Learning Anatomical Structures of Dicot Plants using Jigsaw Puzzles among Middle School Students

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Abstract

Teachers must try different pedagogical strategies in their classrooms according to the nature and need of their learners. The major objective of the study is to assess the effectiveness of jigsaw puzzles in learning the transverse sections of a typical dicotyledon (dicot) stem and root, based on drawing and labelling skills among Class 8 students. The study adopted a single group pretest post-test experimental design with convenience sample of 11 boys and 14 girl students of Class 8 of a rural school in Tamil Nadu. The result indicated a significant positive effect of the jigsaw puzzle method in learning the transverse sections of a typical dicot stem and root based on drawing and labelling skills. Boys and girls did not differ significantly in their performance before and after the intervention in both the drawing and labelling skills. The researcher recommended the adoption of the jigsaw puzzle method in learning the concepts of anatomical structures at high and higher secondary level.

Keywords: Jigsaw Puzzles, Teaching Strategy, Plant Anatomy, Transverse Section, Root Section, Stem Section

Introduction

Life would not be possible without plants. Many have re-realised the importance of plants as a living oxygen factory during the COVID-19 pandemic. The plant anatomy is the heart of modern Botany (Sokoloff et al., 2021). Plant anatomy describes the internal structure and organisation of the cells, tissues and organs of plants in relation to their development and function (Crang et al., 2018). Angiosperms are the recently evolved well adapted flowering plants on this planet. The number of cotyledons found in the embryo is the actual basis for distinguishing the two classes of angiosperms, monocotyledon (one cotyledon) and dicotyledon (two cotyledons). The stem and root anatomical structures that is, the transverse section of the typical dicot plants were considered for the present study.

Probable learning difficulties in learning anatomical structures

Students were probably coming across such anatomical technical terms for the first time. They might not know the fundamentals of such diagrams. The textbook provided to the students did not contain the plant morphology and the outline of the diagram for the concerned anatomical structures. Therefore, students would not have realised the importance of the diagram and simply skipped learning them. The teacher also would not have emphasised on the minute details of the diagram when teaching such anatomical concepts and not introduced the etymological meaning of the term involved. Perhaps the students were not given enough time to learn anatomy, which made them blank or confused while drawing and

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labelling. The conventions used in a diagram also affected diagram comprehension, and results show students had most difficulty comprehending diagrams (Kottmeyer et al., 2020). Biology students found it difficult to interpret, understand, and generate visualisations of the presented plants' photographs, indicating that their visual literacy in plant anatomy was insufficient. The primary reason for students' insufficient visual literacy was lack of conceptual understanding that resulted in their inability to apply and integrate knowledge (Susiyawati & Treagust, 2021).

Common teaching practices used in learning Biology

Consideration of the botanical content taught is less critical than the methods used to teach that content (Uno, 2009). The cognitive abilities of biology prospective teachers in plant anatomy must have knowledge of using the framework of revised bloom taxonomy (Setiono et al., 2017). There are some common teaching-learning approaches in anatomical structures. These may be classified into direct teaching in theory classes, practical classes in the laboratory, using teaching aids, self-learning approaches, indirect approaches, etc. One of the easiest ways is to draw the anatomical structures on the black/ white board with oral descriptions and may or may not draw coloured variations. Another common way is to teach them in the biology laboratory with the help of dissections of specific parts through microscopes, which may be readymade or freshly prepared mounts. The students section plant material and prepare specimens to view under a bright field microscope. Using a camera or cell phone, images of microscope slide contents allow students to label plant parts and engage in discussions with peers (Koehler et al., 2020). Moreover, such practicals can be done with the help of USB digital microscope connected with laptops (Dickerson et al., 2007).

Biology teachers should choose suitable equipment for the course, subject, students' level, setting and objectives. They should also be able to develop teaching materials in line with learning outcomes (Sayan & Mertoğlu, 2020). Teaching aids like charts, objects, models and specimens (Heiss, 1938), 3D models (Bryce et al., 2016), and digital 3D models can be used to allow learners to interact and visually examine the spatial structure, composition and arrangement of objects (Siiman et al., 2014). YouTube videos play a significant role in motivating and engaging students in the learning process, especially with the low-performing students (Cherif et al., 2014). The students' worksheet developed was feasible and able to empower the students' science process skills (Rahayu et al., 2018; Patresia et al., 2020). The teachers insist on students to draw those anatomical structures in the observation record note (Dempsey & Betz, 2001). Quizzes and assignments also play a vital role in leaning anatomical structures.

Students under multimedia aided instructions had better outcome than their colleagues in traditional teaching method (Kareem, 2018). The smart class/ interactive white board class has a positive impact on learning environment as it has enhanced the learning process (Choudhuri & Husain, 2017). There was a significant difference among the students' academic performance in the conventional and smart classroom. In addition, the use of smart classroom has greatly improved students' performance (Phoong et al., 2019). The smart board use in biology classes allows understanding of subjects more easily and rapidly, avoiding time consumption and increasing students' motivation and interest via visual elements (Yapici & Karakoyun, 2016). Other computer-based technique (Wang et al., 2020) and distance-based learning setting for learning biology (Hallyburton & Lunsford, 2013) can also be useful in learning anatomical structures. The use of the jigsaw as instructional strategy enhances students' achievement (Tabiolo & Rogayan, 2019).

This jigsaw puzzle applied to mathematics increases achievement scores (Bubikova-Moan & Opheim, 2020). Jigsaw cooperative learning improves biology lab courses (Colosi & Zales, 1998). The jigsaw puzzles facilitated active learning, enhanced problem-solving skills, and encouraged group discussions (Rodenbaugh et al., 2015).

Jigsaw puzzle

The investigator applied the jigsaw puzzle method to learn the anatomy of plants especially in learning and remembering transverse sections of dicot stem and roots of longer duration. Preparing coloured enlarged anatomical structures on thick charts, then cutting these structures into small parts possibly separating each cell, are referred to as the parts of a jigsaw puzzle. Arranging, assembling or recreating the anatomical structures drawn on the charts is the solution to the jigsaw puzzles in a gaming manner. Jigsaw puzzles will be useful in learning internal structure without dissecting or destroying plants or plant parts. The investigator strongly believes that it is one of the safest methods in learning anatomy besides handing blades, needles, glass items and microscope, etc. The concept of transverse sections of typical dicot stem and root was presented in pages 181-183 of Chapter 3 Class 8, Term 1, Tamil medium Science textbook of the Tamil Nadu State Board and that was considered for the intervention of the jigsaw puzzle method.

Objectives of the study

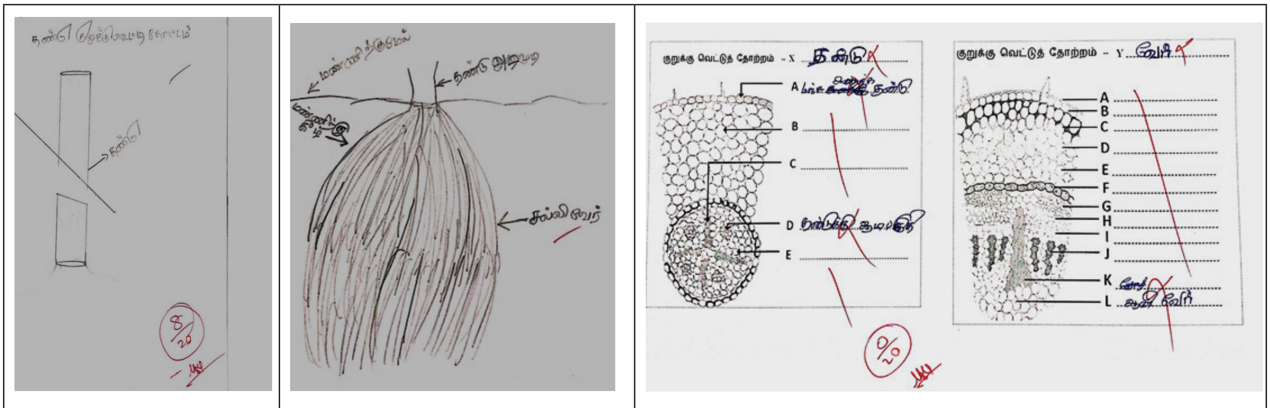
1. To introduce and implement jigsaw puzzle method to students of Class 8 of Panchayat Union Middle School, Ammangudi, Thiruvidaimarudur block of Thanjavur district in Tamil Nadu.
2. To find out whether there is a significant difference in performance between boys and girls, before and after the intervention of jigsaw puzzles in learning the transverse sections of typical dicot stem and root based on drawing and labelling skills.
3. To assess the effectiveness of the jigsaw puzzles in learning the transverse sections of typical dicot stem and root based on drawing and labelling skills among Class 8 students.

Research method and sample of the study

The study adopted single group pretest post-test experimental design with convenience sampling of 25 students (11 boys and 14 girls), the total strength of Class 8 of a rural school in Tamil Nadu, India.

Research tool

A pretest tool was developed, which contained two questions in Tamil, for testing the drawing skills of transverse section of typical dicot stem and root. The investigator wrote the questions on the blackboard and instructed students to draw in the provided A4 blank sheet with 0.7 mm lead refill pencil. The rubric for assessing the drawing skills comprised of the heading of the diagram, diagram proportion, clarity, legibility (neither dark nor light) and one-sided accurate marking used for labelling, each count for 4 marks for a total of 20 marks. The stem and root diagrams were given without labelling for testing the labelling skills of the students. The scoring of the labelling skills contained 19 fill in the blanks questions with 1 mark each and 1 mark was allotted for neat handwriting resulting in a total of 20 marks. The same tools were used for post-test to find the effectiveness of the intervention given to the students. Pretest samples are shown in Figure 1.



a b c

Figure 1. Pretest samples: a. transverse section of stem; b. transverse section of root; and c. labelling skill

Intervention

The investigator discussed the fundamentals in anatomy of plants along with the rubric and scoring of the tools after pretest. Six mixed gender groups of four each were formed. The last one had five members for collaborative learning. Students were instructed to draw the enlarged coloured transverse sections of typical dicot stem and root on the provided thick charts without labelling and heading with the help of the prescribed textbook. It took about an hour to complete this drawing task. The students were asked to cut the charts into pieces in such a way that each small portion possibly signified a single cell. These pieces were put into a small box carefully without misplacing any small piece. Six small jigsaw puzzle boxes of three each for stem and roots were obtained as shown in Figure 2. All six groups were instructed to assemble the small pieces to form the complete transverse section as it was in the chart before being cut into small pieces as shown in Figure 3.

These jigsaw puzzles were interchanged group wise in such a way that the groups that prepared the stem puzzle would get the root puzzle prepared by the other team. The students were encouraged individually also to solve the jigsaw puzzles. The investigator instructed students to learn the naming of various parts while solving these puzzles. The investigator and science teacher of the school observed that the students were really active in creating and solving jigsaw puzzles. Such tasks definitely increased their interest, cooperation, self-confidence through a gaming environment. The next day, a post-test was conducted and the samples as shown in Figure 4 were shown.

a b

Figure 2. Steps in creating jigsaw puzzles: a. drawing transverse stem structure; b. drawing transverse root structure; c. complete transverse section of stem drawn; d. complete transverse section of root drawn; e & f. cutting the transverse section into small pieces; g. jigsaw puzzle box for stem; and h. jigsaw puzzle box for root

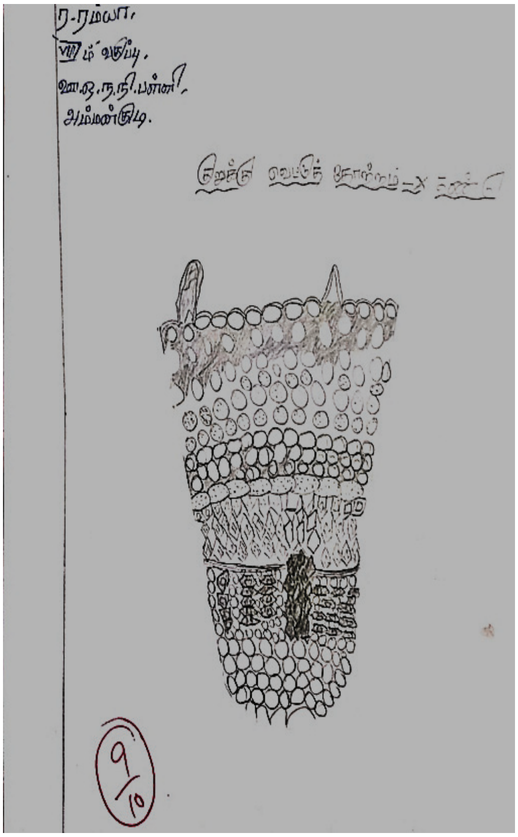
a

b

c

d

Figure 3. Solving jigsaw puzzles: a. assembling the dicot stem pieces; b. assembling the dicot root pieces; c. solved stem jigsaw puzzle; and d. solved root jigsaw puzzle



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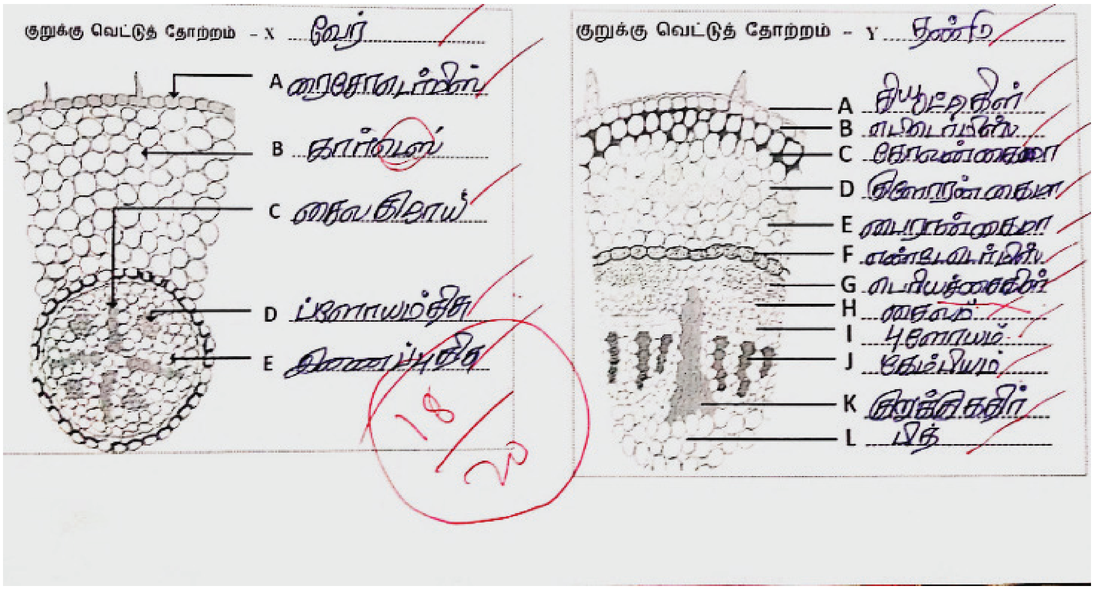

c

Figure 4. Post-test samples: a. transverse section of stem; b. transverse section of root; and c. labelling skill

Results and discussions

The pretest and post-test scores of drawing and labelling skills were evaluated, tabulated and applied for further descriptive and differential analysis.

Table 1. Descriptive and differential analysis of boys and girls in the pretest and post-test scores for drawing and labelling skill

Variable	Boys		Girls		t - value	df
	M	SD	M	SD		
Pretest drawing skill 3.45 1.293			4.29	1.326	1.577	23
Posttest drawing skill	13.45	2.979	14.57	1.989	1.070	23
Pretest labelling skill	0.55	1.809	0.71	1.858	0.229	23
Posttest labelling skill	15.00	3.924	16.93	1.730	1.653	23

Boys and girls did not differ significantly in their performance before and after the jigsaw puzzle intervention on both drawing and labelling skills (Chukwu & Arokoyu, 2019) as shown in Table 1.

Table 2. Descriptive and differential analysis of pretest and post-test scores for drawing and labelling skill of total sample

Variable	Pretest		Post-test		Mean gain	r value	t - value	df
	M	SD	M	SD				
Drawing skill	3.92	1.352	14.08	2.482	10.16	0.549**	24.479**	24
Labelling skill	0.64	1.800	16.08	2.999	15.44	0.253	25.038**	24

Note: ** indicate significance at 0.01 level

The t-value for the scores on pretest and post-test drawing skill for total sample was determined to be 24.479, which is significant at 0.01 level. The mean gain between pretest and post-test scores for drawing skill of total sample estimated to be 10.16 indicates positive effect of jigsaw puzzle method. Similarly the t-value for the scores on pretest and post-test labelling skill for total sample was determined to be 25.038, which is significant at 0.01 level. The mean gain between pretest and post-test scores for labelling skill of total sample estimated to be 15.44 indicates positive effect of intervention. Moreover, there exists a moderate positive significant relationship between the scores on pretest and post-test drawing skill for the total sample, whereas there was no relationship found in labelling skill as given in Table 2.

The results indicate that the jigsaw puzzle method was effective by improving the student's drawing and labelling skills and in turn the academic scores (Renganathan, 2020). Students taught with the jigsaw strategy achieved greater improvement in their mean scores than those taught with the conventional lecture method (Ojekwu & Ogunleye, 2020). There was a significant higher achievement rate among students taught using the jigsaw co-operative teaching/learning strategy and increasing attitudes and values of learners towards study in biology (Juweto, 2015). The results of the study showed that the jigsaw puzzle was an effective instructional strategy for the enhancement of students' academic performance in biology (Chukwu & Dike, 2019). The jigsaw approach had a direct effect on the academic effort (Abbasi et al., 2019).

Educational implications and recommendations

One of the safest ways of teaching anatomy is without the usage of blades, needles and glass items such as watch glass, glass slide and cover slips. The jigsaw puzzles created can be reused for other students of higher classes. The students without doubt can, for years, remember the study as it creates a gaming environment to learn faster (Zirawaga et al., 2017) and also to learn by having fun (Rodenbaugh et al., 2015). Jigsaw puzzles give opportunities to students to create their own jigsaw puzzles for better learning. The students will be able to easily crack any competitive exam regarding anatomical concepts. Self-rectification and self-improvement can be done through this method of learning and that too with ease in case of late bloomers. Pair or group work helps children to work in a team, communicate and collaborate. Moreover, students work in small peer groups, which is one of the better ways to teach science (Webb & Palincsar, 1996). The students prepared only two types of jigsaw puzzles. Similar puzzles can be prepared for other classes based on their conceptual need. These boxes can be prepared and kept safe in the library and can be issued for reference as reference books. 3D jigsaw puzzles can be prepared when the conceptual depiction is insufficient in 2D. The researcher recommended the adoption of the teaching method by using the jigsaw strategy in teaching science because of its effect on the acquisition of scientific concepts (Hamadneh, 2017). The study recommended that teachers should adopt the jigsaw learning strategy in classroom practice especially in learning anatomical concepts.

Conclusion

The effect of jigsaw method worked very well for the students of Class 8, but the real effect of this method can be detected in the higher secondary classes where more complex anatomical structures need to be remembered with accurate labelling. The success of any pedagogical-based research lies in field implementation or in the hands of teachers to take this method to students in need.

References

Abbasi, H., Mehdinezhad, V., & Shirazi, M. 2019. Impact of Jigsaw Technique on Improving University Students' Self-Concept. *Educational Research in Medical Sciences*, *8*(1), 0–4. https://doi.org/10.5812/erms.92010

Bryce, C.M., Baliga, V.B., Nesnera, K.L.D., Fiack, D., Goetz, K., Tarjan, L.M., Wade, C.E., Yovovich, V., Baumgart, S., Bard, D.G., Ash, D., Parker, I.M., & Gilbert, G.S. 2016. Exploring Models in the Biology Classroom. *American Biology Teacher*, *78*(1), 35–42. https://doi.org/10.1525/abt.2016.78.1.35

Bubikova-Moan, J., & Opheim, V. 2020. 'It's a jigsaw puzzle and a challenge': critical perspectives on the enactment of an RCT on small-group tuition in mathematics in Norwegian lower-elementary schools. *Journal of Education Policy*, *00*(00), 1–21. https://doi.org/10.1080/02680939.2020.1856931

Cherif, A.H., Ph, D., Siuda, J.E., Ph, D., Movahedzadeh, F., Ph, D., Street, E.L., & Il, C. 2014. College Students ' Use of YouTube Videos In Learning Biology and Chemistry Concepts. *Pinnacle Journal*, *2*(6), 1–14.

Choudhuri, B., & Husain, A. 2017. Impact of Smart Class on Academic Achievement of Government aided Secondary School Learners of South Delhi. *International Journal for Research in Multidisciplinary Field*, *3*(7), 561–565.

Chukwu, J.C., & Arokoyu, A.A. 2019. Effects of Jigsaw-Puzzle Instructional Strategy on Secondary School Students' Performance on Growth as a Concept in Biology in Abia State. *Advances in Research*, *20*(1), 1–6. https://doi.org/10.9734/air/2019/v20i130148

Chukwu, J.C., & Dike, J.W. 2019. Effects of Jigsaw-puzzle and Graphic Organizer Instructional Strategies on Biology Students' Performance in Abia State. *Archives of Current Research International*, *18*(3), 1–6. https://doi.org/10.9734/acri/2019/v18i330139

Colosi, J.C., & Zales, C.R. 1998. Jigsaw cooperative learning improves biology lab courses. *BioScience*, *48*(2), 118–124. https://doi.org/10.2307/1313137

Crang, R., Lyons-Sobaski, S., & Wise, R. 2018. Plant Anatomy. In *Plant Anatomy*. Springer International Publishing. https://doi.org/10.1007/978-3-319-77315-5

Dempsey, B.C., & Betz, B.J. 2001. Biological drawing: A scientific tool for learning. *American Biology Teacher*, *63*(4), 271–279. https://doi.org/10.1662/0002-7685(2001)063[0271:bdastf]2.0.co;2

Dickerson, J., Dickerson, J., Kubasko, D., & Kubasko, D. 2007. Digital Microscopes: Enhancing Collaboration and Engagement in Science Classrooms with Information Technologies. *Contemporary Issues in Technology and Teacher Education*, *7*, 279–292.

Hallyburton, C.L., & Lunsford, E. 2013. Challenges and Opportunities for Learning Biology in Distance-Based Settings. *Interdisciplinary Science Literacy*, *39*(1), 27–34.

Hamadneh, Q.M.S. 2017. The Effect of Using Jigsaw Strategy in Teaching Science on the Acquisition of Scientific Concepts among the Fourth Graders of Bani Kinana Directorate of Education. *Journal of Education and Practice*, *8*(5), 127–134.

Heiss, E.D. 1938. *The Use of Objects, Specimens, and Models i n the Teaching of Science*. http://online.ucpress.edu/abt/article-pdf/1/2/42/8105/4436856.pdf

Juweto, G.A. 2015. School Location on Students Achievement and Attitude towards Biology in Secondary School in Delta State. *International Journal of Education and Research*, *3*(8), 31–40. https://www.ijern.com/journal/2015/August-2015/04.pdf

Kareem, A.A. 2018. The Use of Multimedia in Teaching Biology and Its Impact on Students' Learning Outcomes. *The Eurasia Proceedings of Educational & Social Sciences*, *9*(1), 157–165. https://dergipark.org.tr/download/article-file/531778

Koehler, A.M., Larkin, M.T., & Shew, H.D. 2020. Under the Scope: Microscopy Techniques to Visualize Plant Anatomy & Measure Structures. *American Biology Teacher*, *82*(4), 257–260. https://doi.org/10.1525/abt.2020.82.4.257

Kottmeyer, A.M., Meter, P. Van, & Cameron, C. 2020. How we teach: Generalizable education research: Diagram comprehension ability of college students in an introductory biology course. *Advances in Physiology Education*, *44*(2), 169–180. https://doi.org/10.1152/ADVAN.00146.2018

Ojekwu, I.N., & Ogunleye, B.O. 2020. Effects of Jigsaw Learning Strategy on Science Students ' Performance and Interest in Biology in Selected Schools in Rivers State , Nigeria. *Sapientia Foundation Journal of Education, Sciences and Gender Studie*, *2*(3), 325–334. https://doi.org/10.13140/RG.2.2.16936.60168

Patresia, I., Silitonga, M., & Ginting, A. 2020. Developing biology students' worksheet based on STEAM to empower science process skills. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *6*(1), 147–156. https://doi.org/10.22219/jpbi.v6i1.10225

Phoong, S.Y., Phoong, S.W., Moghavvemi, S., & Sulaiman, A. 2019. Effect of Smart Classroom on Student Achievement at Higher Education. *Journal of Educational Technology Systems*, *48*(2), 291–304. https://doi.org/10.1177/0047239519870721

Rahayu, Y.S., Pratiwi, R., & Indana, S. 2018. Development of biology student worksheets to facilitate science process skills of student. *IOP Conference Series: Materials Science and Engineering*, *296*(1), 0–11. https://doi.org/10.1088/1757-899X/296/1/012044

Renganathan, L. 2020. A Comparative Study on Effectiveness of Jigsaw Puzzle Method among General Nursing Diploma Students' Academic Level of Performance at Oman Nursing Institute, Muscat. *International Journal of Management Research and Social Science*, *07*(02), 15–18. https://doi.org/10.30726/ijmrss/v7.i2.2020.72003

Rodenbaugh, H.R., Lujan, H.L., Rodenbaugh, D.W., & DiCarlo, S.E. 2015. Having fun and accepting challenges are natural instincts: Jigsaw puzzles to challenge students and test their abilities while having fun! In *Advances in Physiology Education* (Vol. 38, Issue 2, pp. 185–186). https://doi.org/10.1152/advan.00117.2013

Sayan, H., & Mertoğlu, H. (2020). Equipment Use in Biology Teaching. *Journal of Educational Issues*, *6*(1), 357. https://doi.org/10.5296/jei.v6i1.17042

Setiono, S., Rustaman, N.Y., Rahmat, A., & Anggraeni, S. 2017. Students' Cognitive Abilities in Plant Anatomy Practical Work. *Journal of Physics: Conference Series*, *895*(1). https://doi.org/10.1088/1742-6596/895/1/012127

Siiman, L., Mäeots, M., & Pedaste, M. 2014. Learning biology with interactive digital 3D content: Teacher attitudes. *Proceedings of the European Conference on E-Learning, ECEL*, *2014*(January), 478–484.

Sokoloff, D.D., Jura-Morawiec, J., Zoric, L., & Fay, M.F. 2021. Plant anatomy: At the heart of modern botany. *Botanical Journal of the Linnean Society*, *195*(3), 249–253. https://doi.org/10.1093/botlinnean/boaa110

Susiyawati, E., & Treagust, D.F. 2021. Students' visual literacy: A study from plant anatomy learning. *Journal of Physics: Conference Series*, *1747*(1). https://doi.org/10.1088/1742-6596/1747/1/012021

Tabiolo, J.L., & Rogayan, D.J.V. 2019. Enhancing Students' Science Achievement through Jigsaw II Strategy. *Journal of Science Learning*, *3*(1), 29–35. https://doi.org/10.17509/jsl.v3i1.17680

Uno, G.E. (2009). Botanical literacy: What and how should students learn about plants? *American Journal of Botany*, *96*(10), 1753–1759. https://doi.org/10.3732/ajb.0900025

Wang, C., Li, X., Caragea, D., Bheemanahallia, R., & Jagadish, S.V.K. 2020. Root anatomy based on root cross-section image analysis with deep learning. *Computers and Electronics in Agriculture*, *175*. https://doi.org/10.1016/j.compag.2020.105549

Webb, N.M., & Palincsar, A.S. 1996. *Group processes in the classroom.* (pp. 841–873). USA: Prentice Hall International.

Yapici, I.Ü., & Karakoyun, F. 2016. High school students attitudes towards smart board use in Biology classes. *Educational Research and Reviews*, *11*(7), 459–465. https://doi.org/10.5897/err2016.2691

Zirawaga, V., Olusanya, A., & Maduki, T. 2017. Gaming in education: Using games a support tool to teach History. *Journal of Education and Practice*, *8*(15), 55–64. https://files.eric.ed.gov/fulltext/EJ1143830.pdf