Wood Anatomy Teaching: Example of the Vocational School of Forestry

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The teaching of wood anatomy is difficult because of the Latin and foreign terminology and the great number of concepts, definitions, terms, and topics that must be learned and that pose difficulties in understanding for most students. The aim of this study was to describe developed traditional methods and adapt new methods in order to explain wood anatomy more clearly to students in both online and face-to-face education. The teaching of the Wood Structure and Identification course at the Vocational School of Forestry was observed and evaluated over the period of two academic terms (one during the Covid-19 pandemic). Teaching methods used in the wood anatomy course were described in detail. Lesson materials and homework were evaluated. When the usual methods were diversified and enriched with visuals and samples brought to the classroom, the students showed more interest in the lesson. As a result of the student drawing and modelling assignments, the lesson was reviewed and reinforced, which enabled the students to focus on the subject and consequently, to understand and learn more easily. It has determined that all teaching methods can be applied easily in both education periods, except using real wood samples method in online education.

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INTRODUCTION

Today, the role of teaching should move from that of merely transferring information into the dimension of guiding students to increase their performance. In this context, the teacher's ability to use teaching methods and techniques is important for the effectiveness of the process (Aydede *et al*. 2006). In this case, the main goal or duty of educators consists of seeking to achieve the targets and behaviors foreseen in the curriculum and of selecting, organizing, implementing, and supervising external events for the student learning process in line with the determined learning objectives (Erden 1995; Senemoğlu 2007). Educators should abandon traditional teaching methods at schools and adopt contemporary "hands-on" teaching methods, whereby students learn by doing and experiencing. Science educators are learners, and thus are urged to engage pupils in active learning (Allen and Tanner 2005). Active learning promotes the development of higher-order thinking abilities (Altun and Yücel-Toy 2015). Traditional education is educator-centered, *i.e.*, the teacher plays an active role in the teaching and learning process. All scientific facts, concepts, and principles are given to pupils by the educator without questioning. This encourages rote learning (Cimer 2012). However, by using modern

methods based on the individual in teaching activities that enable learning to be implemented, the quality of education is expected to improve (Hevedanlı *et al*. 2004).

For students to establish concepts in their minds in a meaningful and structured way, the learning process must be effective and continual. Incomprehensible concepts can be complex and structured differently in students' minds (Cepni *et al*. 2006). Good learning is permanently retained, and retention depends on the number of sensory organs that the learning activity addresses (Demirel 2004). The type of teaching-learning process (method/technique and equipment selection) presented to students during their educational period depends on the strategy that is implemented. For this reason, teaching methods suitable for each subject and appropriate materials to support these methods should be very carefully and correctly determined (Kaptan 1999). The use of educational materials facilitates perception and learning, increases interest in the subject, and brings vitality to the classroom. These materials can shorten the learning time, reinforce knowledge, and boost permanent retention (Doğdu and Aslan 1993). They can prevent rote learning in teaching and enable creative and constructive thinking. They can facilitate the transition of student understanding of the symbols taught to real structures and situations (Tekışık 2001). From the perspective of students, they learn 83% of what they have seen, 11% of what they have heard, 3.5% of what they have smelled, 1.5% of what they have touched, and 1% of what they have tasted. This emphasizes the importance of the effect of vision and hearing on learning (Ergin 1995; Kılıç 1997). Therefore, the more a training tool appeals to the sense organs, the more effective it will be (Büyükkaragöz and Çivi 1999).

One of the most complex subjects for teaching and learning is biology. Several studies have indicated that students have limited understanding and misconceptions about even the most basic biological processes (Yürük *et al*. 2000; Tekkaya *et al*. 2001; Selvi and Yakışan 2004; Maskiewicz 2006). A great many reasons for the difficulties that students have in learning biology and ways to overcome them have been studied by various researchers (Johnstone and Mahmoud 1980; Finley *et al*. 1982; Tolman 1982; Anderson *et al*. 1990; Seymour and Longdon 1991; Lazarowitz and Penso 1992; Bahar *et al*. 1999). It will be possible to achieve the goals set in teaching in a shorter time and in an effective way, and thus to realize permanent learning by enriching the learning environment only with qualified teachers and effective methods they will use (Scoott 1994; Penick 1995; Rutledge and Mitchell 2002). The literature review shows that the methods of lecture, question-answer, discussion, demonstration and laboratory, project and course trips methods are used in the teaching of biology and science lessons (Yaman 1998; Atıcı and Bora 2002).

The expression method is among the oldest and the most frequently used methods. The lecture is the main teaching agent and gives the student a comprehensive introduction to the main knowledge. This is a one-way communication that is under the control of the source person (lecture), with no response from the students and no interaction. The source could be a textbook, radio or audio tape, video, movie, or teacher. Reading books, listening to tapes, watching videos, and listening to lectures are examples of this method.

The other method used in biology education is the question-answer method. Post-presentation discussions, questions and answers are very important. The teacher asks students many questions about the subject, which reduces the boredom and increases the effectiveness of learning (Büyükkaragöz and Çivi 1999). Questioning and discussing generally help learners to reach a deeper level of thinking, learning, and understanding and to sensitize the inquisitive mind of the learner (Dorgu 2016).

In biology teaching, creating a multi-faceted environment for effective teaching in

the classroom or the laboratory is essential in terms of teacher-student interaction and communication, and the necessary elements to create this versatile environment are equipment (Sayan and Mertoğlu 2020). Although the benefits of using equipment (such as written materials, pictures, graphs, realia and models, visual and aural devices, projectors *etc*.) are many, some of the important ones are as follows; it enhances interest, motivation, and attention, saves time, can be used repetitively, facilitates remembering (Demirel *et al*. 2002; Yalın 2003).

Drawing is a common learning activity that students always do, and drawing is mostly used to record observation data. Drawing has become an essential tool for many educational researchers to help students understand certain biological concepts (Nugraha 2018). Students can express their different ideas by drawing.

Models are commonly used in teaching science to motivate learners, promote engagement, and provide authentic, hands-on activities and links to the real world. Modeling is central to learning and modeling scientific concepts provides opportunities for students to think scientifically. Model-based teaching motivates teachers and students and creates learning opportunities (Chittleborough 2013).

Wood anatomy is a specialized science of unique plant anatomy included in the field of biology. It encompasses the study of the micro- and macrostructure of wood cells and the understanding of these features from a biological and physical point of view. One of the most important goals of the wood anatomy course is to enable students to learn and apply the concepts correctly. Learning wood anatomy is difficult because of the Latin names and foreign terms and the many concepts, definitions, terms, and topics it includes. Wood anatomy books are generally translated, with much of the terminology in a foreign language, making it difficult for students to learn and spell these terms and to retain them.

The wood anatomy educational syllabus covers the three dimensions of wood structure, the shapes of the cells that make up the wood, their distribution, and their appearance in the three different grain directions. Most students find it difficult to understand these issues. Teaching events taking place at the microscopic level, with the support of concrete teaching aids that allow the students to visualize the processes in their minds, thus ensure that items of abstract information are formed as concrete concepts and that misconceptions are prevented (Atılboz 2004).

As already mentioned, several teaching methods are being applied in different fields of science education. Teaching wood structure is quite complex, so it is necessary to use combinations of different teaching methods in order to provide students with effective learning opportunities. This study aimed to develop classical teaching methods and adapt new methods applied in different areas of science in order to explain wood anatomy to students more clearly in online and face-to-face education.

EXPERIMENTAL

This study was carried out in the form of examining the methods applied in the Wood Structure and Identification course at the Vocational School of Forestry in Düzce University, Turkey. The students were attending their first year in the Forestry and Forest Products Department, and some had chosen the Wood Structure and Identification course. The quota averages 15 to 25 students per year. The course includes two 50-minute class periods and a one-hour laboratory period per week for a 14-week term.

The teaching methods used in this study are not new, and all of them have been used in biology education, including giving visual presentations, holding question-answer sessions, drawing the study subjects on paper, bringing real samples to the classroom, making models, giving short visual quizzes, and discovering examples of wood from nature or fabrics. Although expression methods (enriched with visual presentations), and using real samples have always been applied, drawing, question-answer (visual quizzes and discussion), and the creating of models are new for the teaching of wood anatomy.

Used classical teaching and new methods for wood anatomy were explained in detail in this study. The advantages and limitations of these methods are presented. For the drawing method and the model making activity, the most preferred drawing topics were sampled. With the drawing method, students were asked to draw images of the subjects covered up to the mid-term and at the end of the semester. Students were free to choose the subject. The drawings of the students in the 2019-2020 (face-to-face education) and 2020-2021 academic periods (the Covid-19 pandemic period-online education) were evaluated according to their chosen subjects. During the 2019-2020 academic period, 25 students and during the 2020-2021 academic period, 16 students attended the course. All students who took the course participated in the study. The subjects of the drawings and rate of the subjects drawn were listed under headings and the results evaluated.

Due to the start of the pandemic period, the model-making activity could not be applied in the 2020-2021 academic period. Here, the students formed groups with a maximum of three people and were free to choose the subject and material. The selected materials and topics and their selection rates were determined and are given in the findings. The rate was calculated as the ratio (%) of the specific subjects drawn/modeled from total number of subjects drawn/modeled.

With this study, the applicability of many teaching methods used in biology education to the teaching of wood anatomy will be evaluated in face-to-face and online education. By determining the preference of new drawing and model-making methods for students, comments will be made about the problems encountered in practice.

RESULTS AND DISCUSSION

The teaching methods applied in the Wood Structure and Identification course are explained in detail below.

Expression Method

Since the use of oral lessons can be boring for students, it is necessary to make the lesson more fun with various materials. For this reason, attention has been taken to include images in the sources. Several internet resources were investigated, and photos related to the subject were used in data-show presentations. Including more visual sources stimulates student interest and motivates them. Students can ask their questions more easily through visual examples. Some lesson presentation photos are given in Fig. 1. This method helps to convey the knowledge to large groups, and subjects and ideas are explained in a sequence and order that is quite suitable when teaching abstract concepts. It allows the teacher to express some opinions and ideas via suggestions. In addition to the expression method, the visuals were shown again at the end of one or two weeks as a general lesson review.

Fig. 1. Lesson presentation: Tree trunk sections (left), Microscopy of hardwood (right)

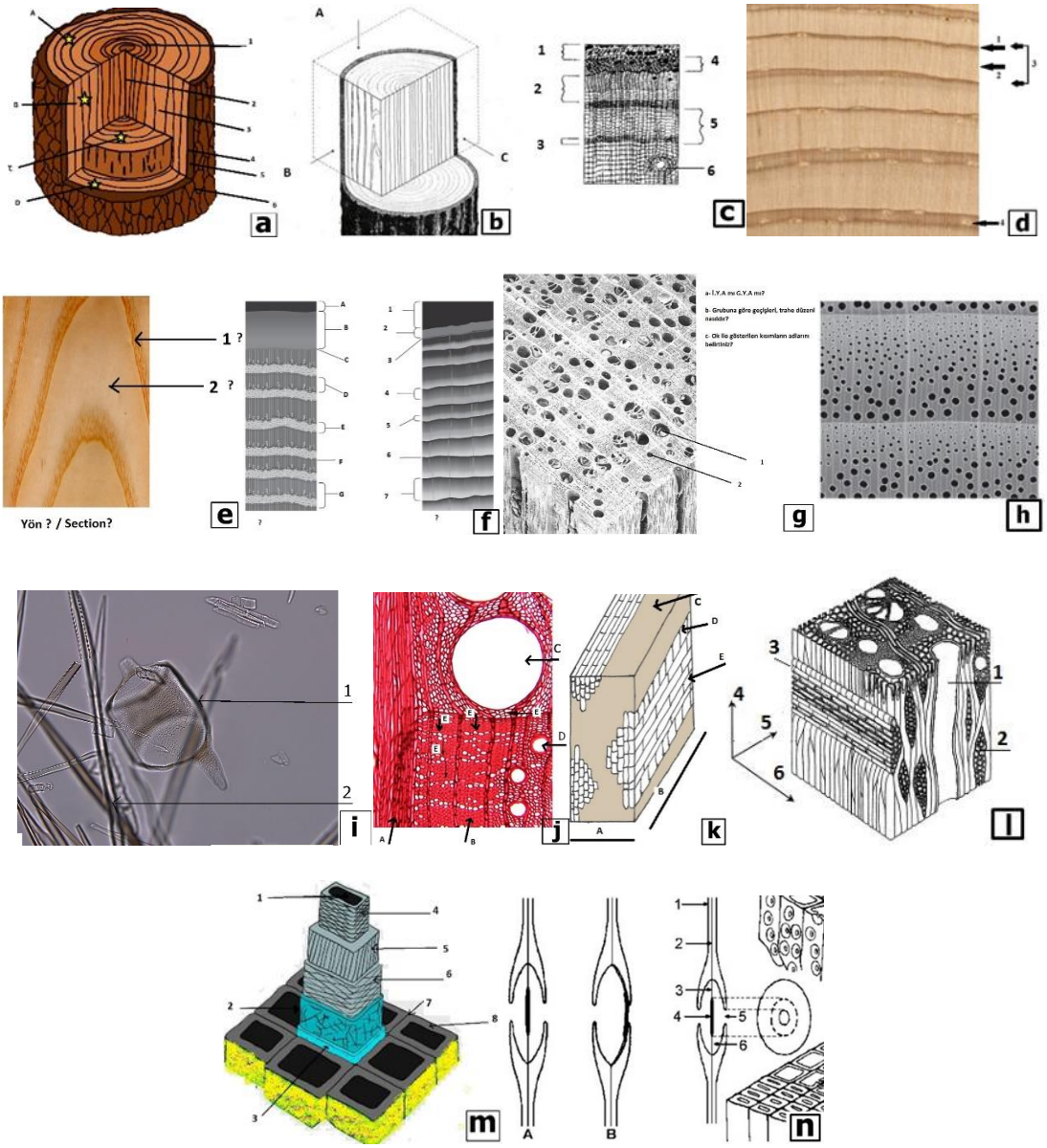

Fig. 2. Images for questions: (a) tree trunk sections, (b) wood sections (Rodrigues 2019), (c) softwood transverse section (Province of Nova Scotia 2019), (d) (Meier 2019) - (e) early and late wood, annual ring, (f) softwood and hardwood transverse section (Nunlist 2019), (g) vessel types (Care for Cultural Material – Wood 2019), (h) vessel distribution type (Nunlist 2019), (i) macerated hardwood cell, (j) hardwood cells in transverse section, (k) rays in different sections (Alden 2019), (l) hardwood cells in transverse sections (Greil *et al.* 1998), (m) cell wall layers, (n) bordered pit structure (Petty 1970).

This teaching method was straightforward to implement for both groups and was understandable for students. Even as the education was online during the pandemic and access from the internet was easier, extra information was accessed by going out of the presentation. Questions asked in real time could be answered promptly by accessing different sources.

Question-answer Methods (Visual Quizzes and Discussion)

In lessons, both classical questions and visual questions were asked via the data-show. Asking questions with visuals is similar to solving a puzzle. Students participate more frequently with such questions. The questions were created by processing the visuals related to the topics in drawing programs on the internet. Some examples of images subject to questions (marked with arrows or other signs and numbered) are shown in Fig. 2.

Such questions are discussed orally, as well as in the form of written answers. The manner of asking questions changes according to the duration of the lesson. If there is sufficient lesson time, then the answers are given orally and discussed. If there is not enough time, answers are put in writing. This method can easily be applied both in the classroom and for online education and is a method that is preferred by students.

Method Using Real Wood Samples

The purpose was to show all the macroscopic characteristics of wood (trunk sections, wood sections, grain directions, wood appearance, softwood and hardwood macroscopy, *etc*.) using a hand lens. Both native and tropical wood species were represented in the author's personal wood collection (Fig. 3). Examination of real wood samples in the lessons arouses student interest and enables the subjects to be explained more clearly in an animated and vivid manner during the lesson. By addressing the senses such as sight and touch, various experiences are presented, and rote learning is avoided.

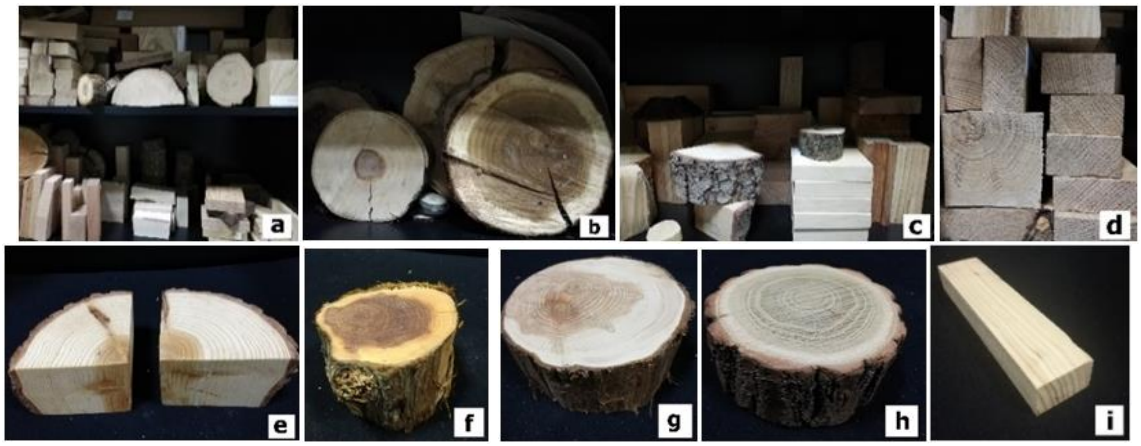

Fig. 3. Some wood samples used in the classroom: (a-b-c-d) wood from the author's collection, (e) softwood sections, (f)-(g) juniper (*Juniperus* sp.), (h) black locust (*Robinia pseudoacacia*), (i) fir (*Abies* sp.).

This practice has limiting factors. The most important of these is the lack of specimens of all wood species to accommodate the number of students. Working with a sample that every student can examine in the lesson helps to accelerate the learning time and facilitates one-to-one learning. Another limiting factor is the inadequacy of the

physical conditions of the classroom. Since the wood samples are kept in a special room, those samples for the subject to be explained for each lesson must be transported to the classroom. In this way, if the teacher wants to show a different sample during the course, it may not be readily available.

Because the number of students was small, there was opportunity to deal with each student individually, and missing information could easily be supplied. Using real samples is possible in courses with a small enrolment, but the same performance cannot be expected in classes with high numbers. In 2020, the instructors did not have the chance to show real samples to students as the classes were held online due to the pandemic. One of the most important factors in recognizing wood is the one-to-one contact. However, the students tried to identify the wood without touching. An attempt was mad to overcome this deficiency by showing copious amounts of macroscopic visual photographs. Of course, it is not as effective as the student's touching and examining the wood.

Drawing Method

Techniques used to teach concepts and to reveal prior student knowledge include concept maps, mind maps, concept networks, meaning analysis tables, V diagrams, prediction-observation-explanation, interviews about concepts and events, drawings, and word association (Karamustafaoğlu *et al*. 2005). When teaching wood anatomy, the drawing technique was used weekly to reveal what the students had learned about the subjects of wood structure. Students drew the subjects they had learned in that week's lesson. In this way, the subject was reinforced not only visually, but also via the drawing. This drawing homework was not mandatory, and the students were asked to draw the subjects they chose and understood. Some examples of student drawings of macroscopic and microscopic wood structure are shown in Figs. 4 and 5.

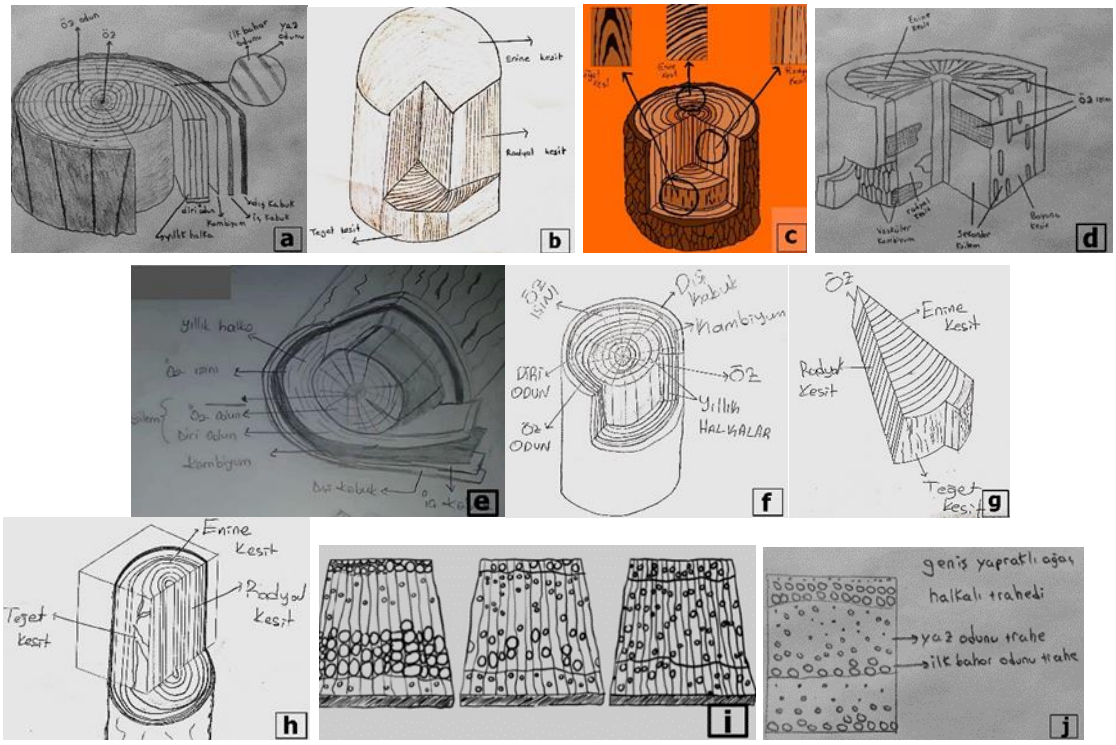

Fig. 4. Macroscopic drawings by students: (a-b-c-d-e-f) tree trunk sections (c was drawn digitally), (g)-(h) wood sections, (i) arrangement of vessels (drawn digitally), (j) ring of porous hardwood.

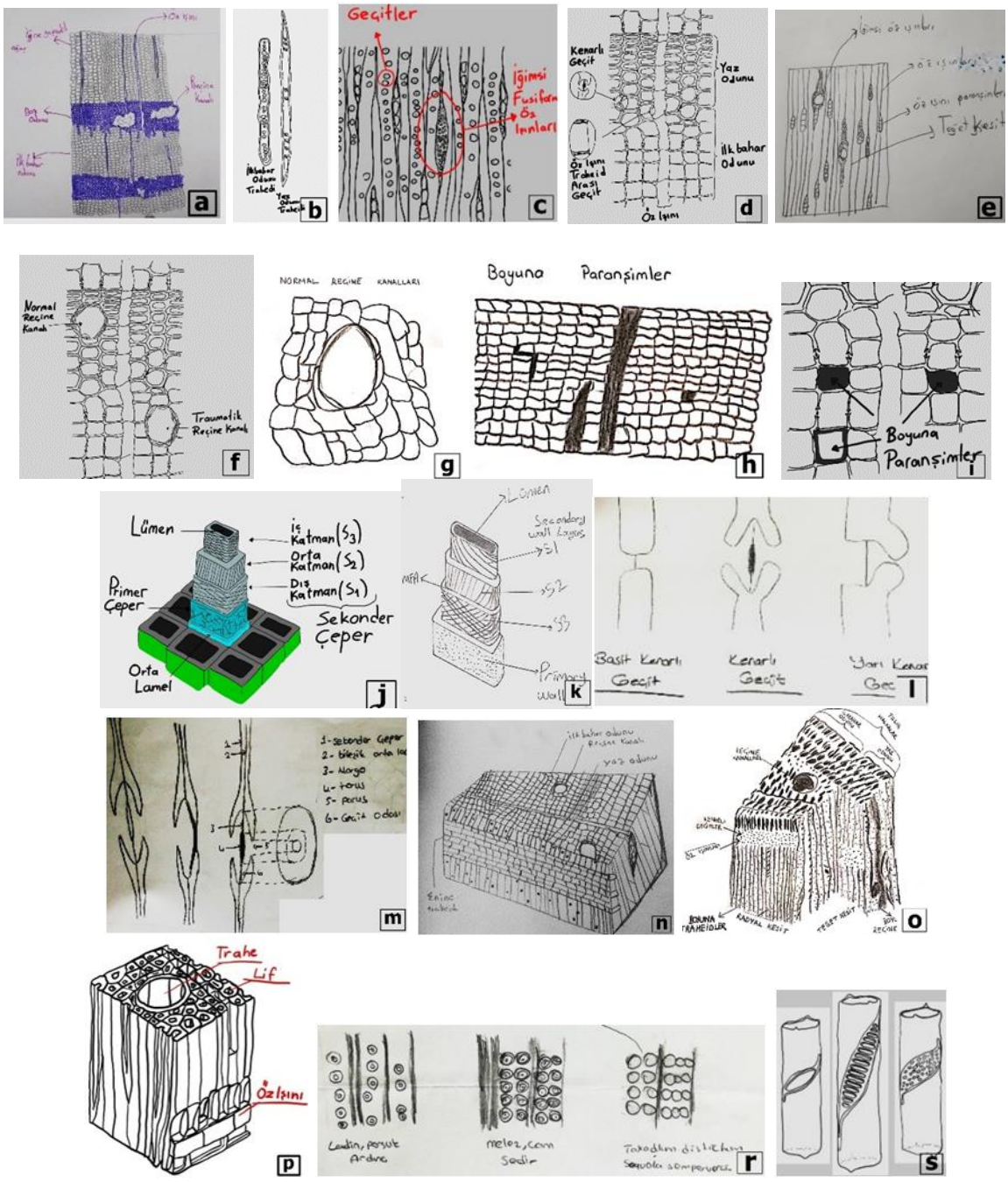

Fig. 5. Microscopic drawings by students: (a) cross section of softwood, (b) early and late wood tracheids, (c) bordered pits and fusiform ray on tangential section (drawn digitally), (d) cross-section of softwood with bordered pits, rays and early/latewood, (e) bordered pit views on transvers section, (f)-(g) resin canal and epithelium cells, (h)-(i) longitudinal parenchyma cells, (j)-(k) cell wall layers, and directions of microfiber, (l) pit types, (m) bordered pit and pit aspiration, (n)-(o) microscopic view of softwood, (p) microscopic view of hardwood, (r) bordered pits on tracheids for different species, (s) vessel elements with perforation plates.

All drawings were examined and then returned to the students with errors corrected on the pictures in red pencil. With this method, they can see their mistakes and the corrections. The students may consider drawing difficult or unnecessary, and thus may not want to do it. This kind of homework may at first seem to be too much for the students to

attempt, so information is given about the importance of the assignments at the beginning of the semester. It was explained to the students that these assignments were not only for taking grades but for reinforcing what they had learned, and this reminder was repeated where necessary. With the advancement of technology, some students make drawings via the computer. The aim is not to make an artistic drawing, but to understand the subject fully, so the quality of the drawing is not emphasized. When the student drawings were examined, the subjects found to be most frequently drawn are shown in Table 1.

The table shows that a very small number of drawings were done of detailed parts in the microscopic structure such as pits, vessels, tracheids, fiber structures, and cell wall layers during the pandemic period. However, wood sections, arrangement of longitudinal parenchyma, resin canals, annual rings/early and latewood, sections of tree trunk, and microscopic views of hardwood and softwood were drawn widely during the pandemic period (2020-2021) at 10%, 10%, 10%, 12%, 13%, and 13% respectively.

Table 1. Subjects and Ratio of Subjects Drawn

Drawing subject	2019-2020 Academic Year (Face-to face education)		2020-2021 Academic Year (Online education)	
	n	%	n	%
Sections of tree trunk	16	18	11	13
Wood sections	16	18	8	10
Transition in softwood	8	9	4	5
Vessel arrangement	14	16	3	5
Annual rings/early and latewood	8	9	10	12
Fiber structures	5	6	2	3
Pit types	6	7	5	6
Vessels	-	0	2	2
Tracheids	2	2	5	6
Cell wall layers	4	5	4	5
Arrangement of longitudinal parenchyma	4	5	8	10
Resin canals	2	2	8	10
Microscopic sections of softwood or hardwood	2	2	11	13
Total subjects drawn	87	100	82	100

The subjects that were the least drawn in both terms were the vessels, fiber structures, and cell wall layers. During the pandemic period, transition in softwood, vessel arrangement, and fiber structure were drawn less frequently than in the 2019-2020 academic year.

It seems that students mostly preferred subjects that are easy to draw (tree trunk and wood sections) for both of the academic periods. As no one preferred to draw complex microscopic structures, the students often drew the subjects that are most emphasized visually. The students who were taught using real wood samples in the normal educational period focused mostly on drawing wood macroscopy. During the pandemic period, students focused mostly on drawing the subjects whose visuals were given and they paid more attention to their drawings, making them clear and descriptive.

The drawing method could be easily applied to teaching wood anatomy both in face-to-face education and online education. In the interviews with the students, some students have stated that they come to understand the subjects that they previously did not understand much better while drawing. Dikmenli (2010) determined in his study that students could reveal what they know and understand with drawings. Although there are many studies on the effectiveness of the drawing methods in teaching of other branches of science, the effectiveness of the drawing method in the teaching wood anatomy should also be investigated.

Modeling Method

The modeling teaching method is applied with the help of real objects and samples made from similar materials or other items. Models are recognizable imitations of the real object and can be larger, smaller, or the same size as the actual object (Çilenti 1985; Okan 1993). A model can show the real object in more detail as well as in a very simplified way (Okan 1993). The purpose of model making is to facilitate understanding of obscure phenomena (Paton 1996). The use of models in teaching helps students understand the real world, increases motivation, and makes learning more effective (Greca and Moreira 2000; Halis 2002; Sezgin and Köymen 2002).

Lachenburch (2011) had her students prepare models showing the macroscopic and microscopic features of wood. Different models were developed with the use of very different materials such as coffee stirrers, toothpicks, Styrofoam, beer cans, and cardboard. She included durable models made by students in her collection and used them for undergraduate and graduate courses and also displayed them to visitors to the university.

The macroscopic structure of wood, the arrangement of wood cells, and the shapes of the cells are all suitable subjects for model making. For this reason, model-making homework was carried out by the students as an out-of-class activity via group work. Some students resisted doing it because of its apparent difficulty. However, completing this homework was made a requirement as a final project in the 2019-2020 education period. The model-making method was applied for the first and last time during this term because afterwards, we had to switch to distance education. At the end of the term, many different creations had emerged from a great variety of materials (Fig. 6).

Models fashioned from cardboard, plaster, straws, cones, real tree bark, toilet rolls, and colored paper were quite beneficial in reinforcing student learning during their creation. Since this was the first implementation of the method, some shortcomings were realized in planning the project and finalizing the details. For example, since specific subjects were not assigned to the students, most student groups produced duplicate models of the same subject. Therefore, this application was considered to be open to further development via experimentation.

When the models were classified according to their subjects, the subjects that had less detail and were easier to do were chosen for the model making as was the case with the drawing (Table 2). Models of tree trunk cross-sections were made using cardboard, plaster, colored paper, and pipets. This was the subject most preferred, with a ratio of 56%.

Some models represented annual rings, some showed heartwood and sapwood on the trunk, and some of them displayed sections. Not all features were shown on models of the same structure and most of the markings were missing.

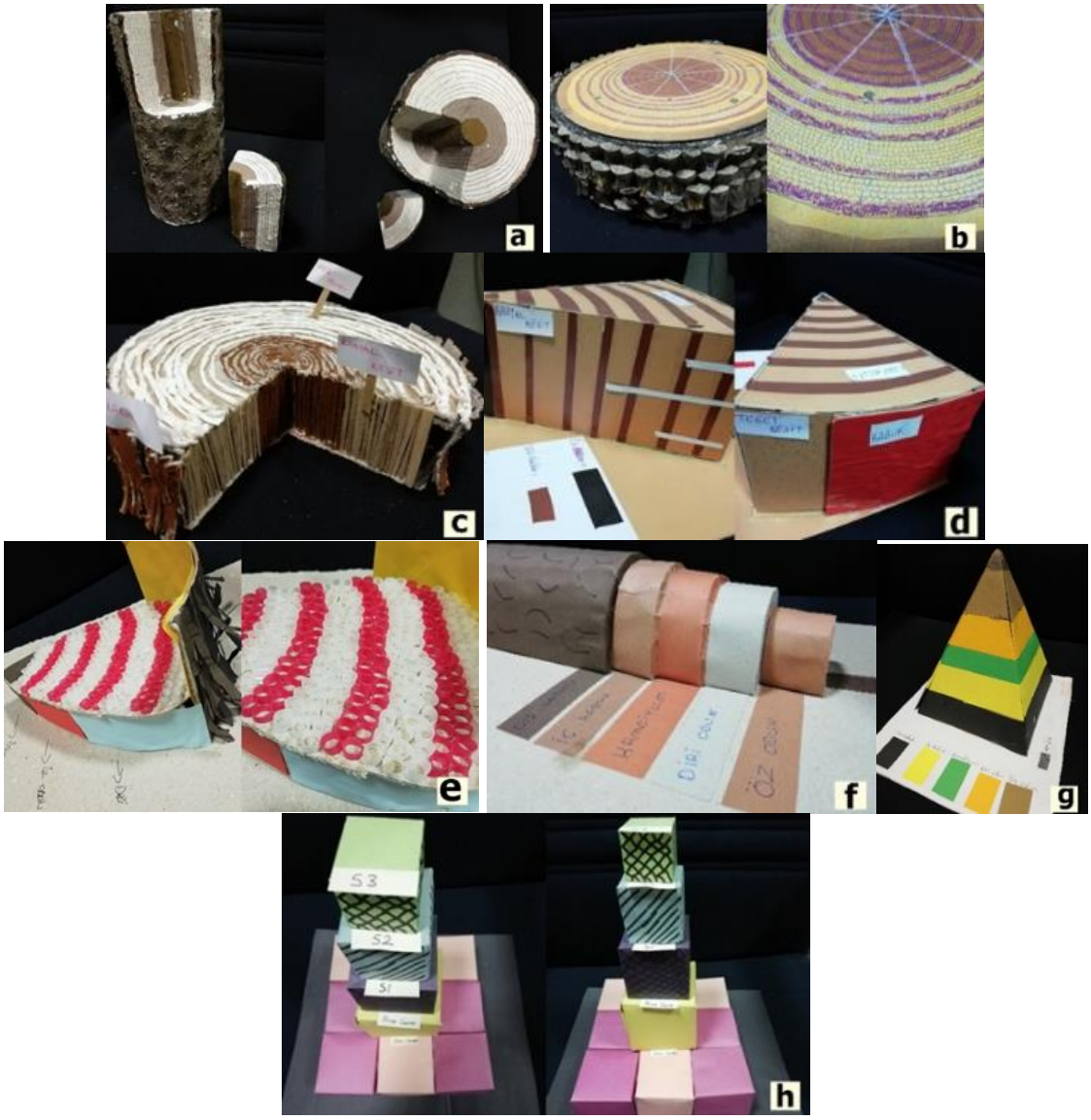

Fig. 6. Examples of student models of anatomical features: (a) Tree trunk parts (pith, heartwood, sapwood, bark, annual ring, and the sections -in plaster- very heavy), (b) tree trunk parts (main body made of cardboard, transverse section drawn by pencil for annual ring, rays, earlywood, latewood cells, and bark from pieces of cones), (c) tree trunk parts, main body (cardboard, colored paper), annual rings (curled toilet roll), (d) tree trunk as a cake slice (cardboard, and colored paper glued on sections as latewood and rays), (e) diffuse porous hardwood vessel distribution as in cross-section (vessels made of plastic pipettes), (f) tree trunk (nested cardboard); all layers made from different colored paper, (g) cell wall layers (layers of a pyramid, made from colored cardboard), (h) cell wall layers (overlapping colored cubes) and microfibril angles (drawn with marker).

Table 2. Ratio of Model Subjects (%)

Model subject	2019-2020 Academic Year	
	Number	%
Sections of tree trunk	9	56
Wood sections	3	19
Vessel arrangement	2	13
Cell Wall layers	2	13
Total subjects modeled	16	100

As can be seen in the table, students modeled only four subjects: sections of tree trunk and wood, vessel arrangement, and cell wall layers. No subjects such as softwood/ hardwood cross-sections, individual wood cells (vessels, tracheids, fibers, rays, *etc*.), pits, resin canals, *etc*. were modeled. Many reasons were considered as to why other subjects were not modeled, but based on these data, it is not possible to form an exact explanation. Since model making was applied for the first time, it was not conducted in a fully planned manner. A more systematic organization is needed to make models. The subjects should be determined in advance and distributed among the students. It might be possible to make the event more demonstrative by drawing lots.

This study, which emphasizes the applicability of various methods, can be further developed. The effectiveness of different methods on teaching/learning wood structure and the teaching methods used by different instructors can be examined in future studies. In this way, after determining the most effective methods, the focus can be directed to their development and application.

CONCLUSIONS

1. This study showed the applicability of the classical and various innovative teaching methods used in different branches of science for wood anatomy. The drawing method, which is a frequently used method especially in biology teaching, could also be applied in online education with the development of technology, and students could easily draw the topics covered in the course easily. The problem encountered here is that the subjects are left to the students' choice. For this reason, at the beginning of the semester, the drawing subjects should be included in the lesson plan, and it should be ensured that the students know which subjects they will draw at the end of each lesson. Since it is thought that model making will be impossible for the educator's group studies in online education by the educator, the model making method has not been applied in online education. In online education, model making topics can be given to students at the beginning of the semester and delivered individually to the end of the semester. It is believed that there are no problems with the applicability of model-making in online education.
2. The importance of classical methods is undeniable, of course. Expression techniques should be developed and enriched with ample visuals and the application of lessons in the form of mutual question-answer sessions. Avoiding monotony will be beneficial for both the educator and the student. The presentation of real wood samples to the students should always be applied so that the effect of learning by touch and feel can also be experienced. In the use of real wood samples, importance should be given to the variety of samples, and each student should have access to a number of samples. Actual wood samples that cannot be used in online education are considered a great loss.
3. Laboratory work is a must for wood anatomy teaching and learning. It is effective to see the cells in their real form. However, there are both physical and financial requirements for laboratory training. The lack of laboratory facilities encouraged us to apply the different teaching methods seen in this study. It is the basic task of an educator to find the best and the most suitable methods under adverse conditions and to conduct a pleasant and educational lesson without boring students. By following new practices,

methods that can be used to teach wood anatomy in the easiest way can be researched and applied.

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