HISTORY OF ENGINEERING SCIENCES AND INSTITUTIONS OF HIGHER EDUCATION

2022/6

No. 6, Sept. 2022, pp. 117–141
https://doi.org/10.7250/HESIHE.2022.007

AN EXAMPLE OF THE USE OF TRADITIONAL WOODWORKING HAND TOOLS IN PRODUCT DESIGN STUDIES AT THE INSTITUTE OF DESIGN TECHNOLOGIES OF THE FACULTY OF MATERIALS SCIENCE AND APPLIED CHEMISTRY OF RIGA TECHNICAL UNIVERSITY

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Summary. Initially, hand tools were created to facilitate the processing of materials in manufacturing utility items. Tool design, technology, and ergonomics evolved along with the growing human ability to process new materials. The tool range has expanded to meet more diverse needs of the woodworking industry, adapting the tools for both universal use and specific functions.

Understanding of the functionalities of woodworking hand tools is essential for observing the sequence of material processing and practical processing operations, as well as in building awareness of the properties of the wood material. This is ensured by the interaction between the operator, the tool, and the workpiece. An important aspect in raising awareness is the relatively low processing speed and the processing of the material with human-controlled movements.

Treatment of wood with craft methods and tools reveals the characteristic properties of the material, including specifics of wood grain direction, the difference in the density of earlywood and latewood, and the difference in the longitudinal and transverse grain direction. It also allows understanding the most typical wood defects.

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To make the process of learning a wood material meaningful in the study process, it is integrated with product manufacturing, making students create a wooden puzzle. This process implies running a sequential crafting process from a solid pine board to a finished and functional product – a puzzle. Students have to make it following a uniform design drawing showing the proportions of the pieces and joints.

While making a wooden puzzle, students choose the most appropriate tools for each processing stage. In the process, it is necessary to check, measure, mark, and cut the workpiece. The result is a three-dimensional product that may be assembled and disassembled. The assembly and disassembly process allows appreciating the role of processing accuracy in the course of work and its impact on the end result.

Keywords: traditional woodworking hand tools, craft, wood processing, product design, education.

Introduction

While educating and training future engineers at Riga Technical University (RTU), right from the very start the focus has always been made on combining the knowledge about materials, technologies, and constructions. Studying at RTU Institute of Design Technologies, apart from various modern technological manufacturing possibilities students also acquire skills for making handcrafted products. Product development is a complex process involving a wide range of considerations. Practical hands-on work with the material is one of the most important aspects in the development of tangible prototypes and products, which allows students to fully understand the inherent properties, as well as processing possibilities, limitations and specifics of the material.

The equipment available for conducting the work is a significant aspect of material processing and product manufacturing opportunities. Based on the specifics of the prototype or product to be developed, it determines the quantity, sequence, and time of manufacturing operations.

The relative order and interaction of these aspects provide the basic understanding of the process of prototyping and product manufacturing from a definite material. Therefore, it is necessary to learn the above-mentioned aspects both theoretically and practically.

Learning the material and the tool by doing allows feeling and getting to know them and gaining experience. Doing clearly connects the theoretically acquired knowledge of materials and their properties with the appropriate choice of woodworking hand tools and time consumption, as well as allows appreciating the role of work performance accuracy both in the making process and in the end result.

The purpose of the developed task is to integrate the use of traditional woodworking hand tools and solid wood processing with the acquisition of knowledge and skills by practically making a product.

As a result, a practical task was developed and approved. In the course of its performance, students gain knowledge about the material and tools, develop an understanding of the processing processes, their sequence, and product manufacturing. The experience gained enables students to analogically transfer learning outcomes from one context to another, where the tool or a processing/treatment process can be applied to a different material or operation in a different context.

Woodworking Hand Tools

Initially, the need for woodworking hand tools emerged along with the need to process wood to produce the items necessary for survival, including housing, fences, weapons, household items, various auxiliary tools, etc. Their production quality increased with the development of skills and tools [1, 2].

In the beginning, raw forms and natural materials such as stone and wood served as tools for wood processing. Over time, as long as the human ability to process existing materials and obtain new materials grew, the shape of tools was perfected, which promoted the development of a more comfortable grasp of the tools and ensured their more efficient use. Improved construction ensured a longer service life and suitability for specific types of processing and promoted development of new manufacturing techniques, later also manufacturing technologies [2, 3, 4].

Expanding the range of tools, they were adapted to more diverse and specific woodworking needs, keeping both universal-use tools and developing tools designed for a specific function, until the variety of known woodworking hand tools as currently offered by tool manufacturers and distributors has been developed.

Considering the wide variety of woodworking hand tools and information about them in various sources, it appears expedient to collect information about the tools and classify the tools based on their similar features. Organized information makes it easier to perceive, remember and compare. Tools can be grouped by different selection criteria based on the function to be performed, the materials used to make the tool, and attribution to certain woodworking trades, such as tools used in carpentry, cooper tools, joiner tools, etc., as well as according to tool construction type [5].

The most comprehensive tool grouping technique is the one based on tool functions, distinguishing measuring, marking, cutting, and auxiliary functions as subgroups of the first level of grouping. The listed functions are associated with the preparation of solid wood for technological processing or its technological processing with hand tools. In turn, the tools included in the subgroups of the next levels are grouped based on common characteristics related to the specifics and sequence of work execution according to the basic tasks and core requirements of the professions of carpenter, joiner, and woodcarver. In this case, the chosen professions have been selected due to their interdisciplinary connection with product designers, who most often entrust the design of solid wood products to the representatives of the aforementioned professions. Starting from the second level subgroup, the tools are grouped depending on the exact professions that use these tools in wood processing, the essential functions they perform, and the construction of the tools. As a result, 7 second-level subgroups of measuring tools, 11 marking tools, 9 cutting tools, and 4 auxiliary tools were obtained (see Figure 1, p. 121) [6, 7, 8].

It should be noted that hand tools have served as a basis for the further development of technological woodworking processes, as a result, electric hand tools, position-type machinery, and industrial machinery have been developed. They are used for the mechanized processing of solid wood, accordingly reducing the amount of manual labour in the production processes.

Even though nowadays products are mainly manufactured using machinery, which allows for faster material processing, woodworking hand tools are still used in the development of individual products, new or improved products, prototypes, or specific products. They are most often used in cases when thinking through making is essential or when due to product's specificity it is impossible to process or adapt them for treatment with machine tools. Hand tools are also still used to preserve craft traditions and culture, as well as in the learning process [7].

Woodworking hand tools play a vital role in helping students understand the principles of material processing and learning the properties of the processed wood. It is possible thanks to the interaction among the worker, the tool, and the processed material. A relatively low material processing speed and human-controlled material processing process can be considered important aspects for promoting awareness of materials and methods.

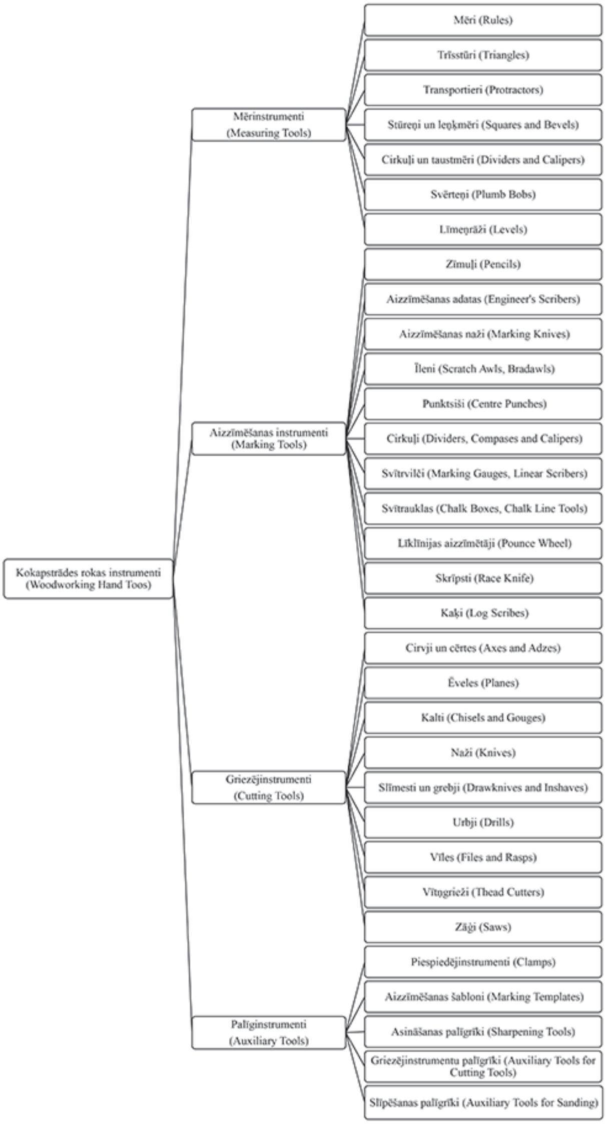

Figure 1. Division of woodworking hand tools into the first and second subgroup levels.

Material Processing

In order to turn a naturally growing round tree stem into wooden products suitable for human needs, it is necessary to process the material. Trees growing in the forest are first transformed by processing them into timber (planks, laths, veneer, etc.), then timber is further processed into wooden objects. The operations performed by the joiner and carpenter play an essential role in this multifaceted material processing cycle. At this stage, the wood material undergoes the greatest transformations, which result in creation of a product. Joiners and carpenters need craft skills and a wide variety of tools – they should be familiar with them, they should know how they work, and they should also be able to use them appropriately in the processing of the material to ensure a high-quality result [9].

The wide use of wood has been conditioned by its appearance, lightness and at the same time relatively high strength, as well as other properties that are essential in the production of furniture, construction, and the manufacture of wooden products. It is also important to be aware of wood defects, such as swelling or shrinking, cracking and warping due to changes in wood moisture content. There are also defects of biological origin, such as knots, grain defects for conifers – resin ducts, etc. These shortcomings can be eliminated mainly by choosing optimal product manufacturing technologies, which include drying the wood, its mechanical processing, gluing, forming various connections, and other operations [4].

In product design, the choice of materials tends to be complex, as it depends on several interrelated and significant factors, such as functional requirements, manufacturing constraints, life cycle aspects, aesthetic material properties, as well as cultural and representative meanings [10]. Thus, the choice of materials affects how the product will be made, how it will work and how users will interact with it – perceive and use it. On the other hand, in relation to the user experience, the visual and tactile properties of the materials used are of primary importance [11]. Objective sensory properties include, for example, colour and texture that exist physically and are measurable. Subjective sensory properties refer to the fact that the perceived properties of a material also depend on individual human factors, such as the individual’s previous experiences, memories, associations, emotions, cultural background, etc. Therefore, the meaning of material is constructed based on the properties of the material, the product in which the material is embodied, the interaction between the user and the product, and the context in which the interaction occurs [10, 12, 13].

On the other hand, while acquiring knowledge and skills, it is important to interact with physical materials and their samples, so that students get direct experience in working with them. Material samples facilitate designer understanding of material properties through direct sensory exposure. Such direct experience is also important because it allows one to visually get to know and evaluate materials in different lighting conditions and from different viewing angles, to feel the smell of materials, to feel the properties and textures of the surface, to feel the weight of the material and appreciate other properties [14].

Material knowledge (know-how) includes an understanding of material processing, its sequence, and knowledge of the tools and techniques used in material treatment. Hands-on work with the material provides significant skill and experience, allowing to find out what wood can offer in the course of processing. Knowledge of materials allows predicting the behaviour of a material in different contexts without relying solely on a trial-and-error approach. Understanding the influence of all relevant factors, the designer is able to choose the most appropriate materials, their cross-sections, and construction, so that it is appropriate in the given context [11].

Solid wood processing with craft methods and tools reveals the characteristic properties and specifics of the processed material. Processing the material, one can get to know the physical, mechanical, and technological properties of wood, as well as get an insight into the most characteristic defects of timber. Processing of material is essential not only in building awareness of the properties of timber, but also in learning wood processing operations, promoting understanding of the sequence of solid wood processing and the processing time in product development.

Importance of Making in the Product Design Study Process

Thinking includes collecting, documenting, mapping, analysing, reflecting, translating, synthesizing, and concluding. It manifests itself not only with the text but also with everything we create – make. It includes designing subjects, organizing activities, telling stories, and designing systems and experiences. All these areas can be fields of knowledge that are expressed not only in words [15].

Thinking-through-making is a process in which making and thinking constantly interact and enrich each other. Reflection on what has been done creates knowledge and insights. Creation and reflection go hand in hand – the relationship between making and thinking opens up the possibility of expressing knowledge through the manufactured product. It is related to such concepts as thinking with hands and learning by doing. By combining thinking and making, new types of logic and new solutions emerge [15].

Handcrafting means interacting with an object, and this interaction is shaped by many emotions and experiences. Making products by hand enriches the social and material world with a variety and complexity that cannot be achieved by industrial production methods [16].

Making brings together cognitive and physical abilities in a sensory interaction with the world around us. Every interaction results in change and learning is embedded in that change. It is the emotional and intellectual transformation that occurs as a result of the process of making. The human need to transform and create acts as a conduit between the learning we do with our hands and our cognitive development. The ability to conceive and create an object from start to finish, to analyse and adapt during the making process makes the making a transformative learning process [16, 17].

In order to make the learning of material handling with hand tools meaningful, it is integrated into the production of a product – a wooden puzzle, which includes the learning of the tool and material and the process of making the product from a live edge plank of solid pine into a functional wooden puzzle. It is made on the basis of a dimensional drawing, which shows proportions of all pieces and placement of the notches.

Wooden Puzzle

Wooden burr puzzles or brain teasers are one of the most common types of wooden puzzles today. These are three-dimensional puzzles consisting of wooden pieces with joints that can be assembled and disassembled several times. The six-piece burr puzzle is best known among all wooden puzzles (see Figure 2). Notches are located in the central part of these wooden puzzle pieces, which form detachable cross joints during the assembly process that are fixed with the closing piece without notches [18].

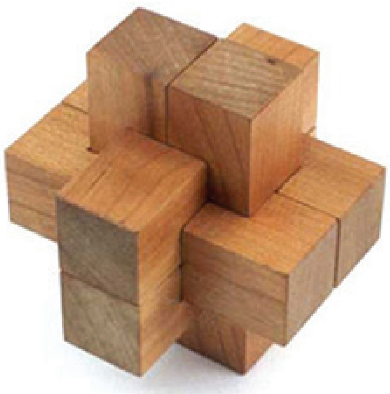

Figure 2. Wooden burr puzzle from six pieces.

The first written evidence about wooden puzzles dates back to 1803 in Germany – it was mentioned in the catalogue of Georg Hieronimus Bestelmeier (1764–1829), but it is assumed that they were known in Europe and Asia earlier [18]. For example, a drawing (1698) by Sébastien Leclerc I (1637–1714) in the British Museum of the Academy of Sciences and Fine Arts shows a similarly shaped object in the lower left part of the drawing [18].

Puzzles of this type are also called Chinese puzzles, because at the beginning of the 20th century, their mass production and import to Europe and America started in China. It is not precisely known and proven where and when the first puzzles of this type were created, but there is a remarkable similarity between the design of these puzzles and the detachable wooden joints used in traditional Chinese carpentry in furniture and household items (see Figure 3) [19, 20].

Figure 3. Chopsticks holder with detachable joints (19th/20th century).

In general, several versions of wooden puzzles are produced, but the oldest patent for a six-piece wooden puzzle is patent No. 1 225 760 by Oscar W. Brown (?–?) in the United States, filed on 27 June 1916. It was followed by several other patents registering even more unusual puzzles, whose shape was modified by adding decorativeness, the pieces and notches were modified resulting in the changes in the assembly/disassembly process, for example, adding hidden pins, rotating parts, interlocking pieces, and other modifications [19, 21, 22].

Six-piece burr puzzles can include three types of parts: puzzles with no embedded notches, puzzles with relatively simple notches in three side surfaces of the piece, and puzzles with complex joints in all side surfaces of the pieces. The pieces are most often of equal length with a square cross-section, where the length of the piece is equal to or at least three times their width. They are symmetrically arranged in three perpendicular pairs. The size of the square cross-section of the pieces is half the depth of all notches. All joint points are embedded in the intersection area of the pieces – in the inner core of the puzzle. The six-piece wooden burr puzzle takes an outwardly symmetrical shape when assembled. In addition, there may be different variations of shapes in parts of pieces that do not have embedded joints, for example, 3D geometric shapes (see Figure 4) [19, 20].

Figure 4. Shape of puzzle pieces with geometric elements (19th/20th century).

Variations of the six-piece burr puzzle make a wide family of designs, the maker having the choice of how to notch each piece. Puzzle analysts led by Bill Cutler (?–?) have defined 59 types of pieces (including the pieces without joints), of which 25 pieces can be used in puzzles where assembly does not create internal voids (see Figure 5, p. 127). The pieces can be chosen in sets of six and assembled in a total of 314 different ways, as well as assembled in several levels of difficulty [22].

Creating a six-piece puzzle requires a wide range of skills. They can be learned and applied from the theoretical to the practical skills and from the mathematical to the artistic level. On the practical level, manufacturing a complex, precisely made wooden puzzle can be a challenging project for both the student and the skilled woodworking professional. People are also interested in the geometric shapes and decorative design associated with polyhedra, as well as the psycho-aesthetics of puzzle design [22].

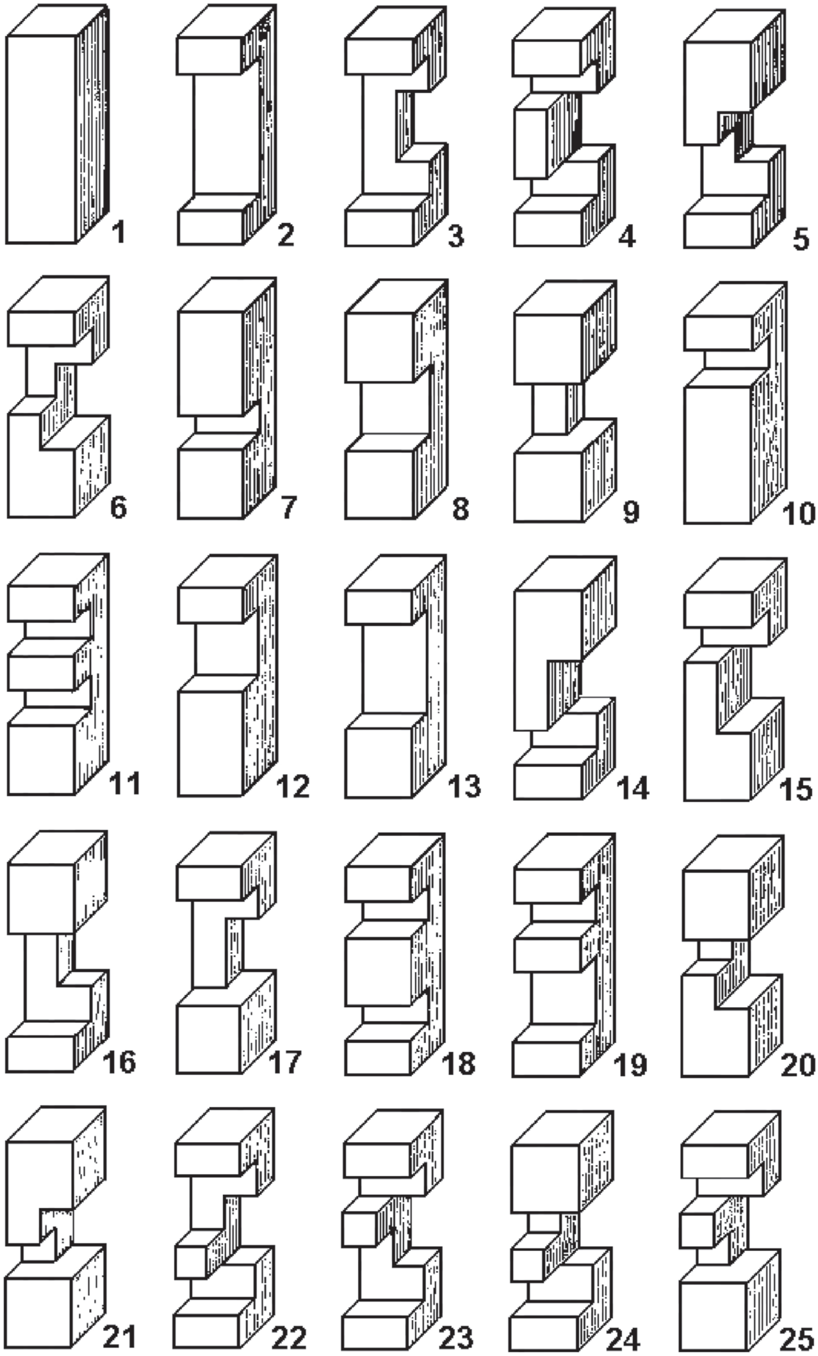

Figure 5. Types of puzzle pieces.

Use of Tools in Product Design Practice

The task was developed taking into account the experience of the students, the selected material to be processed for the execution of the work, and the specifics of the manufactured product, mainly the number of details, complexity of the shape and size, as well as the time resources available during the study process.

In the course of implementing the practical task, there is an interaction between the student or the work performer, the tool, and the material, which results in a manufactured product.

The task is performed by first-year students mostly without previous knowledge of woodworking. Before starting the execution process, students acquire theoretical knowledge closely related to the task, including the variety and applications of woodworking tools, work techniques, and work safety, as well as the most important information about solid wood, its properties, and processing specifics. Making a wooden puzzle is one of the several tasks to be done during the semester. It focuses on kinetic and visual perception, getting to know the material practically, and processing it with woodworking hand tools.

The cross-section of the puzzle pieces is relatively small, in this case it does not exceed 24 mm (taking into account the 26 mm thickness of the material – pine solid wood board). Therefore, the production of the product requires woodworking tools suitable for precise work with small workpieces.

It should be noted that when starting the work, the solid wood blank is larger than the details obtained as a result of the work. Therefore, the choice of tools at different stages of product readiness may differ not only in type, but also in size. This affects the worker's control over the tool. A tool that is too large will be difficult to control, while one that is too small will not be able to handle the full length, width or depth of the workpiece. In both variants, processing precision and the quality of the processed surface are compromised.

The sequence of material processing during puzzle production is affected by the dimensions of the puzzle pieces, so before processing, a step-by-step puzzle production sequence was developed (see Figure 6, p. 129) to ensure the possibility of processing workpieces and obtaining an accurate result according to the students' skills.

The process of making a puzzle mainly includes inspection of workpieces, measuring, marking, cutting, resulting in a three-dimensional product that can be disassembled and reassembled. In the assembly and disassembly process, it is possible to assess the role of processing accuracy in the course of work and its impact on the end result with regard to both each separate piece and the assembled product.

Figure 6. Stages of making a puzzle.

Content of the Task Assigned to the Students

In order for students to fully develop a wooden puzzle, the purpose of the task was defined – to make a wooden puzzle with hand tools using various woodworking methods. Students are also offered a description of the work to be done: a wooden puzzle consisting of six pieces. They are made with various woodworking tools, measuring, marking, sawing, planing, paring (chiselling) filing, and sanding. Using these woodworking techniques, joints are made in the pieces as indicated in the dimension drawing (see Figure 7), so that the resulting puzzle can be assembled. The joints must be made tight and precise enough to hold the puzzle together, and they must also allow the puzzle to be disassembled. Processing the material, it is necessary to ensure high quality of the pieces.

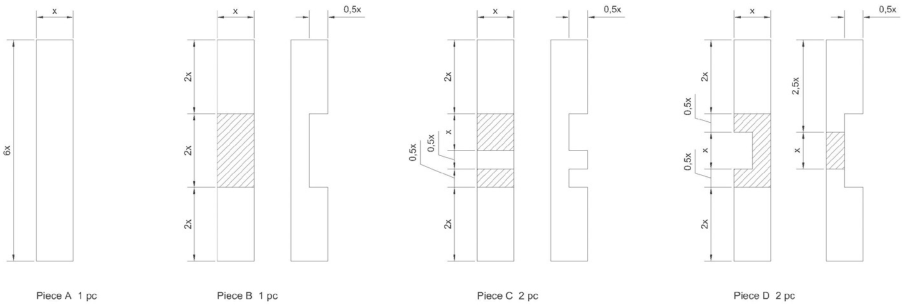

Figure 7. A dimension drawing of the puzzle pieces.

Puzzle manufacturing technology:

1) acquaintance with the task, drawing;
2) material selection;
3) marking of the workpiece;
4) workpiece with offset crosscutting and rip cutting;
5) two surface plane planing and squaring;
6) marking workpiece dimensions;
7) planing of the remaining two surfaces and squaring against planed surfaces and according to dimensions;
8) marking of the workpiece length;
9) workpiece with offset crosscutting according to length markings;
10) marking out the notches;
11) sawing out the notches;
12) chiselling out the notches;
13) notch paring or filing, workpieces end grain paring or filing;
14) design development by cutting, planing, trimming, and other types of processing (if envisioned);

15) sanding of the workpieces;
16) finishing the pieces, design development, varnishing, painting and other types of processing (if envisioned).

Skills to be learned:

- selection and evaluation of the material;
- setting and marking dimensions;
- rip cutting;
- crosscutting;
- planing;
- chiselling (paring);
- filing;
- sanding;
- applying finishing material or creating a design.

Evaluation criteria:

1) conformity of each piece of the puzzle to the dimension drawing;
2) accuracy and quality of finished pieces and notches obtained in material processing with hand tools;
3) mutual compatibility of pieces and joints – fit and precision, so that the puzzle can be assembled, hold together, be further disassembled and reassembled;
4) added value – design development, decoration (if envisioned).

Task Execution Process

Before starting the execution process, the task, its content, and purpose are explained to the students. The material processing operations to be performed sequentially are demonstrated and explained, consultations are provided during the work.

The task is performed in person in the woodworking laboratory at the workbenches. It is carried out in accordance with the content of the assignment following the established work procedure. The evaluation criteria are known previously.

1. Acquaintance with the task, drawing. After a verbal explanation, students receive the description of the task that specifies the sequence of technological processing of the puzzle and a dimension drawing of the puzzle pieces.

2. Material selection. First of all, a visual assessment of the selected live edge plank should be performed, identifying wood defects that could negatively affect the subsequent processing of the material and the finished product. It is essential to notice cracks, knots and resin ducts in the wood. After that, it is necessary to choose the part of the live edge plank to place the expected workpieces with an offset so that the material is used rationally. A measuring tool from the roller measures sub-group of measures – spring tape – is used for this purpose. If live edge planks are used, the shape and width of the live edge should also be taken into account.

3. Marking of the workpiece. This is followed by the calculation of the size of the workpieces with the oversize based on the dimension drawing of the puzzle pieces and the cross-section of the live edge plank chosen for its making. In the next step, the dimensions of the workpieces must be determined measuring and marking them on the timber to be processed. At this stage, the use of woodworking hand tools in the work execution process begins. Taking into account that at this stage the measurement has not yet been carried out with very high accuracy, several tools are applied – rules for cutting from the subgroup of rules, a right isosceles triangle from the subgroup of triangles, and framing squares from the subgroup of squares and bevels. Pencils and mechanical pencils can be used for marking the workpieces. Other tools include single ended scribers and double ended scribers from the sub-group of engineer's scribers, all types of marking knives from the subgroup of marking knives, and round point awls intended for marking from the subgroup of scratch awls. Two rectangular workpieces are measured and marked on the wood plank to be processed, each containing three pieces with an offset measurement.

4. Workpiece with offset crosscutting and rip cutting. Next, the marked workpieces are sawed out. Before sawing, the workpiece needs to be immovably secured so that sawing can be done in the appropriate working position. The workbench vise or vise with wedges, or C clamps, F clamps or lever clamps can be used for securing and holding the workpiece. Firstly, crosscutting is done obtaining oversized workpieces of the required length. Secondly, the rip cutting is done to widen the oversized workpieces. The most suitable tools for performing the operation are general purpose handsaws, backsaws, frame saw with the universal blade or, respectively, the blade suitable for the sawing direction of each of the mentioned saws from the subgroup of saws.

5. Two surface plane planing and squaring. Before planing, the workpiece needs to be immovably secured using the workbench vise or vise with wedges, or C clamps, F clamps or lever clamps which do not protrude above the workpiece. Planing is one of the most difficult treatment processes in this task. First, one surface of the workpiece is planed until it is flat and straight, the planing is checked both lengthwise and crosswise using a cutting rule, try squares or framing squares. Then the adjacent surface is planed at a 90° angle to the planed surface. Here, it is important to observe both the right angle to the previously planed plane and the flatness and straightness of the surface of the plane. The resulting angle with the adjacent plane is examined using a try square or a framing square. Bench planes are suitable for planing the workpiece surface. The size of the plane is chosen according to the size of the workpieces to be processed, so that the foot of the plane rests firmly on the workpiece and its length is shorter than the length of the workpiece. Jack planes and smoothing planes are suitable for this processing operation.

6. Marking workpiece dimensions. Based on the thickness and width of the two planes of the workpieces obtained in the planning process, recalculations of the dimensions of the workpieces are made at this stage, taking into account the dimension drawing of the puzzle pieces and the cross-section of the workpieces obtained in the planing process. Measuring and marking is then done on the workpieces to plane the remaining two surface planes. At this stage of processing, the measurement must be carried out with high accuracy, and several tools can be applied for this purpose, such as a right isosceles triangle from the subgroup of triangles and framing squares from the subgroup of squares and bevels. Pencils and mechanical pencils can be used for marking workpieces, as well as all types of marking scribers and marking knives from the sub-group of engineer's scribers, round point awls intended for marking from the subgroup of scratch awls, and tools from marking gauges subgroup. Marking is done for the workpieces along the perimeter, setting aside the planed cross-sections of the parts without the offset in the width and thickness.

7. Planing of the remaining two surface planes and squaring against planed surfaces and according to dimensions. Before planing, the workpiece needs to be immovably secured using the workbench vise or vise with wedges, or C clamps, F clamps or lever clamps which do not protrude above the workpiece. Planing is carried out considering the dimensions marked on the workpieces. First, one of the unprocessed surfaces of the workpiece is planed until it is flat and straight, corresponds to the marked dimensions along the perimeter and forms a 90° angle with the adjacent workpiece plane. The planing is checked both lengthwise and crosswise using a cutting rule, try squares or framing squares, the resulting angle with the adjacent plane is also checked using a try squares or framing squares. Then the adjacent workpiece plane is planed at a 90° angle to the previously planed surface. Here, it is important to observe both the right angle to the previously planed workpiece plane and the flatness and straightness of the surface. Bench planes such as jack planes and smoothing planes are suitable for planing the workpiece surface.

8. Marking of the workpiece length. Based on the thickness and width of the workpieces obtained as a result of the planning process, at this stage the dimensions of the workpieces are recalculated according to the dimension drawing of the pieces. After that, the dimensions of the workpieces are set measuring and marking on the workpieces to be processed in order to perform the lengthening of the workpieces. At this stage of processing, the measurement must be carried out with high accuracy and several tools can be applied for this purpose – rules for cutting from the subgroup of rules and try squares from the subgroup of squares and bevels. Pencils and mechanical pencils are used for marking the workpieces, as well as all types of scribers from the sub-group of engineer's scribers and round point awls intended for marking from the subgroup of scratch awls of marking knives. Marking is done for the workpieces along the perimeter, setting the lengths of the parts with a small offset (up to 1 mm).

9. Workpiece with offset crosscutting according to length markings. Next, the marked pieces are cut out by cross sawing the timber, obtaining workpieces of the required length with a small surface offset. The most suitable tools for performing the processing operation are the general-purpose handsaws, backsaws, frame saw with blade for universal or crosscut sawing. Before sawing, the workpiece needs to be immovably fixed using the workbench vise or vise with wedges, or C clamps, F clamps or lever clamps.

10. Marking out the notches. The dimensions of the notches are calculated according to the dimensions of the workpiece and the dimension drawing of the pieces, they are placed symmetrically from the centre of the workpiece at both sides. Next, the dimensions of the workpieces are measured and marked on the timber to be processed. At this stage, rules for cutting from the subgroup of rules and framing squares for measuring from the subgroup of squares and bevels can be used. Pencils and mechanical pencils are used for marking the workpieces, as well as single ended scribers and double ended scribers from the sub-group of engineer's scribers, all types of marking knives from the group of marking knives, and round point awls intended for marking from the subgroup of scratch awls.

11. Sawing out the notches. Sawing of the notches is done before paring the joints to facilitate paring work and prevent possible errors and inaccuracies. This is done by making notches in the marked joints in each plane surface. The cuts need to be made very precisely. The most suitable tools for performing the processing operation are the general-purpose handsaws and backsaws with small cutting teeth or Japanese saws for crosscutting. Before sawing the workpiece needs to be immovably fixed using the workbench vise or vise with wedges, or C clamps, F clamps or lever clamps.

12. Chiselling out the notches. Before chiselling the workpiece needs to be fixed using the workbench vise or vise with wedges, or C clamps, F clamps or lever clamps. Chiselling is done on each plane of the workpiece, where a notch or part of it is intended. Carpenter's chisels of the subgroup of chisels are suitable for the processing operation, chisels of different widths can be used depending on the dimensions of the workpiece to be processed. If necessary, an auxiliary tool – a wooden mallet – can be used to facilitate the work process.

13. Notch paring or filing, workpieces end grain paring or filing. The notches and piece end grains are processed for the workpieces immovably fixed with the workbench vise or vise with wedges, or C clamps, F clamps or lever clamps. After sawing, both the joints and the ends of the workpieces need to be precisely processed so that the workpieces fully comply with the size ratios indicated in the dimension drawing. It can be done with the tools of the subgroup of chisels – firmer chisels or carpenter's chisels, or the ordinary files of the file and rasp subgroup, choosing them according to their shape and size depending on the shape of the workpiece to be processed. At this stage of processing, it is important to choose a file with a fine cut to obtain a quality result.

14. Design development by cutting, planing, trimming, and other types of processing (if envisioned). This stage of processing can be done optionally. The student has the opportunity to individualize the puzzle, to make shape modifications with wood subtraction techniques, keeping a constant piece of the joints embedded in the workpieces. Taking into account that at this stage there are no restrictions on the type of processing and the tools used, the student individually consults with the academic staff about the chosen solution and the sequence of its implementation.

15. Sanding of the workpieces. The workpieces are ground with an abrasive material, grinding aids can be used in its execution depending on the shape of the workpiece and the desired result.

16. Finishing the pieces, design development, varnishing, painting and other types of processing (if envisioned). This processing step is optional. If desired, the student can apply finishing touches to the pieces of the completed puzzle. At this stage, there are no restrictions regarding the type of finish and adopted application techniques, so the student individually consults with the academic staff about the chosen solution and its implementation possibilities.

Result

As a result, six pieces of the puzzle are obtained, four of which are different from each other, while two form pairs. Therefore, the production of both different and identical individual pieces is realized.

The manufactured pieces are, first of all, evaluated individually, looking at each piece from all sides and taking control measurements to make sure that the pieces and their size proportions correspond to the task specified. The accuracy of the manufactured pieces and joints and the quality of the machined surface are important (see Figure 8 (a)).

Figure 8. (a). Assessment of separate puzzle pieces.

Figure 8. (b). Checking the joints of the puzzle pieces.

Figure 8. (c). A puzzle assembly test.

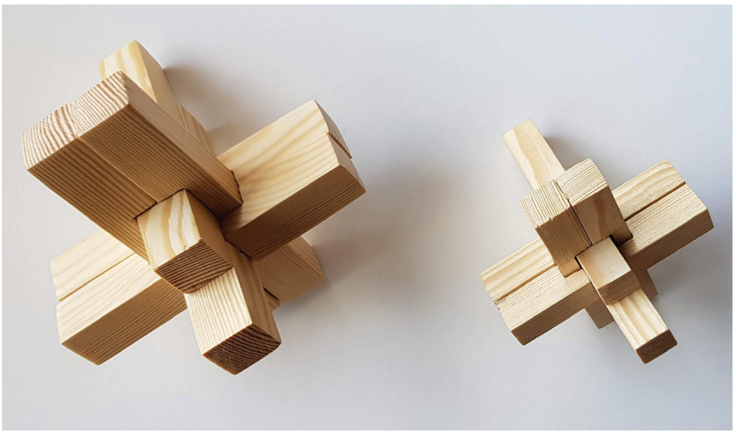

Figure 8. (d). Checking the size and proportions of the puzzle.

This is followed by checking the mutual compatibility of the pieces and joint points – tightness and accuracy when assembling and disassembling the puzzle so that it can be assembled, hold together, be disassembled and reassembled observing the angular parameters of the pieces and not creating unnecessary voids between the joint points of the pieces (see Figures 8 (b) and 8 (c), p. 136).

As a result, the cross-section of the obtained pieces is also inspected with regard of the thickness of the raw material. This indicates inaccuracies during the machining process, resulting in re-machining and reduced cross-section size (see Figure 8 (d), p. 136).

Individualization of the product or design development with wood removal techniques and/or the application of finishes performed voluntarily at the initiative of the student is the final aspect to be assessed.

Conclusions

The role and meaning of hand tools have changed over time, but today they are still relevant and allow preserving the knowledge about history and culture in crafts and woodworking, as well as acquiring the knowledge and skills in working with hand tools used and produced today, to compare their functionality both in theory and practically in manufacturing of a product. Traditional woodworking hand tools take an important place in learning the basics of woodworking when dealing with solid wood, learning the properties of the material and the specifics of processing.

Within the current study, a task has been developed and approbated in the study process, which helps students learn traditional woodworking hand tools, linking it to solid wood processing and product manufacturing, reveals the aspects that are essential in the process of manufacturing prototypes and products and help them choose materials before starting production, shows the importance of planning processing sequence and the role of dimensional precision of the parts of the finished product. The task also helps students conduct practical work making the product according to the dimension drawing of its parts.

Such knowledge and skills are essential for future product designers, since they will help them learn various materials, their properties, and processing options used in the design, prototyping, and manufacturing of new products. That will increase the diversity of students' knowledge relevant to this interdisciplinary sector, as well as increase their empathy and understanding of the operational specifics of the related industries, such as carpentry and crafts.

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SOURCES OF ILLUSTRATIONS

Figure 1. Autoru veidots attēls.

Figure 2. The Puzzling World of Polyhedral Dissections [online]. *https://johnrausch.com/PuzzlingWorld/introduction.htm* [cited: 24.01.2022].

Figure 3. Interlocking Burr Puzzles [online]. *https://chinesepuzzles.org/interlocking-burr-puzzles* [cited: 24.01.2022].

Figure 4. Interlocking Burr Puzzles [online]. *https://chinesepuzzles.org/interlocking-burr-puzzles* [cited: 24.01.2022].

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Figure 6. Autoru veidots attēls.

Figure 7. Autoru veidots attēls.

Figure 8 (a). Autoru veidots attēls.

Figure 8 (b). Autoru veidots attēls.

Figure 8 (c). Autoru veidots attēls.

Figure 8 (d). Autoru veidots attēls.

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Ilze Gūtmane, Silvija Kukle, Jānis Kalniņš, Inga Zotova, Artūrs Ķīsis

Tradicionālo kokapstrādes rokas instrumentu lietojuma piemērs produktu dizaina studijās Rīgas Tehniskās universitātes Materiālzinātnes un lietišķās ķīmijas fakultātes Dizaina tehnoloģiju institūtā

Sākotnēji rokas instrumenti radīti, lai cilvēki spētu apstrādāt dažādus materiālus, iegūstot izdzīvošanai nepieciešamos priekšmetus. Laika gaitā attīstoties prasmei apstrādāt jaunus materiālus, tika attīstīta instrumentu konstrukcija, tehnoloģija un ergonomika. To klāsts paplašināts, pielāgojot daudzveidīgākām kokapstrādes vajadzībām – gan universālam lietojumam, gan konkrētai funkcijai. Kokapstrādes rokas instrumenti ir būtiski materiāla apstrādes procesu un veicamo apstrādes operāciju secības ievērošanai, kā arī apstrādājamā kokmateriāla īpašību iepazīšanai, praktiski darbojoties. To nodrošina darba veicēju, instrumentu un apstrādājamā materiāla mijiedarbība. Būtisks aspekts izpratnes veicināšanai ir salīdzinoši zemais materiāla apstrādes ātrums un cilvēka vadītais apstrādes process. Koka apstrādāšana ar amatniecības metodēm un darbarīkiem atklāj materiāla raksturīgās īpašības. To skaitā koksnes šķiedru virziena specifiku, agrīnās un vēlīnās koksnes blīvuma atšķirības, apstrādes atšķirības šķiedru garenvirzienā un šķērsvirzienā, kā arī ļauj iepazīt raksturīgākās koksnes vainas. Lai apstrādājamā materiāla apgūšana būtu jēgpilna, studiju procesā tā integrēta produkta – koka puzles – izgatavošanā, ietverot secīgu izgatavošanas gaitu no priedes masīvkoka dēļa līdz apdarītam un funkcionālam produktam – puzlei. Studentiem tā jāizgatavo pēc vienota parauga, pamatojoties uz zīmējumu, kurā norādītas detaļu un savienojumu vietu proporcijas. Koka puzles izgatavošanas laikā studenti izvēlas atbilstošākos instrumentus katra etapa izpildei. Procesā nepieciešams veikt sagatavju un detaļu pārbaudi, mērīšanu, aizzīmēšanu, griešanu, rezultātā iegūstot trīsdimensionālu produktu, kas ir izjaucams un saliekams. Salikšanas un izjaukšanas process dod iespēju novērtēt apstrādes precizitātes nozīmību darba gaitā un rezultātā.

Atslēgas vārdi: tradicionālie kokapstrādes rokas instrumenti, amatniecība, koka apstrāde, produktu dizains, izglītība.