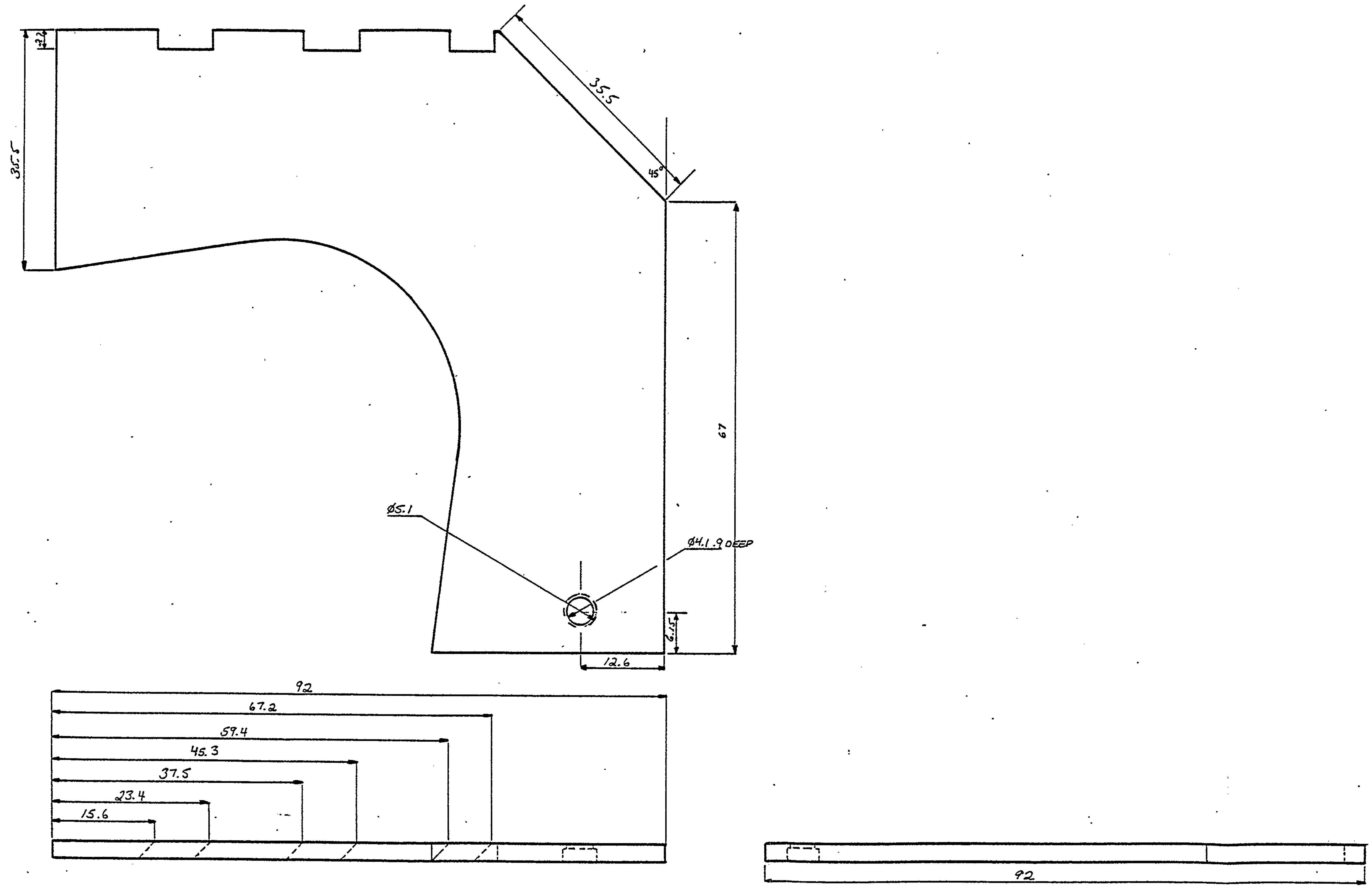
Drawing: General Arrangement

Scale: 1:2

Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 136



WORKSURFACE
NOTES:

MATERIAL: Wooden version - birch plywood.

FINISHING: Laminate top. Polyurethane coating to edges.

TOLERANCE: general tolerance is +/-.1cm. Angle tolerance is .5 degree.

Project: Elementary School Students' Work Station

Drawing: General Arrangement

Scale: 1:6

Drawn by: Eugene Armbruster

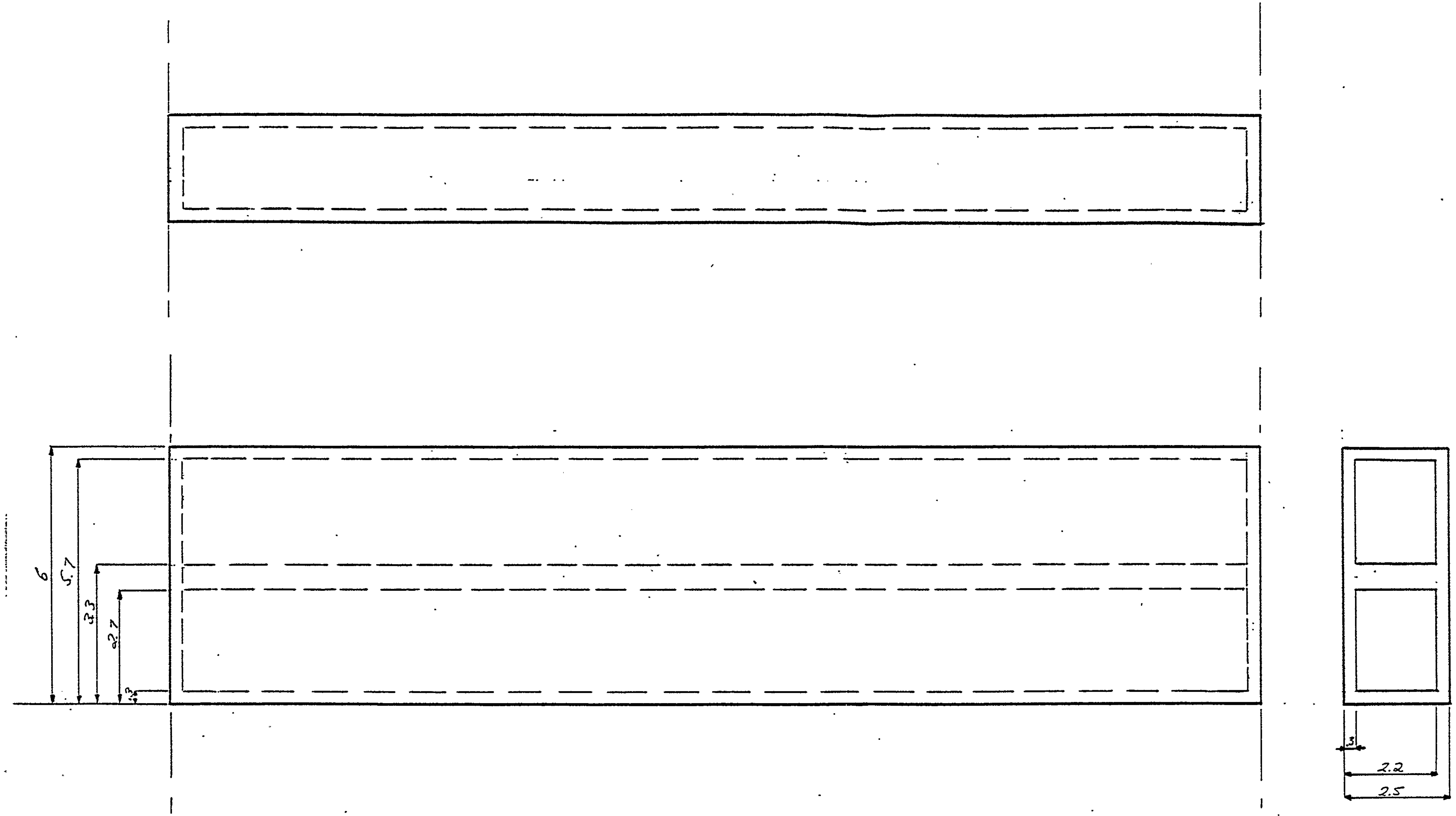
Dimensions in: cm

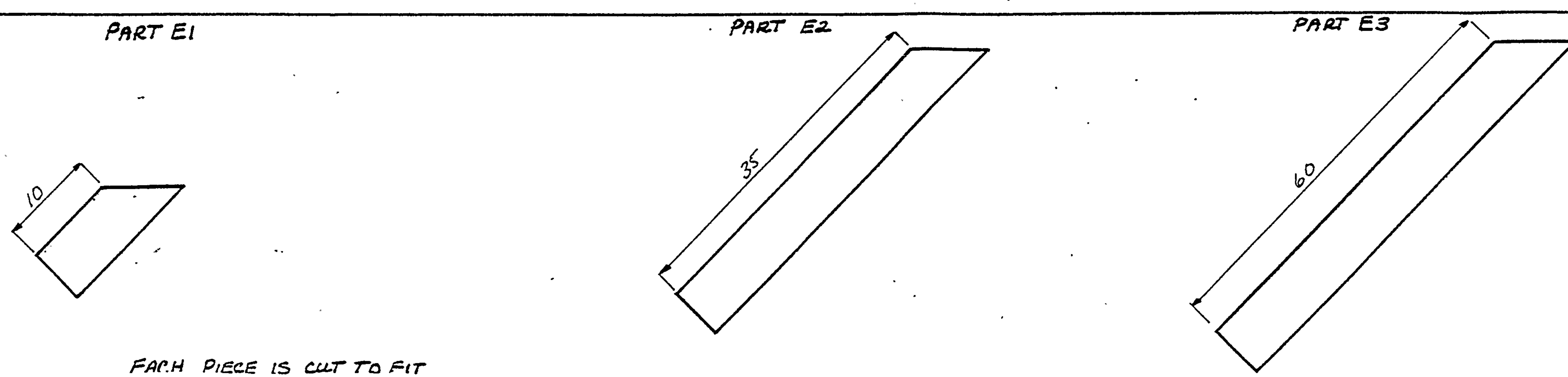
Drawing No. 137

CABLE PATHWAY GUIDE NOTES:

MATERIAL: Cold rolled steel

TOLERANCE: +/- .025cm





EACH PIECE IS CUT TO FIT

Project: Elementary School Students' Work Station

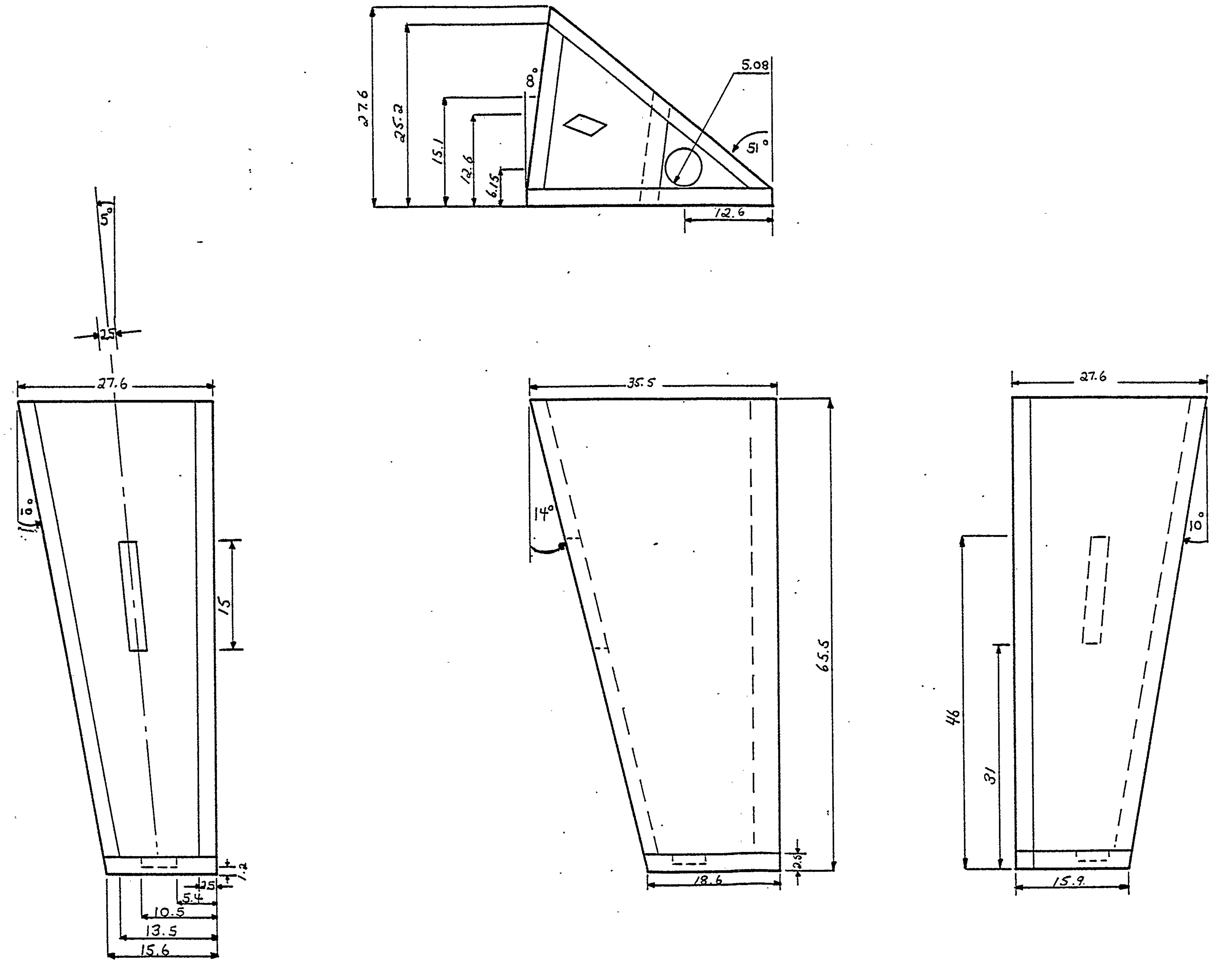
Drawing: General Arrangement

Scale: 1:4

Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 138



SEAT SUPPORT STRUCTURE NOTES:

MATERIAL: Wooden version: maple

Plastic version: polypropylene

FINISHING: Wooden version: polyurethane coating on wooden pieces.

TOLERANCE: general tolerance is +/-.1cm on wooden pieces. Angle tolerance is .5 degree.

Project: Elementary School Students' Work Station

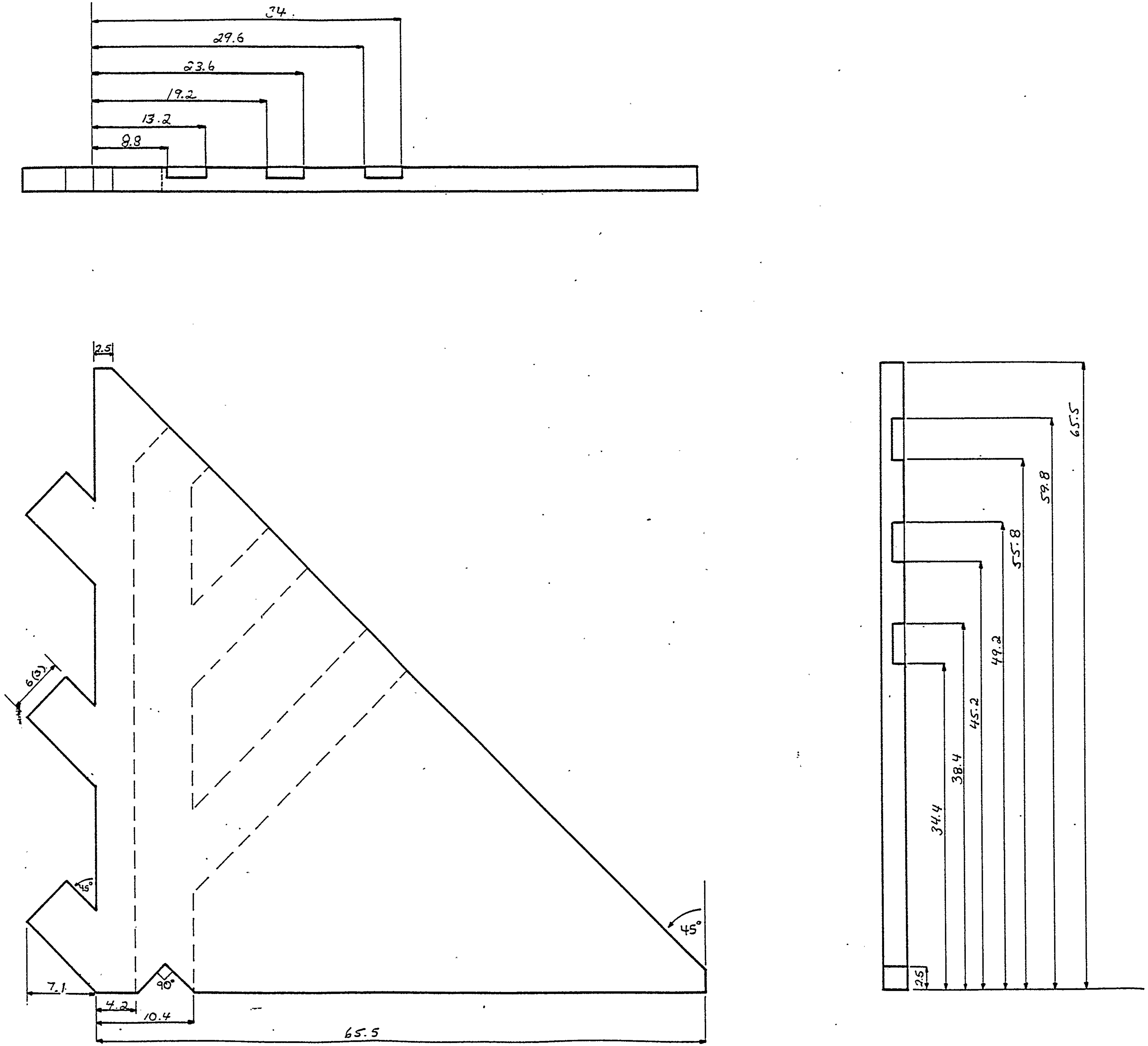
Drawing: General Arrangement

Scale: 1:6

Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 139



COMPUTER & SHELF SUPPORT
NOTES:

MATERIAL: Wooden version - maple.

FINISHING: Polyurethane coating to surfaces.

TOLERANCE: general tolerance is +/-.1cm. Angle tolerance is .5 degree.

Project: Elementary School Students' Work Station

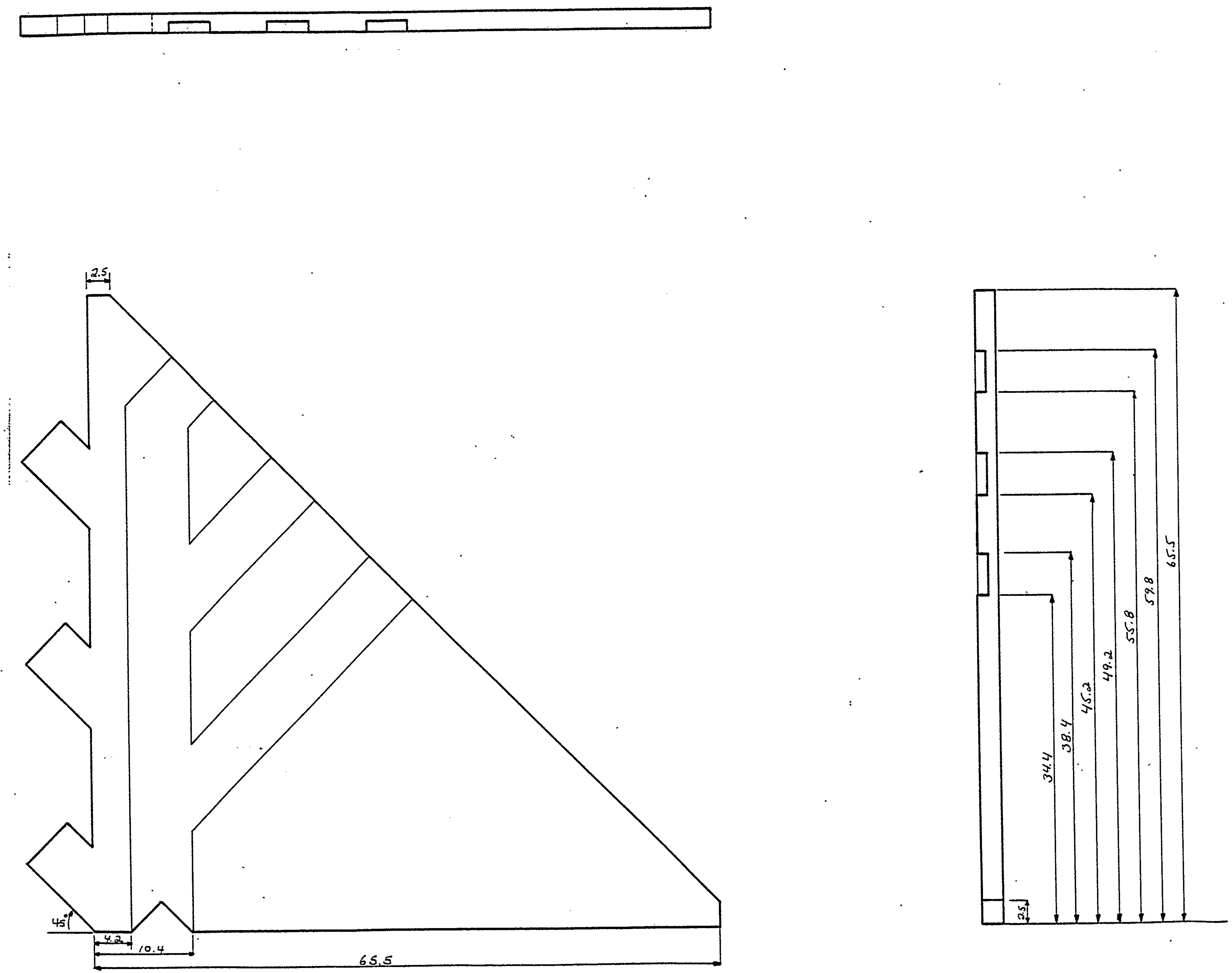
Drawing: General Arrangement

Scale: 1:4

Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 140



COMPUTER & SHELF SUPPORT
NOTES:

MATERIAL: Wooden version - maple.

FINISHING: Polyurethane coating to surfaces.

TOLERANCE: general tolerance is +/-.1cm. Angle tolerance is .5 degree.

Project: Elementary School Students' Work Station

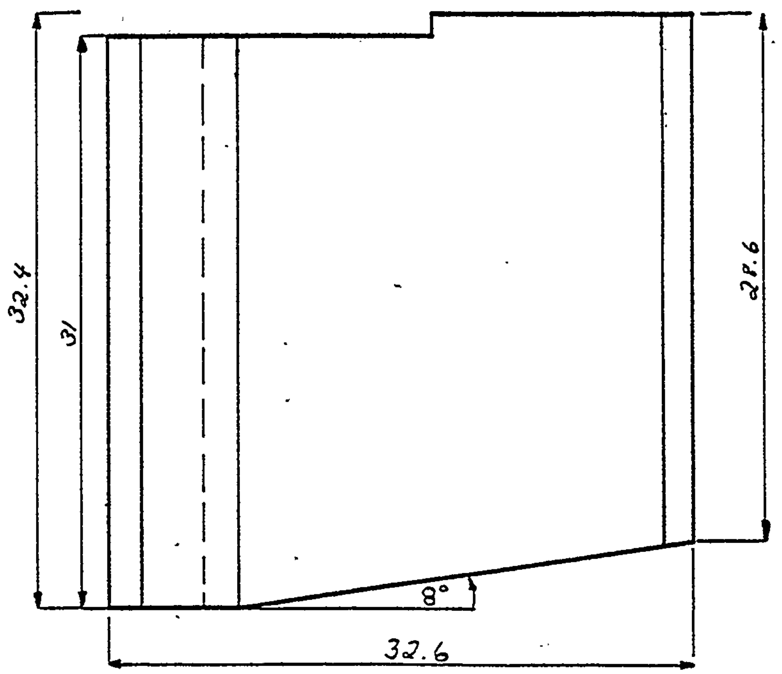
Drawing: General Arrangement

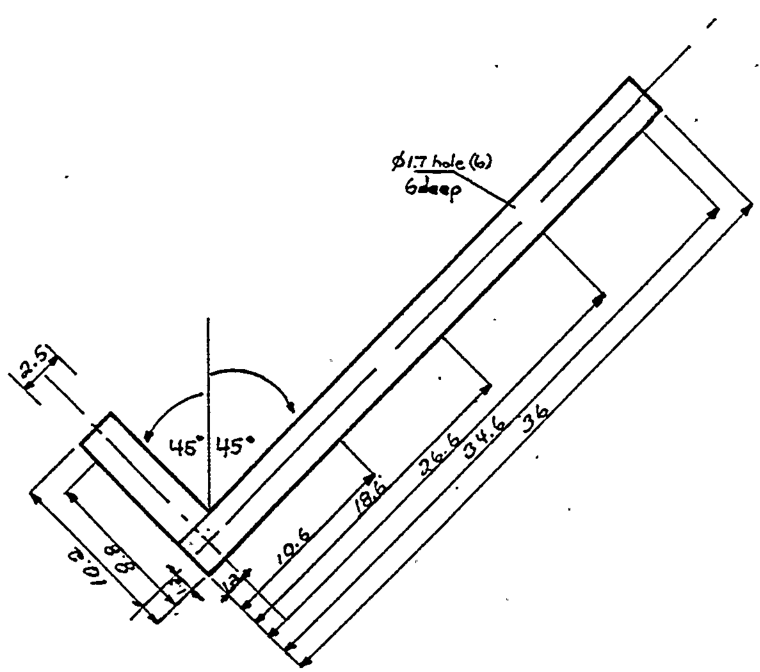
Scale: 1:4

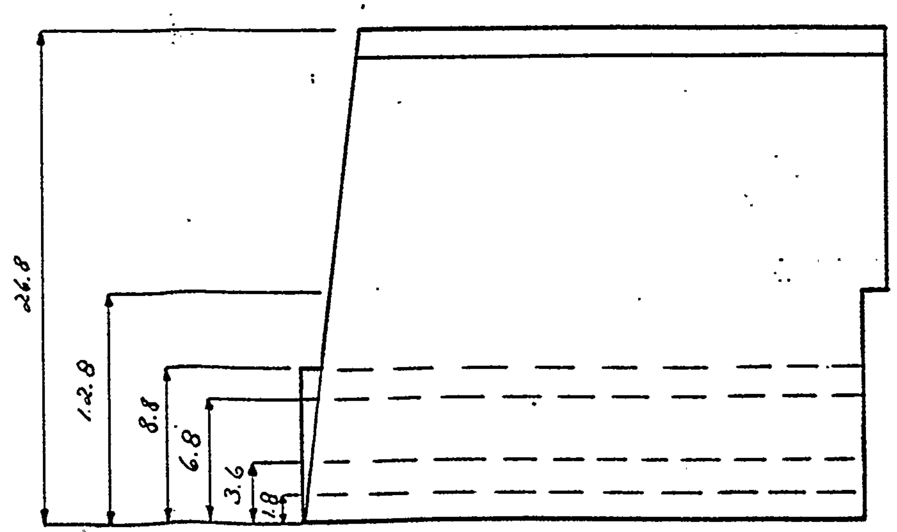
Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 141







SHELF STRUCTURE
NOTES:

MATERIAL: Wooden version - maple.

FINISHING: Polyurethane coating to surfaces.

TOLERANCE: general tolerance is +/-.1cm. Angle tolerance is .5 degree.

Project: Elementary School Students' Work Station

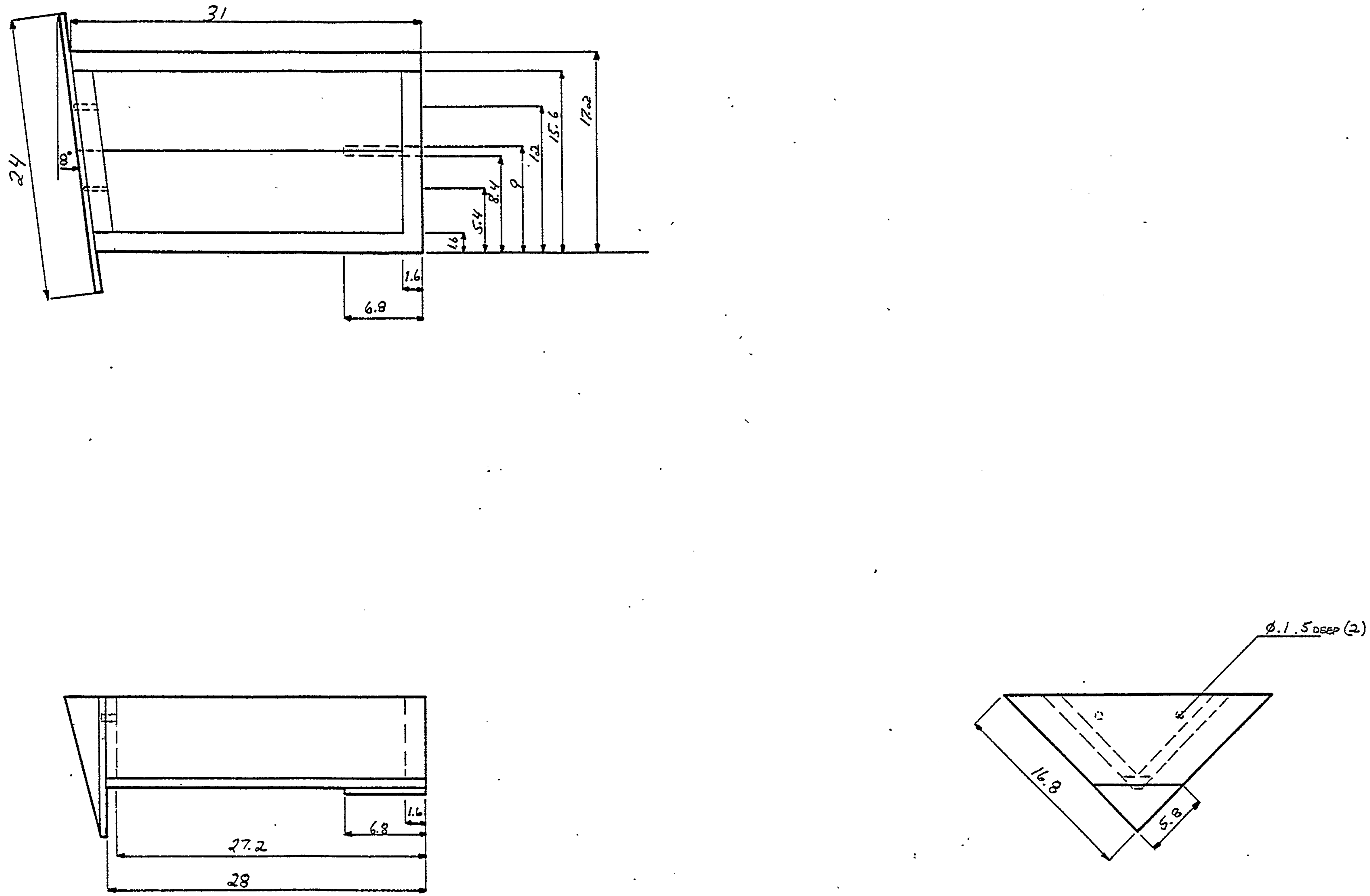
Drawing: General Arrangement

Scale: 1:4

Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 142



PERSONAL DRAWER
NOTES:

MATERIAL: Wooden version - maple
Plastic version - PP

FINISHING: Wooden version - polyurethane coating

TOLERANCE: +/- .1 cm

Project: Elementary School Students' Work Station

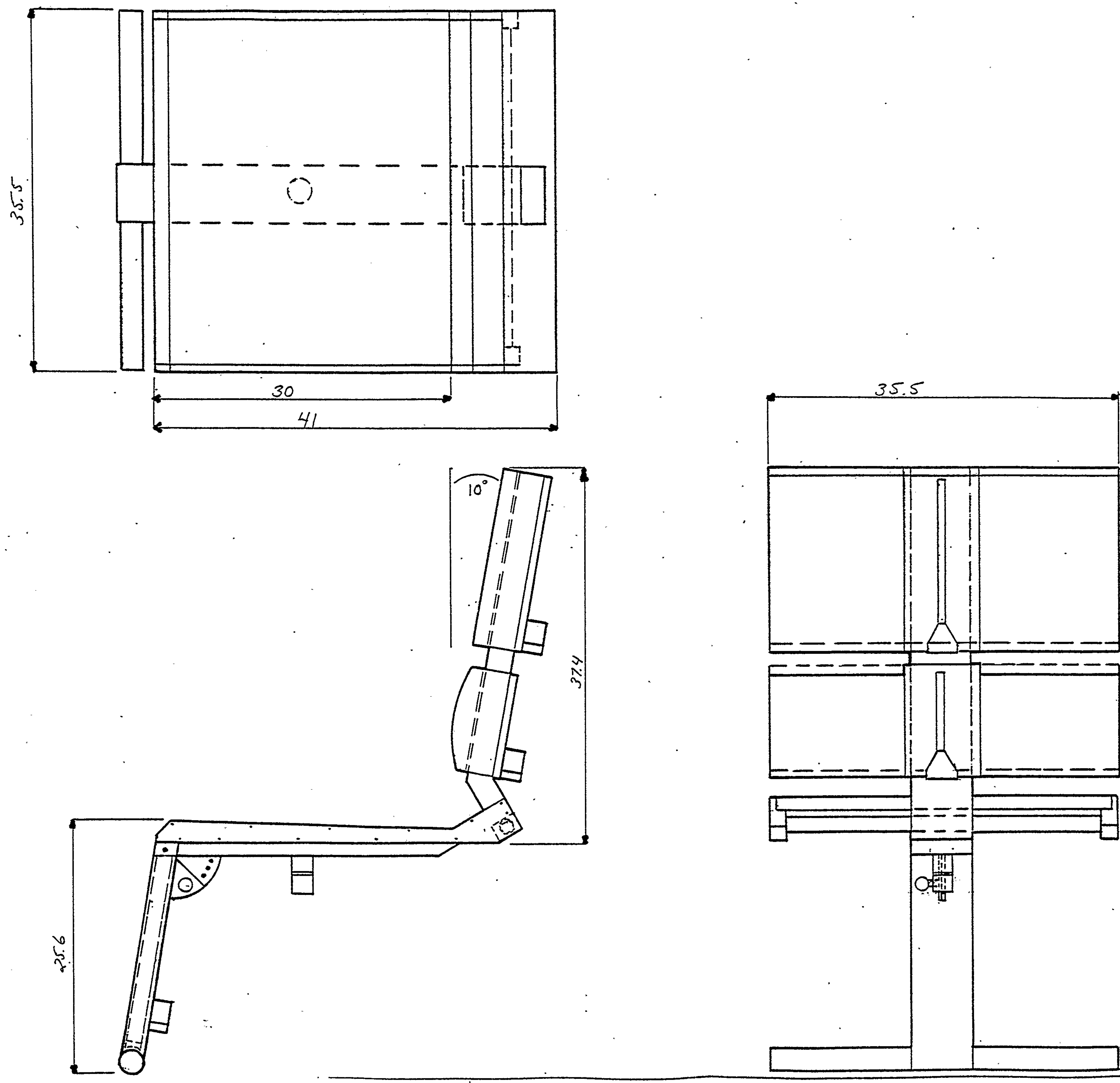
Drawing: General Arrangement

Scale: 1:4

Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 143



SEATING & FOOTREST DEVICE

NOTES:

MATERIAL: Wooden version: maple, cold rolled steel.

Plastic version: polypropylene, cold rolled steel.

FINISHING: Wooden version: polyurethane coating on wooden pieces. Powder coating on metal pieces.

Plastic version: Powder coating on metal pieces.

TOLERANCE: general tolerance is +/- .025cm on metal pieces and +/- .1cm on wooden pieces.

Project: Elementary School Students' Work Station

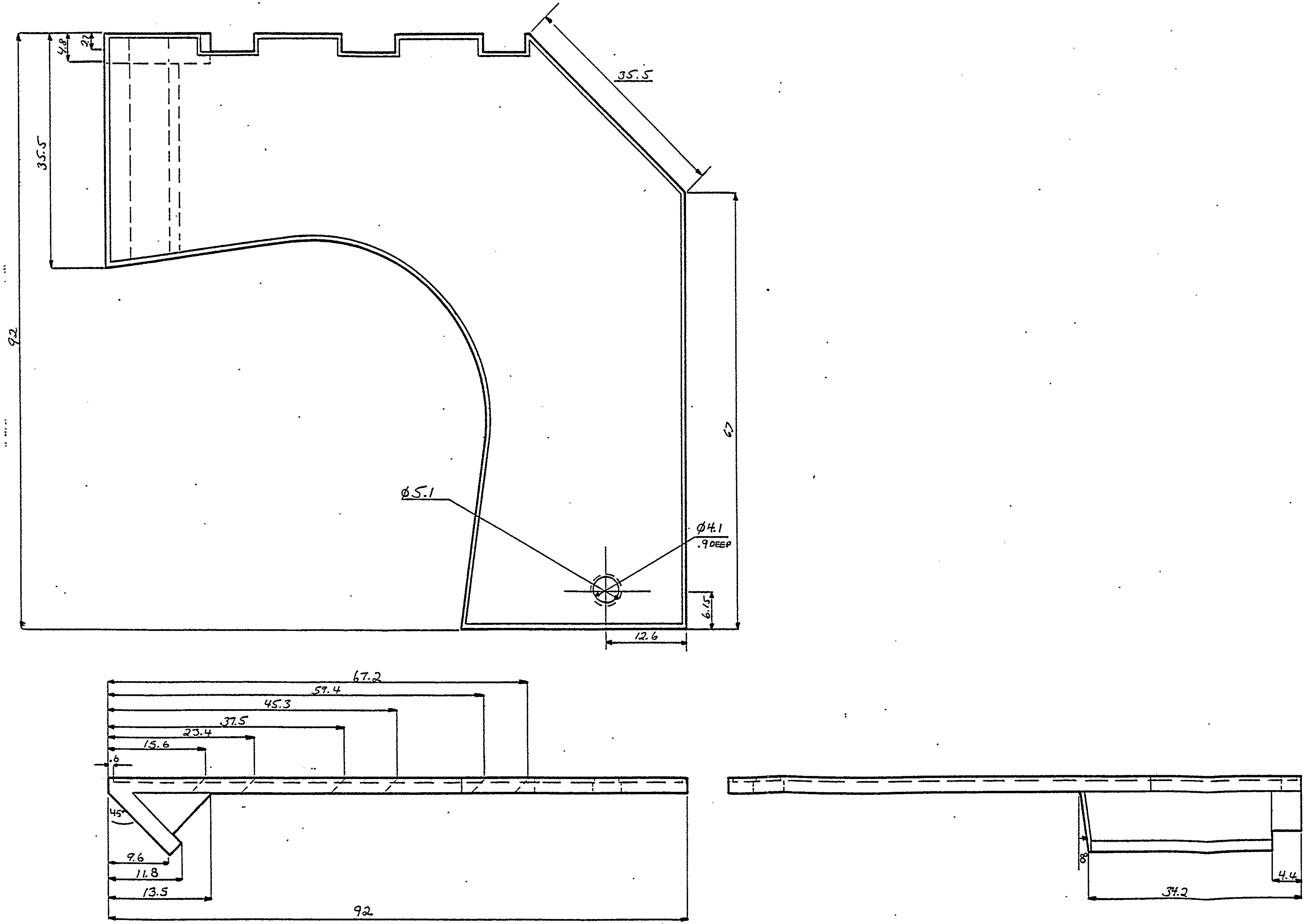
Drawing: General Arrangement

Scale: 1:4

Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 144



WORKSURFACE NOTES:

MATERIAL: Plastic version: polypropylene (glass reinforced) Recessed worksurface is made from birch plywood.

FINISHING: scrap removed.

TOLERANCE: general tolerance is +/-.025cm. Angle tolerance is .5 degree.

Project: Elementary School Students' Work Station

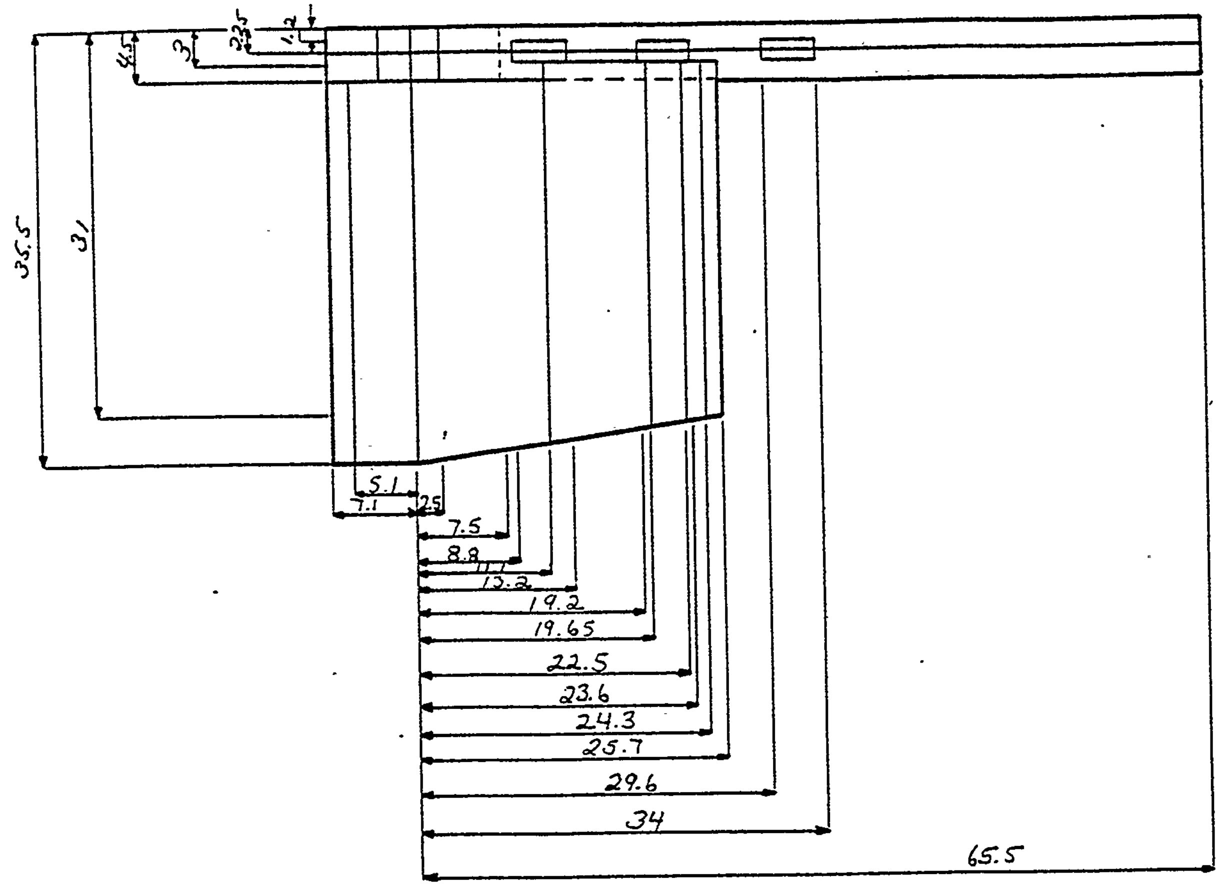
Drawing: General Arrangement

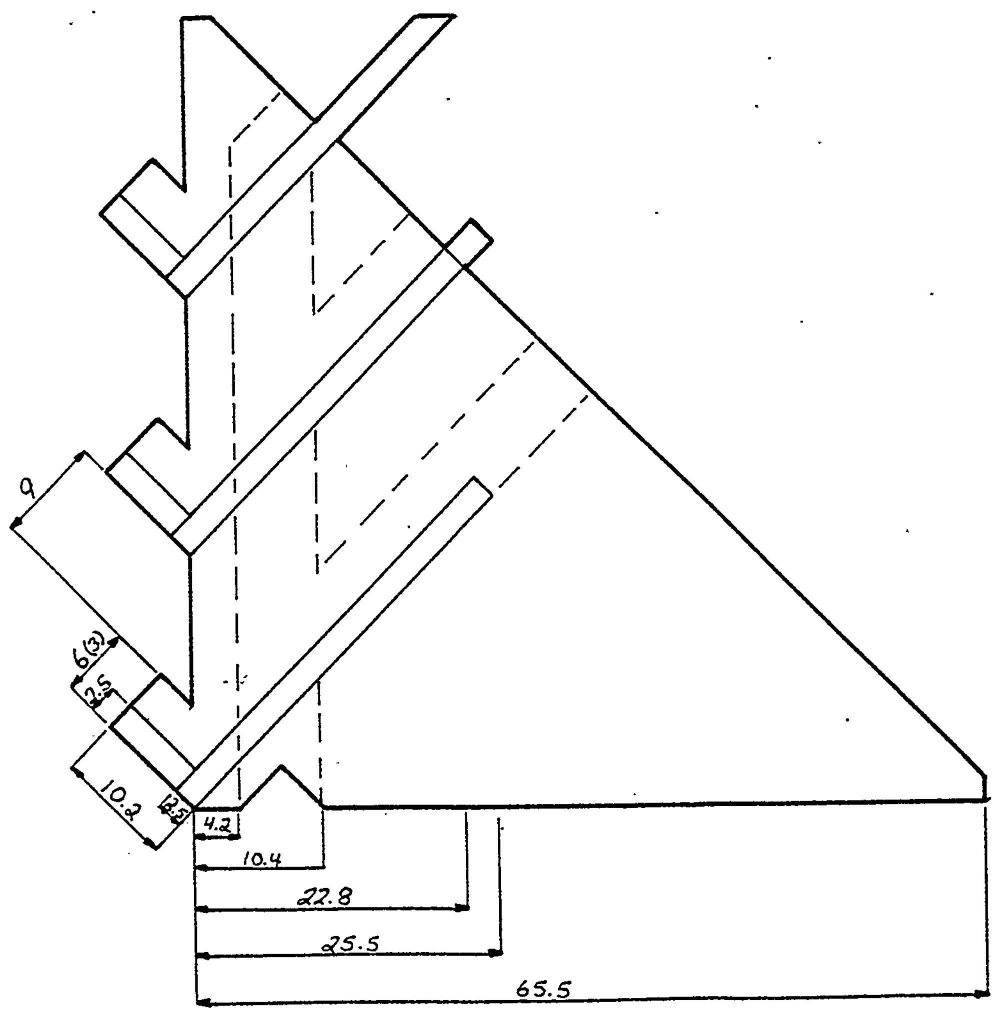
Scale: 1:6

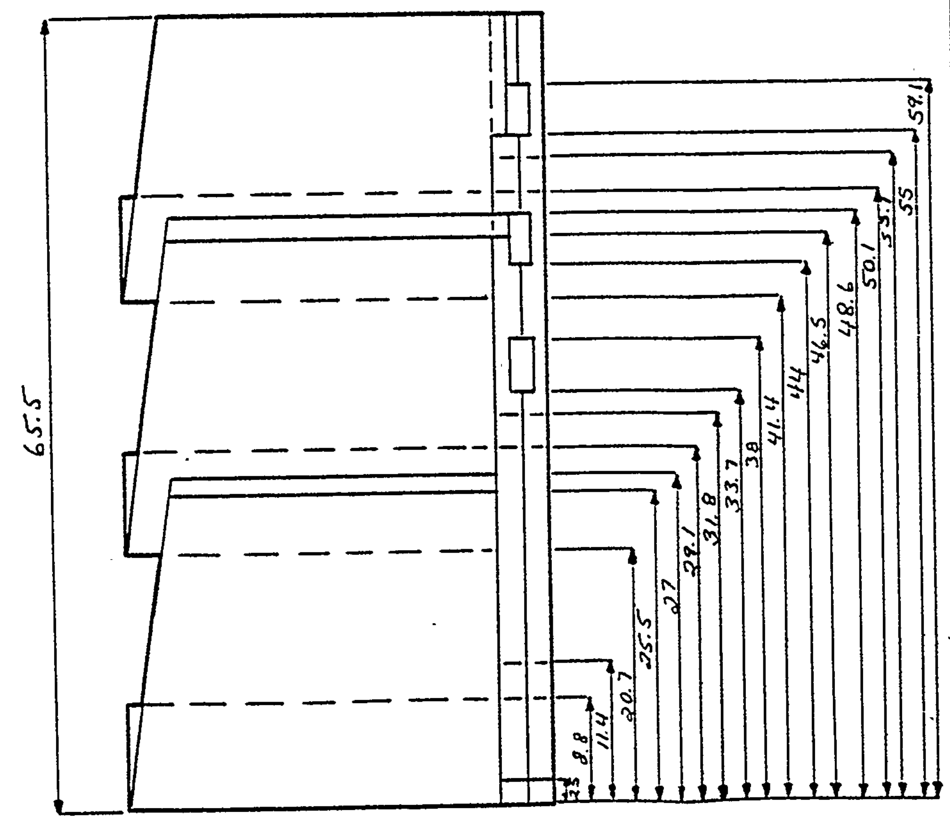
Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 145







SHELVES & COMPUTER SUPPORT STRUCTURE

NOTES:

MATERIAL: Plastic version: polypropylene (glass reinforced)

FINISHING: scrap removed.

TOLERANCE: general tolerance is +/-.025cm. Angle tolerance is .5 degree.

Project: Elementary School Students' Work Station

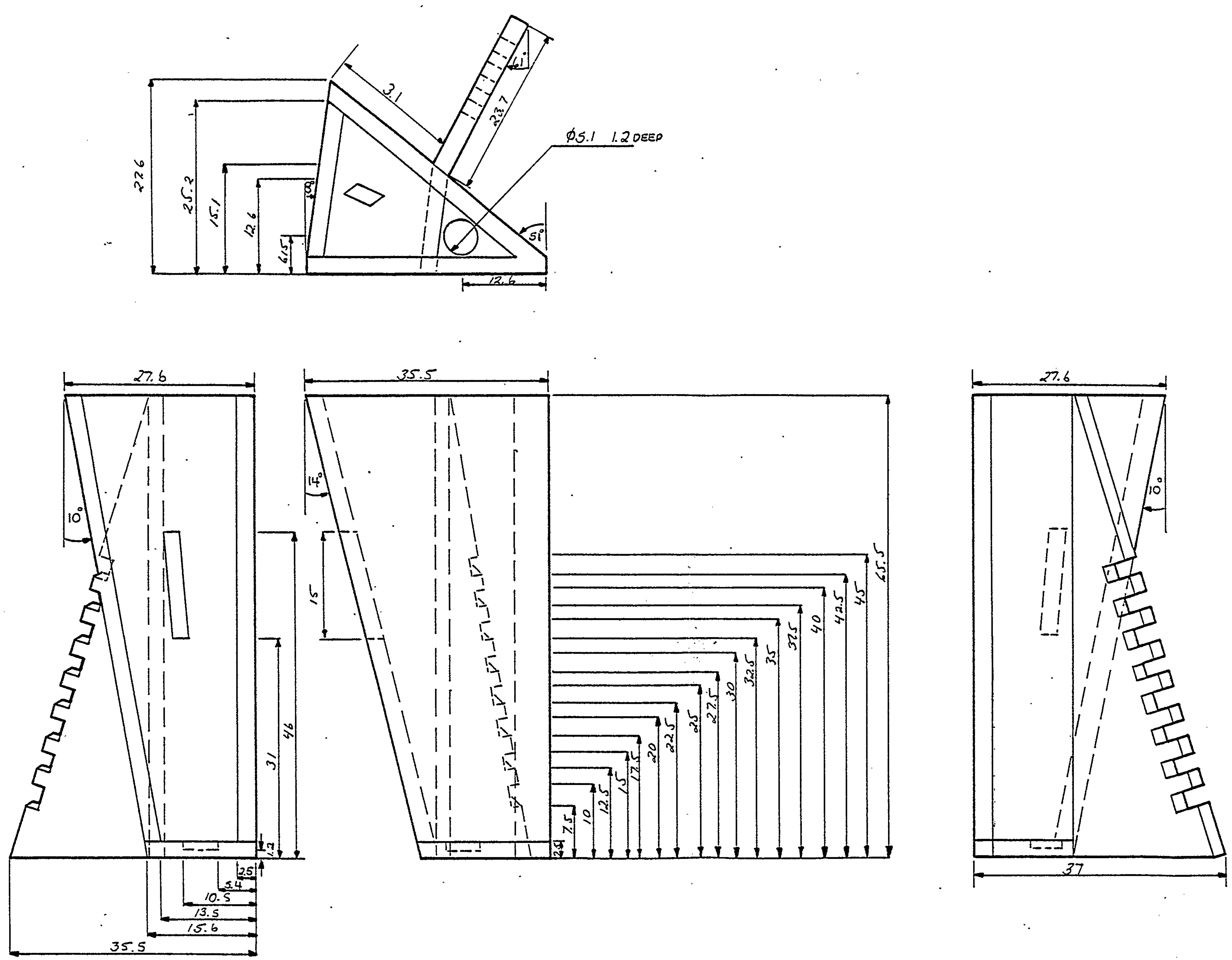
Drawing: General Arrangement

Scale: 1:6

Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 146



SEAT SUPPORT STRUCTURE NOTES:

MATERIAL: Plastic version: polypropylene (glass reinforced)

FINISHING: scrap removed.

TOLERANCE: general tolerance is +/-.025cm. Angle tolerance is .5 degree.

Project: Elementary School Students' Work Station

Drawing: General Arrangement

Scale: 1:6

Drawn by: Eugene Armbruster

Dimensions in: cm

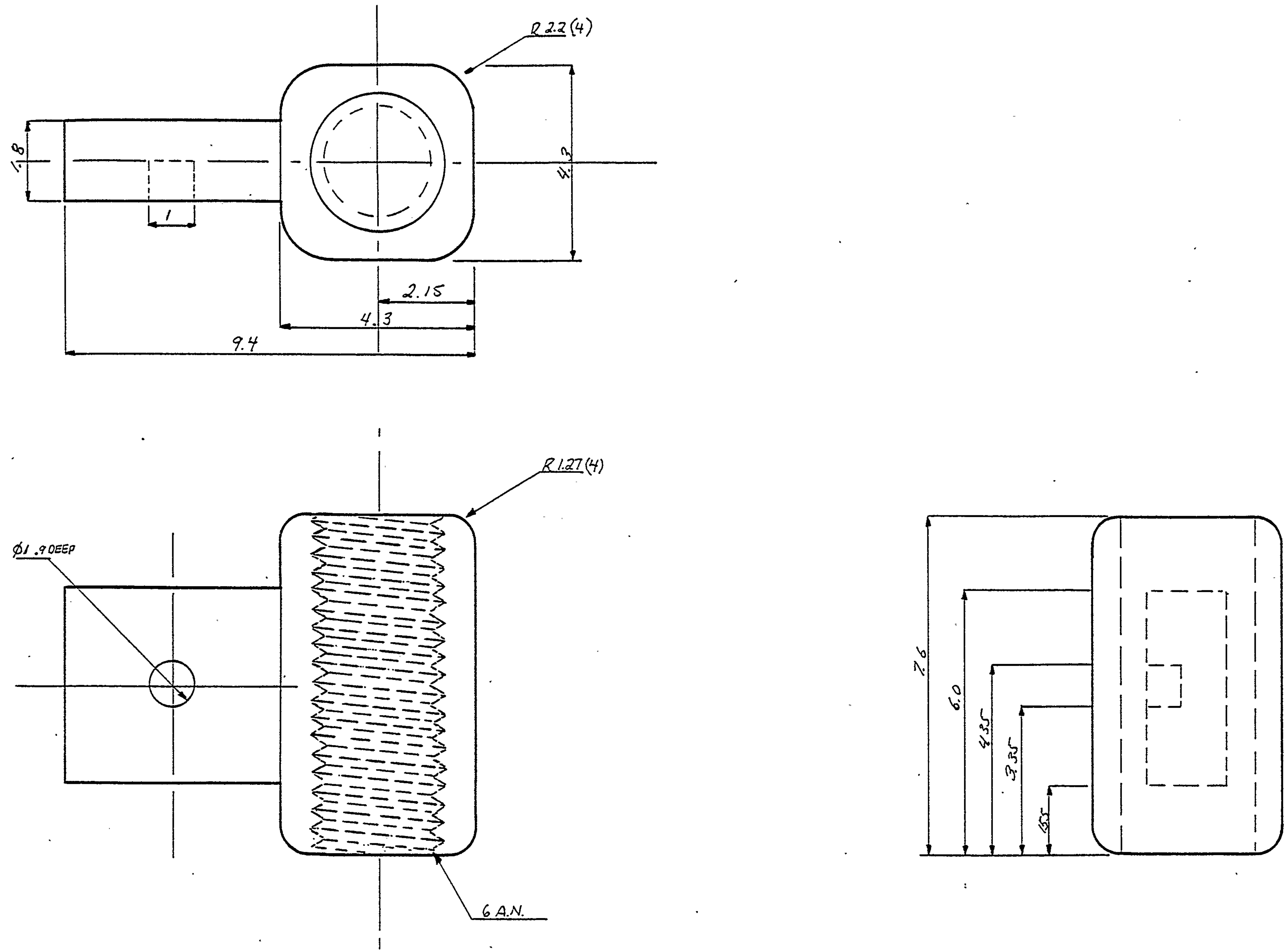
Drawing No. 147

SEAT BRACKET COLLAR

NOTES:

MATERIAL: Cold rolled steel

TOLERANCE: +/- .025cm



Project: Elementary School Students' Work Station

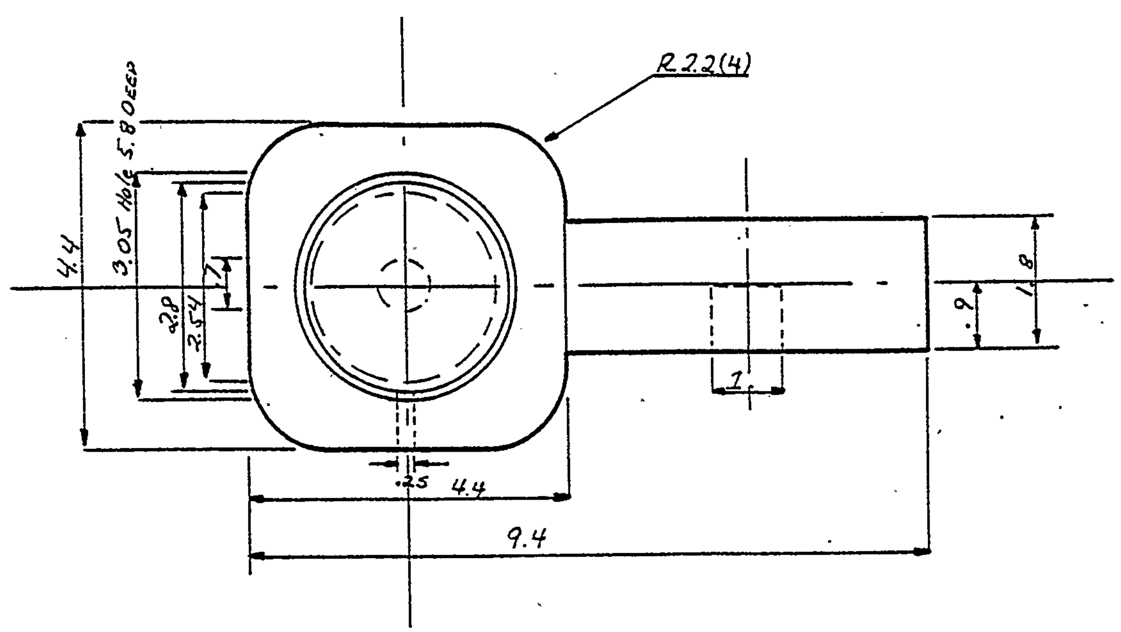
Drawing: General Arrangement

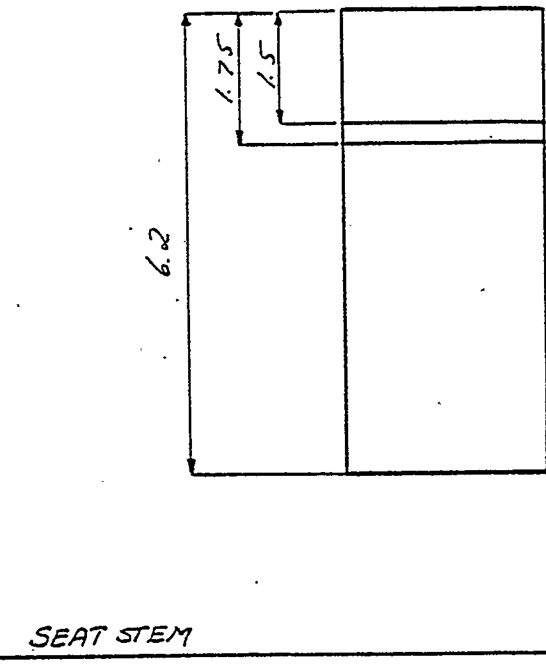
Scale: 1:1

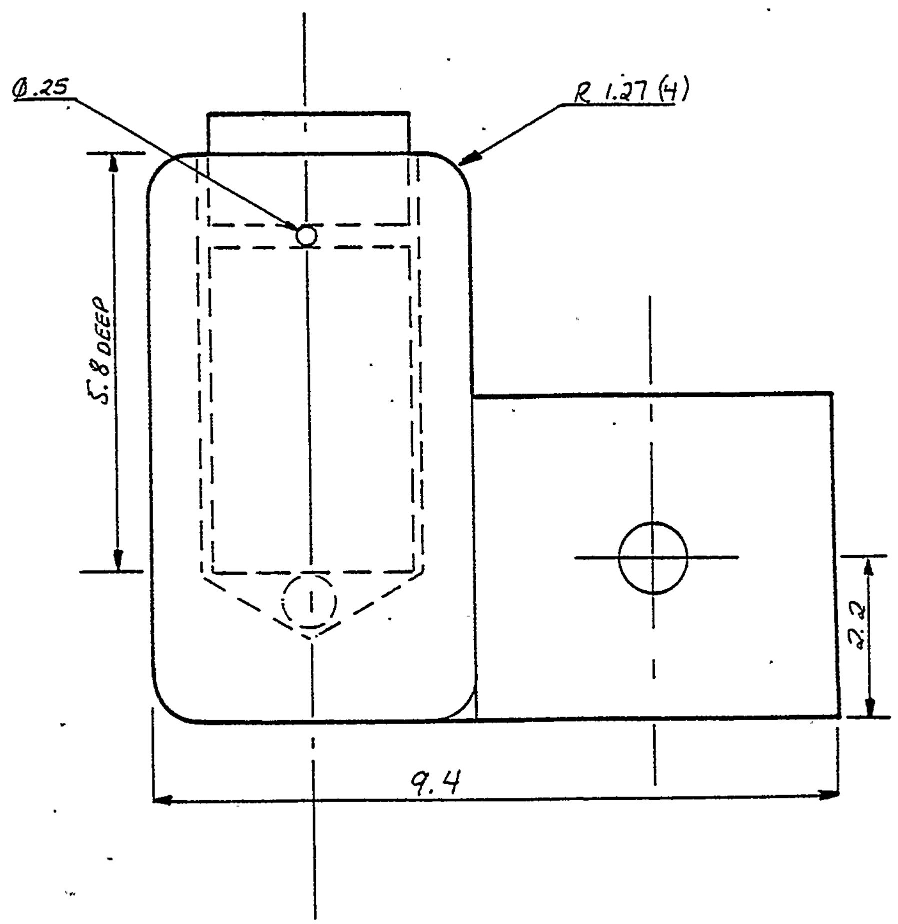
Drawn by: Eugene Armbruster

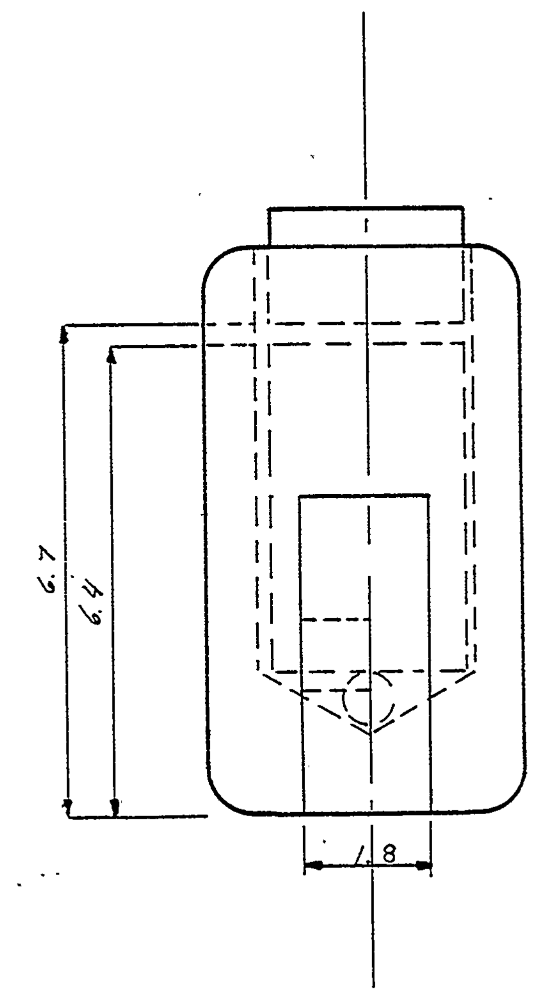
Dimensions in: cm

Drawing No. 148









SEAT PAN PIVOT INSERT

NOTES:

MATERIAL: Wooden and Plastic version - cold rolled steel

FINISHING: powder coating.

TOLERANCE: +/- .025 cm. Angle tolerance is .5 degree.

Project: Elementary School Students' Work Station

Drawing: General Arrangement

Scale: 1:1

Drawn by: Eugene Armbruster

Dimensions in: cm

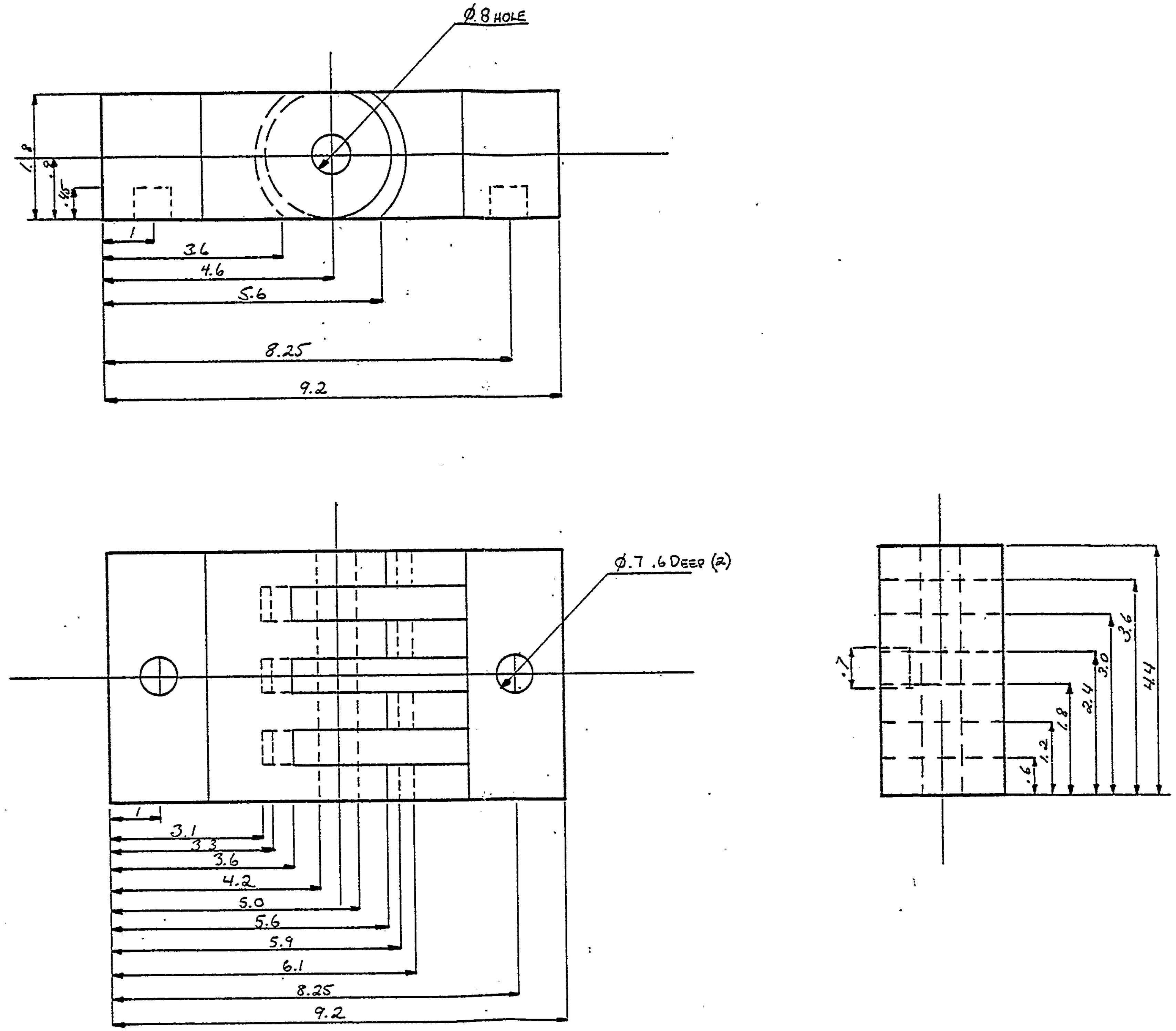
Drawing No. 149

SEAT BRACKET HINGE
NOTES:

MATERIAL: Wooden and Plastic version - cold rolled steel

FINISHING: powder coating.

TOLERANCE: +/- .025 cm. Angle tolerance is .5 degree.



Project: Elementary School Students' Work Station

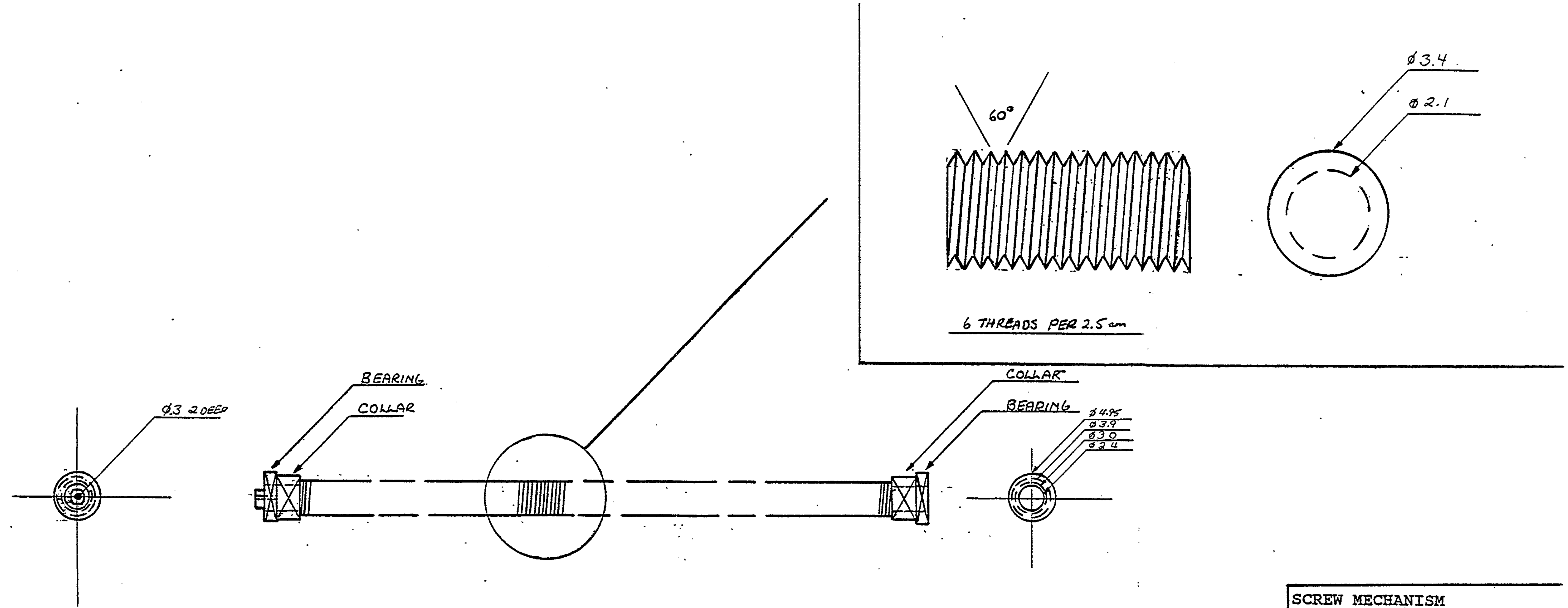
Drawing: General Arrangement

Scale: 1:1

Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 150



SCREW MECHANISM

NOTES:

MATERIAL: Cold rolled steel

TOLERANCE: +/- .025cm

Project: Elementary School Students' Work Station

Drawing: General Arrangement

Scale: 1:4

Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 151

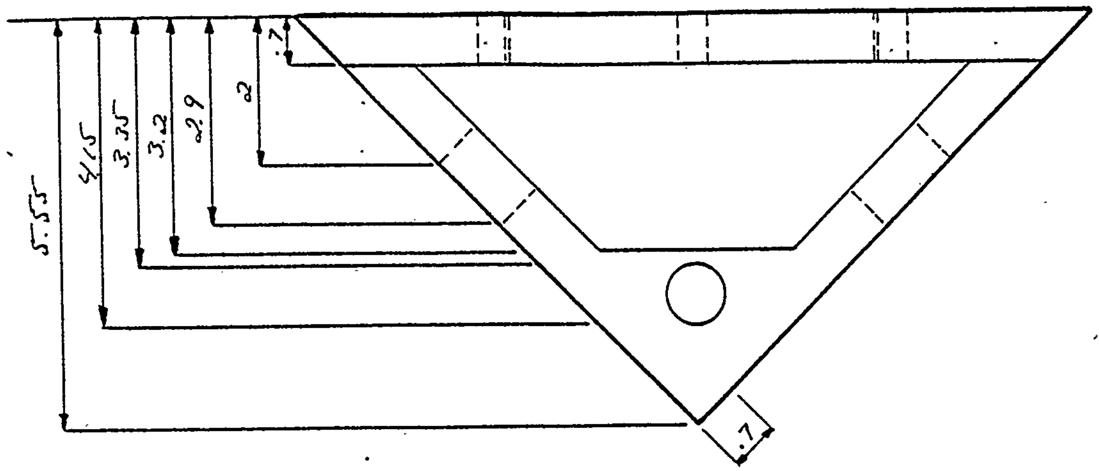
CABLE SECURING DEVICE

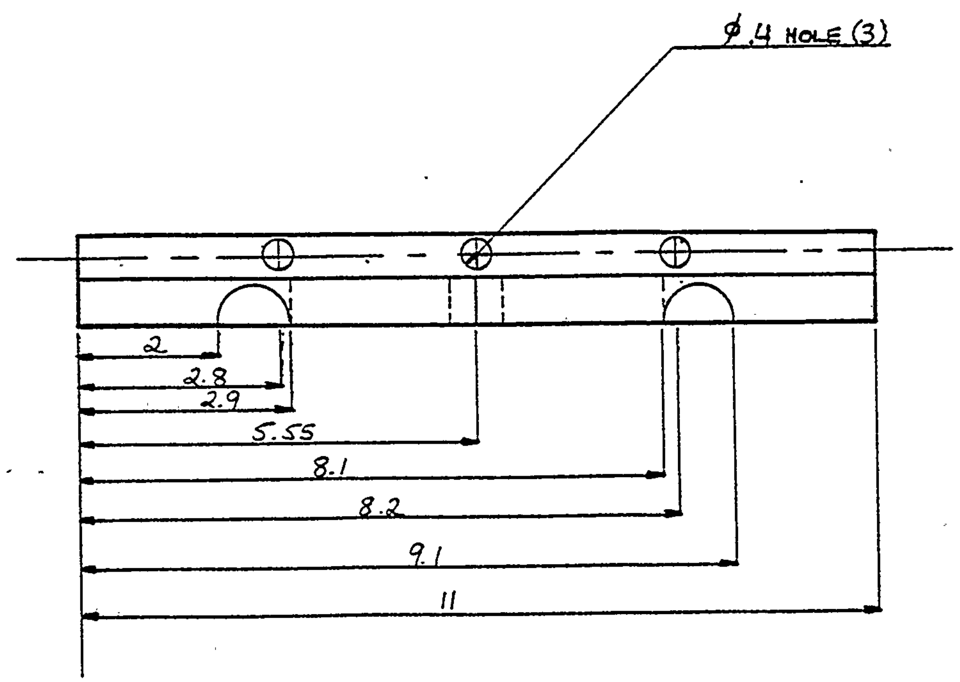
NOTES:

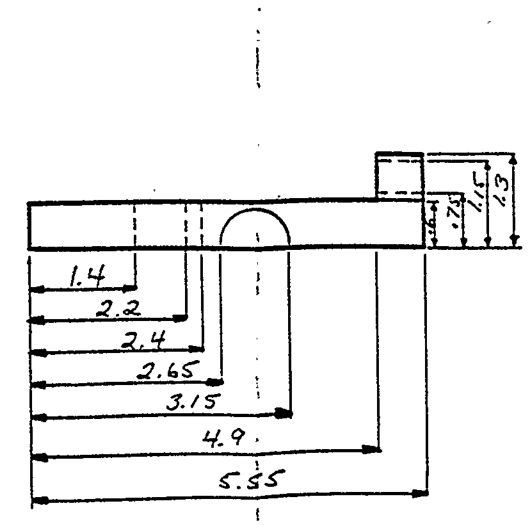
MATERIAL: Wooden and Plastic version - cold rolled steel

FINISHING: powder coating.

TOLERANCE: +/- .025 cm. Angle tolerance is .5 degree.







Project: Elementary School Students' Work Station

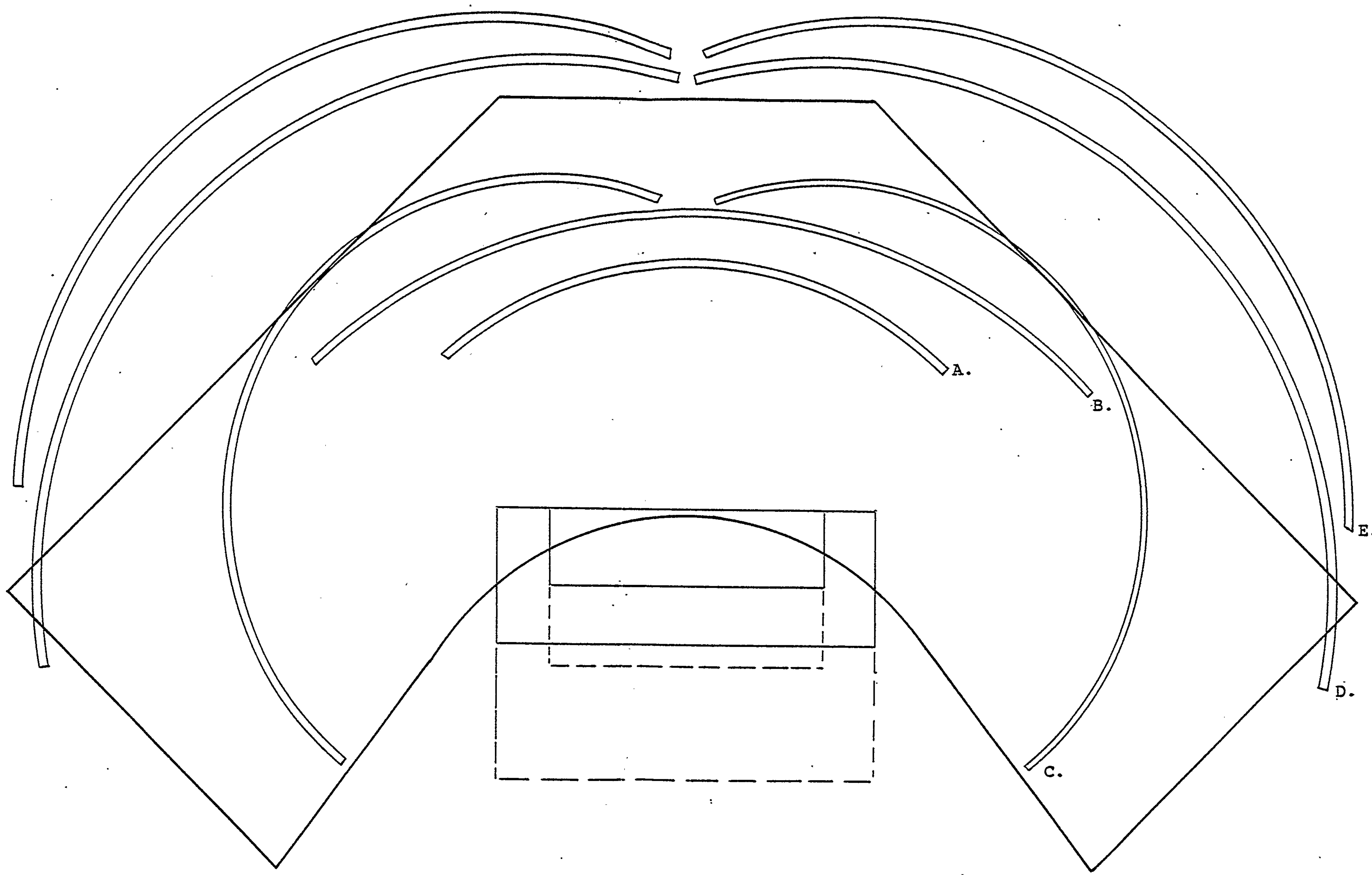
Drawing: General Arrangement

Scale: 1:1

Drawn by: Eugene Armbruster

Dimensions in: cm

Drawing No. 152



Reach Envelope Diagram

5th percentile 8 year old female
95th percentile 12 year old female

A. 8 year old female buttock to knee envelope
B. 12 year old female buttock to knee envelope
C. Working area of 8 year old female
D. Working area of 12 year old female
E. Zone of comfortable reach of 8 year old femal

Drawing No. 153

Source: Pheasant (1986)