Lesson 4:
Box structures

Subject: Design
Age(s): 11 and up
Duration: 45 minutes
Difficulty: low to medium

Objectives

By the end of class, students will be able to:

- Understand what finger joints are and their benefits.
- Design an object that incorporates finger joints in its construction.

Overview

In this lesson, students will follow a hands-on approach to learn about a type of joinery called finger joints or comb joints. Once they understand its working principles, they will proceed to design and produce an object, in this case an open box, incorporating finger joints in its construction. The class will look together at the outcomes and think about ways to improve or enhance their designs.

Key Focus

- Use of digital tools like construction- and design software
- Understand the properties of certain joinery techniques
- Use of digital production equipment

Pre-lesson Checklist

For the teacher:

- Computer with XCS (xTool Creative Space) installed
- 2D Vector Design/Illustration software (e.g., Inkscape) (optional)
- xTool P2 connected to the Smoke Purifier
- 3mm basswood sheet or equivalent material to create a box

- Adhesive and other materials to assemble the box (optional)

For the students:

- Computer with XCS (xTool Creative Space) installed
- 2D Vector Design/Illustration software (e.g., Inkscape) (optional)
- 3mm basswood sheet or equivalent material to create their boxes
- Adhesive and other materials to assemble the boxes (optional)

Content Standards

Type	Indicator	Standard
ISTE	1.1d	Students understand the fundamental concepts of technology operations, demonstrate the ability to choose, use and troubleshoot current technologies and are able to transfer their knowledge to explore emerging technologies.
	1.2c	Students demonstrate an understanding of and respect for the rights and obligations of using and sharing intellectual property.
	1.3a	Students plan and employ effective research strategies to locate information and other resources for their intellectual or creative pursuits.
	1.3c	Students curate information from digital resources using a variety of tools and methods to create collections of artifacts that demonstrate meaningful connections or conclusions.
	1.3d	Students build knowledge by actively exploring real-world issues and problems, developing ideas and theories and pursuing answers and solutions.
	1.4a	Students know and use a deliberate design process for generating ideas, testing theories, creating innovative artifacts or solving authentic problems.
	1.4c	Students develop, test and refine prototypes as part of a cyclical design process.
	1.6b	Students create original works or responsibly repurpose or remix digital resources into new creations.
	1.6c	Students communicate complex ideas clearly and effectively by creating or using a variety of digital objects such as visualizations, models or simulations.

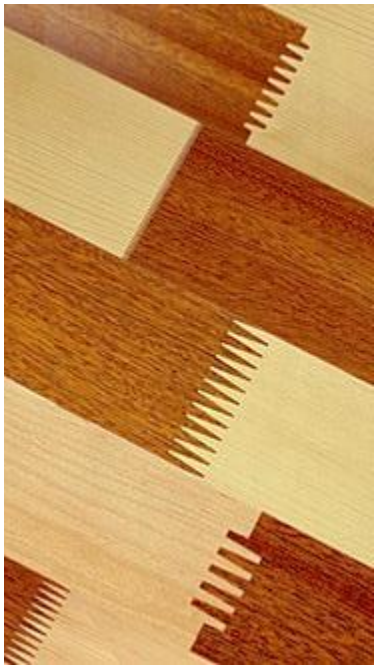
Agenda (45 minutes)

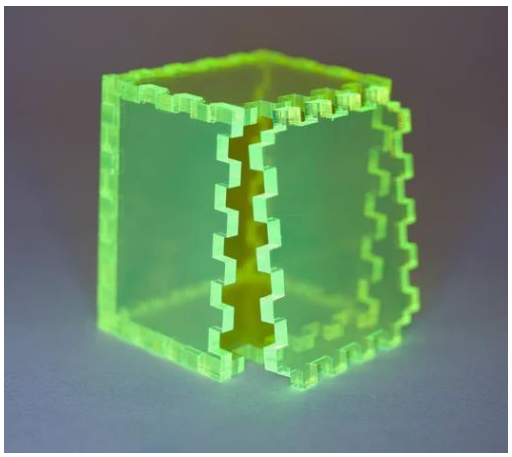
Duration	Content
5 minutes	Section 1- Engage (Introduction) • Introduction about finger joints • Real-world applications of this type of joinery
5 minutes	Section 2 – Explore • Students experiment by using a single finger joint between two pieces and analyze the results
10 minutes	Section 3 - Explain • Discuss the findings from the previous step • The characteristics and working principles of finger joints are explained • Students investigate and learn about the digital tools available to produce objects using finger joints
20 minutes	Section 4 - Elaborate • Students experiment by joining 3 planes using finger joints • Students are divided into groups to design different boxes to support the organization of classroom materials • Students make use of the xTool laser machine to fabricate their products • Ideas to extend the lesson
5 minutes	Section 5 – Evaluate and Exchange • Review of the lesson objectives (summary) • Couple of questions • Key vocabulary used • Reflection • Invite students to present their outcomes and ask questions to each other

Section 1 - Introduction (Engage)

Finger joints, also known as comb joints, is a type of joinery made by cutting a set of complementary interlocking wedges or "fingers" in two adjacent pieces which are then put together by using pressure and often some type of adhesive.

This type of joinery has different purposes. For example, to form longer pieces or to produce several pieces of the same length. A similar technique is also used to join pieces at an angle and create objects such as boxes or furniture.



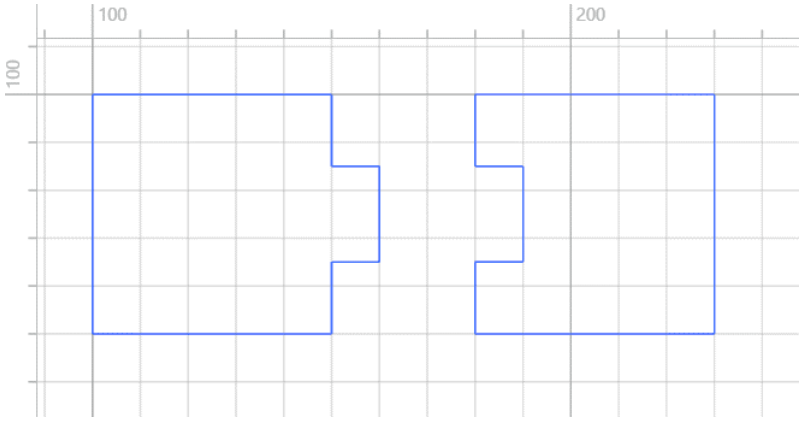


This technique produces a much stronger joint compared with simply gluing two pieces together in what is known as "butt joint". Because of this, it is often utilized in projects with structural requirements. The properties of finger joints will be further discussed in Section 3.

Another added value of this technique is that it helps to use less materials (such as adhesive, nails, or even more wood) for the fabrication of an object, and it allows to reuse small pieces of wood that perhaps wouldn't find another application as individual pieces.
Invite students to think about other examples of objects using finger joints.

Section 2 - Explore

As a first approach, students should experiment by creating single finger joints between two pieces of wood: one finger with one corresponding slot on the adjacent piece. They can work directly on the XCS software to design their test models, making sure that they use complementary dimensions between both parts.



The importance of the joint measurements will be discussed in the section 3; as a warm-up, the teacher should ask the class to make use of precise measuring tools such as Verniers to compare the resulting laser cut pieces against the digital drawings.
Are there any differences between the digital and physical models? Is there empty space between the pieces? Can the pieces hold together without any help? If not, can students think of ways to improve this? Let them document their tests and findings.

Section 3 - Explain

As mentioned in the previous sections, finger joints consist of interlocking elements, where every "finger" has a corresponding slot. Therefore, during the design process, one must make sure that each protruding finger has a complementary slot in the adjacent piece that perfectly matches its dimensions and proportions.

Using finger joints has a great structural advantage: it increases the contact area between two pieces and it adds spaces where they fit tightly with one another, thus increasing the force of friction between them. The larger the contact area is and the number of fitting spaces, the greater the force of friction, making for a firmer joint.

Creating finger joints can be a difficult process when using ordinary manual tools, since the effectiveness of the joint depends on precise measuring for the contact and friction between the pieces. Luckily, modern fabrication tools such as laser cutters allow us to achieve with minimal effort the level of precision required.

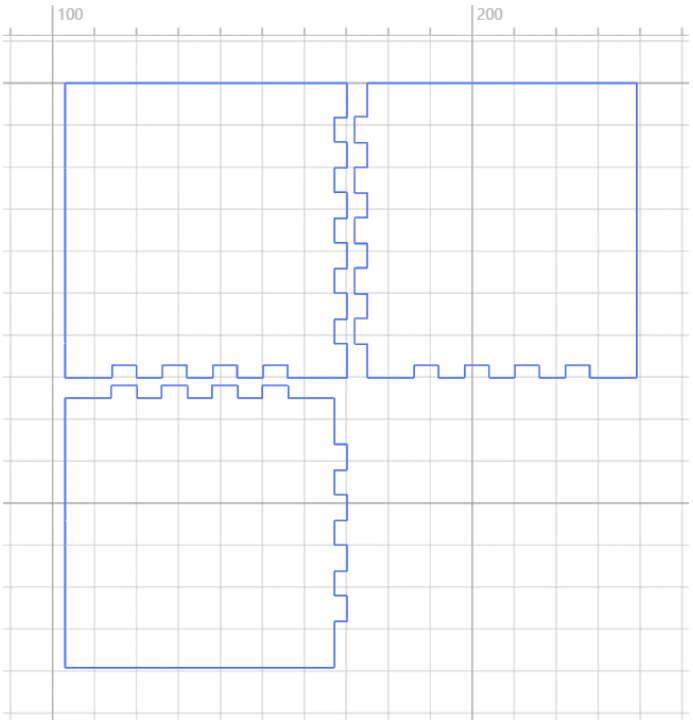
It is important to understand the principles behind the design of finger joints, although nowadays there are some widespread software solutions that take care of the hard work for us. Some examples of free online tools are https://www.festi.info/boxes.py/?language=en and https://www.makercase.com/#/

Students can research further into this readily-available tools for their future projects using laser cutting technology with the xTool machines.

Section 4 - Elaborate

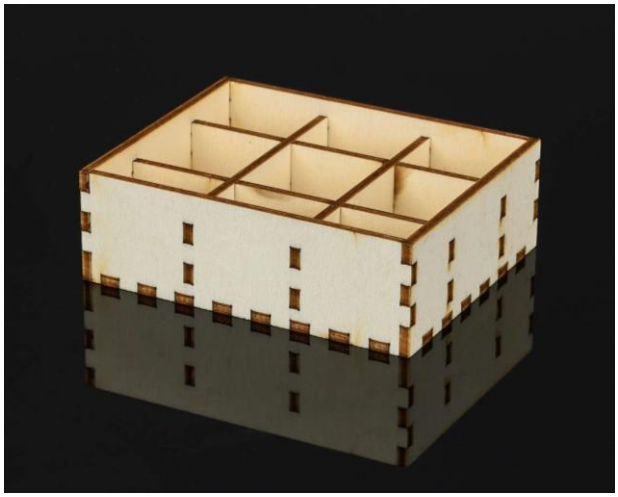
Before students create their own objects using finger joints, they will practice by putting together three planes by the edges. The assembly should now consist of multiple finger joints between the pieces.

The following image can be used by the teacher as a means to support the explanation:



We recommend using the 3mm basswood sheets available as consumables from xTool. Please double-check the thickness of the material prior to the design of the joints to ensure the success of the result. As the pieces will be fabricated using a laser cutter, remind students about the material-removing effect of the laser known as kerf, and ask them to try to compensate it by fine-tunning the dimensions of the interlocking spaces to produce tighter joints.

Once the students manage to ensure the quality of the finger joints, it is time to proceed to the group assignment. They will create boxes to help organize the materials in the classroom. Ask the class to observe the classroom and identify situations where a box would be useful (for example to collect used batteries, to store electronic equipment, materials for the art class, etc.). Different groups of students will work on different boxes. To distinguish the task according to the level of individual student's performance, other than rectangular shapes can be chosen (scaffolding). Here are some examples of designs that they can explore:



https://www.festi.info/boxes.py/

For more refined results, students are advised to match the depth of the fingers and slots with the thickness of the material used, resulting on cleaner edges of the box.
Once they have finished fabricating and assembling their boxes, bring all the projects together and ask the class to observe the result.

Extending the lesson

There are multiple ways to explore further the topic of boxes using finger joints:

- Invite students to apply some of the knowledge from previous lessons, such as the cross-halved joints. Ask them to enrich the design of their boxes by adding other fixed elements to their boxes such as handles, internal dividers, etc.
- They can also include some decorative elements to personalize their boxes.
- Students could also resort to some of the tools available online and try out new designs with the assistance of software.

Section 5 – Evaluate and Exchange

It is now time for a brief reflection. The students should think on their own and discuss with the group the following questions:

- What do you think turned out well?
- What could be better?
- Which parts of the lesson did you find easy, and which did you find more difficult?
- What would you like more explanation about?
- Who could help you with that?
- Could you think of improvements regarding the design of your box?