CONSIDERATIONS IN THE DESIGN AND DEVELOPMENT OF SCHOOL FURNITURE FOR DEVELOPING REGIONS BASED ON LOCAL RESOURCES

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ABSTRACT

In many, if not most, of the underdeveloped and developing countries of the world, school furniture is poorly designed, of low quality, and often unfit for school use, yet it is costly and consumes a disproportionate share of limited educational budgets. This situation need not continue. Our research indicates that attractive, well-designed, durable, maintenance-free furniture can be produced from locally available woody materials, including plantation thinnings and semi-processed materials such as pallet deckboards, by local industry. Only the simplest machining and joinery processes are required to construct the furniture. Cost of the furniture is generally less than that of competing products, yet performance tests indicate that the furniture produced is very durable. Thus, attractive, sturdy, easily maintained furniture can be produced from local woody materials at a modest cost in any developing country.

Education of children is held as a sacred trust by every civilized nation. It is an especially important charge in developing regions of the world where education of children has long been regarded as a key to economic progress.

Education is expensive, regardless of the nation or region in which it is practiced, whereas financial resources available for education are universally limited. Financial support for the education of children in underdeveloped regions is particularly limited, however, amounting in many cases to no more than a few dollars per child (6). Hence, funds for physical facilities that contribute to the learning environment are largely lacking. School furniture presents a particularly onerous problem. On the one hand, proper-fitting functional school furniture contributes to the comfort and sense of well-being of the children and thereby facilitates learning. On the other hand, school furniture in developing regions tends to be expensive, but poorly designed, both structurally and ergonomically, and ill-suited to its intended purpose. These problems arise largely because the furniture has not been optimally designed to meet school service requirements either from a structural or a production point of view.

For many countries, the solution to the problem lies in the design of furniture specifically suited to school needs that can be constructed from locally available materials by local industry using only low-technology production processes. The challenge in producing such furniture is two-fold: 1) can school furniture be produced from locally available materials? and 2) can high-technology processes be simplified to the extent that they can be used in cottage industries? In the case of developing regions, a greater latitude exists in the production processes available for production of the furniture, but the underlying precepts remain largely the same.

This paper deals primarily with feasible solutions to chair and desk frame constructions (5). Use of slats in the construction of seats is briefly discussed, and a method of forming back and top rails for chairs is also shown. Construction of desk tops is not discussed. Medium density fiberboard provides an immediate solution to the problem, but the search for solutions based

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on use of locally available materials forms the basis for ongoing research.

**Overview of Basic Concepts**

School furniture should be designed and engineered to most efficiently utilize the resources of the country while simultaneously satisfying the primary objective of providing children with furniture that facilitates and contributes to their learning. Thus, it should conform to appropriate national performance quality standards, be ergonomically correct, and be aesthetically pleasing.

Intuitively, it is expected that school furniture should be designed for maximum durability. Therefore, it should be structurally sound and designed in keeping with rational engineering principles. Ideally, the furniture should be modular in design, with many interchangeable parts so that any desired functional design can be assembled from a common pool of parts. Thus, the fastening systems should allow the furniture to be readily assembled from components. Finally, the furniture should be designed so that it can be easily maintained and simply repaired. Hence, joints used in construction of the furniture should be inherently reliable, easily inspected, and readily repaired, and finishes should be easy to apply and maintain.

The design of the furniture should also be appropriate to the production technology of the region. Design of the furniture should be such that many parts as well as some complete pieces can be produced by local cottage industries, whereas other parts, assembling, and completed pieces should be designed to efficiently utilize factory production techniques.

Design of the furniture should be based on the use of locally available materials such as woody stem plantation thinnings and other agricultural wastes but must also allow for the use of semi-processed supplementary wood materials such as pallet boards.

**Conversion of Tree Stems into Furniture Parts**

The most likely source of material for construction of school furniture, particularly in remote regions, is small woody stems obtained from plantation thinnings, perhaps 4 to 9 inches in diameter (11), or from smaller saplings grown specifically to provide the materials of construction. Traditionally, however, the production of wood furniture parts requires that mature tree stems first be cut into lumber, which is then further processed into various furniture parts such as chair back posts, side rails, etc. There are several processing advantages associated with this procedure; the most important is that the lumber is available in flat rectangular shapes of uniform specified sizes that can be obtained in a stabilized condition, i.e., dried. A major problem, however, is that relatively large tree stems are required for efficient processing into lumber, i.e., the smaller the stem, the greater the waste associated with the processing. Hence, more efficient processes must be considered for the conversion of small woody stems into school furniture; conventional production processes must be re-thought and re-engineered. In general, there are at least five processes that deserve consideration; these are discussed in the following sections.

**Conversion of Stems to Lumber with Thin-Kerf Saws**

Small stems, often of short length, are cut with thin-kerf saws (4) into lumber whose thickness is closely related to the desired thickness of the furniture parts to be cut from it. Because the lumber is cut with a thin-kerf saw, only minimum planing is required to remove saw marks and machine the part to a desired thickness. When the lumber is cut from short bolts, the overall size of the part may closely correspond to the dimensions of the board.

**Conversion of Stems to Squares**

When suitable equipment is available, small stems may be converted into squares and rectangles that in turn may be converted into furniture parts such as front and rear back posts for chairs and legs for tables and desks. The principal problems anticipated in working with squares cut from small stems (which include the center of the stem) are subsequent splitting of the material as the wood dries, along with twisting and warping. Only those woods with good drying and shrinking and swelling characteristics should be selected for use in this type of construction.

**Conversion of Stems to Dowels**

Stems may be processed into large- and small-diameter dowels of standard size by passing them through doweling machines. These dowels may then be converted by further turning and drilling operations into rails, legs, back posts, and other furniture parts that, in turn, may be assembled into several types of furniture similar to that known in the United States as mountain furniture. This type of construction has a major advantage in that relatively small stems may be used. Hence, this process is able to make use of what is otherwise likely to be waste material. In addition, plantings made for the specific purpose of producing school furniture may be harvested and converted to parts after a relatively short growing period.

Stems converted into dowels should have essentially the same growth-related properties as those converted directly into parts. Primary concerns include severe checking and splitting of the dowels as the wood dries. Therefore, this conversion process has the disadvantage that it is largely limited to those select species whose stems dry without splitting. It is also very important for the stems to have a solid core. Wood species that satisfy these criteria vary from region to region. In the Central American country of Costa Rica, for example, Cabrellia (Carob guianensis) and Gmelina (Gmelina arborea) satisfy the above criteria, whereas small-diameter teak (Tectona grandis) stems are not well-suited for direct conversion into dowels because of their unsound pith (3).

**Direct Conversion of Stems to Parts by Sawing**

Parts such as table legs and back posts of chairs may be sawn directly from small stems without intermediate conversion. In this process, the stem likely would first be surfaced on two sides by passing it between two parallel saws. The resulting flat stem would then be laid on one of its two flat sides, and the remaining two sides cut to shape.

This type of conversion requires that stems be available that are largely free of growth stresses, have low shrinkage coefficients, and exhibit minimum juvenile wood characteristics. Ideally, the wood should also have good steam bending characteristics.

Through thin-kerf sawing, small stems may also be converted directly into slats that may be used in chair seats and backs. Often, slats may be bent to form while green in order to obtain a final desired curvature. The need for steam bending is thereby eliminated, thus in-
creasing the variety of species that can be used.

CONVERSION OF STEMS TO THICK VENEER

Stems may be converted into thick veneer that is subsequently used in the fabrication of laminated furniture parts and frames. This process is of particular interest in that it allows for the widest variety of aesthetic and functional designs.

Small stems may be converted into thick veneer either by conventional veneer production processes or by sawing small stems into veneer by means of thin-kerf saws. A major disadvantage of sliced or rotary cut veneer is the high cost of the equipment required to produce it. Recent developments in peeling equipment make it practical to produce rotary-cut veneer from small stems, but nonetheless, the cost of the equipment is likely prohibitive in less-developed regions. These high equipment costs dictate that veneer in most less-developed regions be produced by sawing processes.

Relatively low-cost thin-kerf saws make it entirely feasible to produce 4- to 6-mm-thick sawn veneer from small stem logs. In addition to the process in which a small stem is simply sawn into sheets of veneer, the stems may first be cut into boards of desired thickness that are then turned on edge and cut into veneer strips.

Where thin-kerf sawmills are not available, the next most practical procedure for producing veneer strips is to first process the small stems into boards of desired thickness, perhaps 25 to 40 mm thick, at a local sawmill. The resulting boards are then cut into veneer strips, which measure perhaps 6.5 mm thick by 25 to 40 mm wide, by means of simple, presumably homemade, thin-kerf circular saws. Fortunately, some of the thinner portable sawmills used in remote regions are able to perform both operations. Although greater material waste results, the procedure makes it possible to produce veneer in areas where it would otherwise be economically impossible to do so.

PRODUCTION OF CURVED PARTS AND FRAMES

Although curved parts may be produced both by sawing solid wood blanks to shape and by glue-laminating parts from veneer, other processes can also be used to produce sculptured or shaped parts.

Steam bending. — Steam bending may be used to produce a wide variety of curved shapes from either doweled or flat sawn parts (8). Tropical woods are notorious, however, for being difficult to bend (as opposed to many temperate species). High-temperature steam bending may allow some intractable woods to be bent, but the cost of equipment and safety considerations may negate the advantages.

Wet bending. — Bending thin-sawn wood to shape and allowing it to dry while restrained provides a practical process for producing curved seat slats and parts for chair backs as well as other parts where gentle bends are required. This process is well-suited for use by cottage industries in remote areas.

Chemical bending. — Chemicals such as ammonia (9) may be used to facilitate bending, but simple low-cost procedures are needed for their use by cottage industries.

Mechanical pre-compression. — Mechanical longitudinal pre-compression may also be used to make wood flexible. Numerous operations need to be perfected before this process could be widely used, however.

Growth-induced bending. — In the case of direct conversion of stems into parts such as chair back posts where only moderate bending of rather large members is required, live stems could be gradually bent to the desired shape as they grow. Although bending of live plants has been practiced to produce artistic shapes and perhaps to some extent to produce ship ribs, its applicability to the production of curved furniture parts holds promise but remains to be proven.

FABRICATION OF LAMINATED PARTS AND FRAMES

Construction of laminated parts and entire frames from veneer (Fig. 1), provides one option for converting small woody stems into school furniture. It represents an important aspect of re-engineering of the furniture since it not only allows parts to be specifically engineered to meet strength requirements, but it also reduces the number of parts and joints required in any piece of furniture. Therefore, critical joints that are prone to failure such as the side rail to back post joint in chairs may often be eliminated. Design is thereby simplified while durability and reliability are significantly increased.

Fabrication of such furniture, however, requires a higher level of production technology than does fabrication of conventional "stick" furniture. Hence, if such furniture is to be produced by local cottage industries, a corresponding appropriate technology must be developed for its production.

Conversion of small stems to veneer is the first problem to be solved. Assuming that veneer slicing equipment will not be available at the cottage level, non-traditional means of conversion are needed. Where thin-kerf sawmills are available, small stems may be relatively efficiently converted into sheets of sawn veneer. Alternatively, the stems may be converted into narrow cants, turned on edge, and resawn into strips of desired thickness as previously discussed.

In general, the fabrication of furniture similar to the type shown in Figure 1
with the accompanying side frame shown in Figure 2, begins with steaming of the strips. These strips are then bent around a form to produce the desired shape of the side frame and clamped into place until they dry. Subsequently, the individual laminations are removed from the form, covered with adhesive, reassembled around the form, and clamped at close intervals to produce the desired gluing pressure. The thickness of the laminations is governed largely by the ease with which they can be bent to shape, i.e., the easier the wood is to bend, the thicker the lamination that may be used.

Although excellent frames may be produced by means of the procedure just described, several difficulties attend the process. Perhaps the most serious problem is that long continuous strips of essentially defect-free veneer are required.

Furthermore, they must be amenable as a group to free bending around a form. Therefore, most species will require steam treatment prior to bending. Finally, the entire set of strips must be bent and clamped before they cool.

Keeping the strips straight between corners joints is frequently difficult and requires multiple clamping. Subsequently, the strips must be coated with adhesive, rapidly re-assembled on the form, and clamped in place until the adhesive cures. Several of these activities require considerable manual dexterity.

Modified design and construction techniques are used to overcome these difficulties. A simpler procedure in concept is to fabricate the side frames from sub-assemblies. Each sub-assembly in this method of construction consists of a joint and adjoining sides (Fig. 3). The ends of the side members are constructed in such a manner that one forms the male and one the female end of a multiple mortise and tenon joint. These sub-assemblies can then be glued together to form a complete side frame (Fig. 4). Multiple mortise and tenon joints are both rigid and strong, but the joints (and frame) may be readily strengthened and stiffened by adding an additional lamination on the tension side of the frame after the side frame has been assembled as shown in Figure 4. The value of this procedure is that it is simpler to construct a sub-assembly than a full side frame, and the procedure also allows the use of much shorter lengths of material.

Fabrication of Lap-Jointed Parts and Frames

Lap-joint construction in which straight laminations are glued together at the
joints to form what are in effect multiple mortise and tenon joints may also be used to fabricate school furniture side frames. A simple method that may be used to construct such frames is shown in Figure 5.

In this procedure, the joint centers of the frame are first located on a flat panel such as a piece of plywood. Holes are then drilled through these points, and either bolts or lengths of threaded rods are inserted through the holes and fastened securely in place with nuts. The lap areas of the laminations are then coated with adhesive, and the laminations slipped over the lengths of threaded rod. Large washers are then slipped over the threaded rods, and nuts are then threaded onto the rods and tightened to apply pressure to the lap-joint areas. Once the adhesive has dried, the frames are removed from the forms and dowels are inserted and glued in the holes previously occupied by the threaded rods.

If desired, shorter lengths of material can be glued in place in the slots between laminations in order to produce solid members (Fig. 6). This results in what is in effect multiple mortise and tenon construction.

A major advantage of this method of construction is that it allows the use of relatively short straight members. Therefore, the need to bend the laminations to form corners is eliminated. This is an important consideration in dealing with many woods and, in particular, those tropical woods that tolerate only very mild bending before fracturing. In addition, dimensionally accurate frames can readily be produced by this method. Simple jigs can easily be fabricated that locate the laminations for drilling with respect to the ends and the outside edge of the laminations. Of particular importance, “springback” that occurs when conventionally laminated frames are removed from drying forms is eliminated.

The amount of adhesive required in fabrication of a frame is greatly reduced with the simple lap joint construction. Furthermore, the need for C-clamps and other related apparatus required for clamping the joints until the adhesive sets are eliminated.

The procedure provides a means of producing solid laminated frames with strong and durable multiple mortise and tenon joints at the outside corners of the frame and with conventional mortise and tenon joints at interior locations such as the side stretcher to front and back post joints in chair side frames (Fig. 7).

**Corner bending apparatus**

In free-bending laminations about a form, it is often essential that the adjacent “wings” of the laminations remain perfectly straight, i.e., that the wings in effect form straight lines that are tangent to the central curved portion. A simple piece of equipment fabricated largely of pipe and threaded rod (Fig. 8), can be used to produce such bends. The length of the jig is not critical, but it is advantageous if it is of sufficient length to allow several sets of strips to be formed at the same time. In practice, the laminations are bent between two lengths of pipe by a third pipe located midway between the first two. A length of threaded rod located at each end of the center pipe with an attached nut is used to provide the force required to shape the laminations. Forces are applied perpendicular to the laminations by the walls of the two outer pipes only at the point of contact of the strips with the pipes. Since no forces are applied to the strips beyond these points, the wings remain straight. Since metal pipes may stain the wood, it is necessary to cover them with a protective material such as plastic. In practice, a short piece of plastic pipe can be slipped over the metal pipe to provide this protection. Provided it has the necessary strength, heavy-walled plastic pipe may be used alone and the metal pipe eliminated.

**Creep bending of green wood strips**

Although wood must normally be steamed before it can be bent to a relatively small radius, some woods can be forced to gradually assume a desired radius by forcing them to creep under load. This “creep bending” process may be carried out with the pipe jig bending apparatus just described (Fig. 8). In practice, green strips of wood are inserted in the press and the nuts tightened on the center pipe until the strips are slightly bent. The strips are moistened periodically, and the nuts again tightened at a later time, usually the next day. This process is repeated until the desired degree of curvature is obtained. Although the procedure may take several days to complete, several sets of laminations may be bent at the same time. Furthermore, the jigs are inexpensive so that a user might reasonably be expected to be able to afford a number of jigs consistent with desired output.

**Green bending of wood**

Many woods can be bent sufficiently while green to form parts suitable for seats and back slats. In this process, the slats are simply bent to shape on a suitable jig and allowed to dry. In general, only simple equipment is required for the production of parts by this process.
The bending jig previously described may also be used in this process. More complex curves may also be formed by this process as shown in Figure 9. In this case, a modified form of the bending jig is used to produce top rails for chairs by green bending in which the ends of the rail remain parallel to its original longitudinal axis. If desired, one end of the center load pipe may be pulled farther down than the other end in order to provide a taper across the width of the back rails or back cross slats.

Chemical Bending of Seat and Back Slats

Research has shown that wood treated with ammonia (7,9) may be bent into shapes and particularly into smaller radii than is possible with wood treated by means of conventional processes such as steam bending. Although there are several difficulties associated with the use of typical ammonia-based processes, an adequate treatment of seat and back slats can be obtained by soaking the ends of the slats in a solution of household ammonia for 24 hours. After this treatment, the ends of the slats can readily be bent to radii less than 12.5 mm.

A typical use of slats bent in this manner is shown in Figure 10. In the chair shown, the slats are first bent to the desired seat or back contour, either by a green bending process or by steam bending. The ends of the slats are then soaked in ammonia and bent to the desired radius at each end. The slats are slipped over the free ends of the cross stretchers as the chairs are assembled and cannot be removed without disassembling the chair. This construction effectively locks the slats in place and helps to hold the chair frame together.

Round Tenons

A major problem in the construction of sturdy school furniture is the fabrication of three-dimensional furniture from two-dimensional frames. In general, the fabrication methods that allow robust durable joints to be constructed in side frames or front and back frames cannot be used to assemble the resulting flat frames into complete chair frames. Robust mortise and tenon joints can readily be constructed in cross-lapped laminated side frames, for example, but these lamination techniques cannot be used to assemble the side frames into a complete chair assembly. To join the front and back rails to the side frames with mortise and tenon construction, mortises must be cut into the side frame by conventional techniques. Neither conventional mortise and tenon nor dowel joint construction is well-suited for school furniture in developing regions. However, precise machining of parts is required, adequate glues must always be used, and there is no simple method of inspecting joints to determine if sufficient adhesive has been used. Finally, the joints cannot be repaired readily, which is an important consideration in view of the points just listed.

Round mortise and tenon joints provide an effective construction for joining basically slender members such as stretchers to other members. Round tenons are often used to join stretchers to front and back legs in chairs. Stretchers are well-suited for this type of construction because of their size and shape; they generally measure about 22 mm square in cross section, which allows a 19-mm diameter pin to be turned on their ends. Round tenons, or, turned pin ends, are also used with round stretchers and rails in the construction of Shaker style (2) and "mountain" furniture such as that shown in Figure 11.

A major advantage of round tenons is that it is relatively easy to obtain a close fit between the round tenon and the hole into which it fits. Holes (round mortises) can be drilled to size with relatively simple equipment; a brace and bit will suffice. Ends may be turned on the ends of the stretchers with equipment specifically made for the purpose, but they can also be turned on a simple wood lathe.

Most importantly, however, round tenons of any diameter can also be cut with hole saws. In this process, the end of a stretcher is "fed" into the hole saw. A jig is needed both to align the stretcher and to prevent it from turning. Once the tenon has been cut, the excess material around the pin must be removed by hand. This process provides an inexpensive procedure for producing turned ends of uniform diameter. A hole saw can be mounted on the shaft of an electric motor as shown in Figure 12, for example, and incorporated into a simple piece of equipment for cutting quality tenons on the ends of members.

By matching the size of the drill bit used to machine the holes for the pins with the diameters of the pins, a close fit between pin and hole can be obtained. The ability to match the diameter of the tenon to the diameter of the hole without the need for strict quality control procedures provides the key to the construction of uniformly durable furniture. More specifically, it allows the use of "shrink and swell fit" construction (1). In this construction, the tenon is cut to a slightly larger diameter than the hole or mortise into which it fits. The part with the tenon is then dried in an oven or in an overhead loft until the diameter of the tenon is smaller than that of the hole. The walls of the hole are then coated with adhesive and the tenon inserted. As the tenon regains moisture, it swells to

Figure 12.—Hole saw mounted on shaft of electric motor used to cut turned pin ends on stretchers.
form a very tight connection that is both strong and durable. This method of construction is effective both in constructing very strong side frames and in joining side frames together to form complete chair or table frames. Although this construction can be used in essentially any region of the world, it works particularly well in those areas characterized by high humidities with relatively high accompanying equilibrium moisture contents.

Typical examples of chairs in which stretchers with round tenons are used to join side frames together or front and back frames together to form a complete chair are given in Figures 13 and 14. In Figure 13, stretchers with round tenons are used to join two cross-lap laminated side frames together. Use of six stretchers in this construction ensures that the chair will have excellent resistance to side forces (5). Furthermore, use of a “swell fit” between tenon and mortise will ensure that joints will not work loose with time.

A chair in which the stretchers connect the front frame to the back frame is shown in Figure 14. This construction is of particular interest in that it provides a simple method of constructing chairs with curved backposts in which the backposts are of laminated construction.

**FRAMES CONSTRUCTED OF ROUND WOOD**

It is anticipated that most furniture frames constructed with round wood, i.e., large dowels, would be of post and stretcher construction such as the chair shown in Figure 11. An example of a desk side frame is given in Figure 15. Such frames are relatively easy to make with simple tools and are of robust construction. Steam bending of dowels is, of course, possible for those designs that require it. Smaller diameter dowels in particular may be bent to various shapes and used in the construction of furniture somewhat reminiscent of that produced by Thonet (10). The back posts for chairs could likely be bent to form using green bending or steam bending techniques.

This is an efficient process for production of wood furniture parts and one with significant potential for meeting existing and future world needs. This type of direct conversion of tree stems and limbs into furniture parts and complete furniture frames is not new. “Mountain” chairs have been produced from round stems for many years. When properly constructed, such chairs are quite durable and frequently outlast chairs of “modern” construction. The validity of these historical designs, arrived at by trial-and-error methods, can be proven through present-day mechanics and performance tests.

**FRAMES CONSTRUCTED OF SQUARES OR RECTANGLES**

Presumably, most of the furniture constructed of squares would be of stretcher and post construction in which stretchers with turned pin ends are used to join the posts together to form three-dimensional frames. This construction has several advantages. Individual parts are easy to machine from stems. Construction of joints is relatively simple: holes must be drilled in the posts at the appropriate locations and pins must be turned or cut on the ends of the stretchers. The walls of the holes are coated with adhesive, and finally, the frame is assembled with a “swell fit” between the tenons and the posts. A tight fit between these parts is useful in that it eliminates the need to clamp the assembly while the adhesive dries.

Frames constructed in this manner are both strong and durable. The forces acting on the stretchers in a side frame are relatively uniformly distributed among the joints so that none of the joints is heavily loaded and a robust construction results.

Essentially identical frames can be constructed with rectangularly shaped posts as opposed to square posts. Use of such sections usually reduces the weight of the chair. Furthermore, if the stock is sufficiently wide, the backposts may be sawn to give a backward tilt to the top rail as shown in Figure 16.

A desk frame constructed of square and rectangular elements is shown in Figure 17. Since there is no lower stretcher on the student side of the desk, the side strength of the frame is correspondingly reduced. Larger diameter tenons are used in the top stretchers, therefore, to provide the strength needed to compensate for the lack of the bottom stretcher. To provide added strength, the top is sup-
ported by rectangular rather than square rails. The tenons on these members are cut off-center as shown in Figure 17. An added advantage of off-center tenon placement is that the mortise can be placed some distance below the top edge of the post in order to eliminate any possible splitting of the top of the post.

Conclusions

Several methods may be used to construct attractive robust school furniture from small woody stems with relatively simple tools and production procedures. Production techniques vary from those best-suited to cottage industries to those more appropriate for small factories in more developed regions.

Small stems may be converted into squares or dowels that are subsequently cut into furniture parts. Alternatively, the stems may be converted into small strips that are subsequently used to fabricate individual furniture parts or entire frames.

Curved laminated construction can be used when woods can be easily steam bent. Creep bending with simple jigs can also be used to form parts with sharp corners and straight sides. Green bending may be used to form parts with mild bends such as seat and back slats. Simple chemical bending with household ammonia may also be used to form extreme bends in the ends of such items as seat slats.

Cross-lap laminated construction is well suited for those woods in which only short lengths of clear wood can be obtained or which have poor bending characteristics. This method of construction produces robust geometrically accurate frames with very simple equipment.

Turned pin end construction provides a simple yet durable means of connecting members and side frames together. Turned ends may be produced on a conventional wood lathe or they may be cut with a simple hole saw.

In conclusion, preliminary results indicate that sturdy, well-designed school furniture frames can be produced from small woody stems by a variety of production processes; some are best suited to cottage-level industries, others to more conventional industries. Thus, school furniture and the accompanying production processes can be matched to the level of development of essentially any targeted country.

Durability is ensured by design. Furthermore, none of the processes involved in the construction of the frames are inherently costly. Thus, it is anticipated that attractive, sturdy, easily maintained furniture can be produced at a modest cost in any developing region.

Literature Cited