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Design analysis and reconstruction of laboratory activities on fruit's DNA isolation practice

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ABSTRACT

Practicum is very important in science learning because it provides direct experience to students so that students can understand the context of natural phenomena through direct observation. This research aims to evaluate and improve the design of laboratory activities (DKL) in fruit DNA isolation practicum. This research uses a qualitative descriptive analysis design. The sampling method used was purposive sampling, namely by analyzing the DKL contained in Biology textbooks. The instrument used is an instrument development based on the Vee diagram principle. The results of the analysis show that DKL has a fairly good quality level, namely reaching a percentage of 72%, but still requires several adjustments in the form of reconstruction. The reconstruction carried out included adding verbs to learning objectives, replacing and adding equipment specifications, using standard units in measuring materials, restructuring procedures, adding units to observation tables, and data transformation using graphics. It is hoped that the results of the DKL reconstruction can provide more effective and relevant guidance for students and contribute to efforts to improve the quality of practical learning in the context of DNA isolation.

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Keywords
Biology Practice, Laboratory Activities Design, Vee Diagram Analysis.

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INTRODUCTION

Biology is a life science that studies living things and their relationship with the environment. Biology in learning is as facts, concepts and processes. Where in its implementation this process is presented in scientific or practical form. Biology learning is closely related to scientific activities in the form of practicums (Siregar et al., 2022). Practical activities are very effective for science learning, because they can encourage students' contextual understanding through direct experience to reveal phenomena that occur around them (Seprianto et al., 2022). Other skills that can be provided in practical activities include observation, classification, interpretation, communication, planning and conducting investigations, proposing hypotheses, controlling variables, asking questions (Hofstein & Mamlok-Naaman, 2007) and communicating research results (Setiawan et al., 2020).

Practical activities can develop students' knowledge in the realm of objectives and phenomena (Millar, 2004; Wahidah et al., 2018). Through practical activities, students are trained to develop cognitive, affective and psychomotor skills in understanding science phenomena (Wahidah et al., 2018). Where practical activities can give rise to developed ideas by students (Abrahams & Millar, 2008; Siregar et al., 2022). So practicum is believed to be able to develop students' knowledge and skills (Setiawan et al., 2020; Siregar et al., 2022; Toplis & Allen, 2012). Students have freedom to construct knowledge based on factual information through observing objects and phenomena (Siregar et al., 2022). This knowledge can support students' understanding of the concepts and theories that have been studied in classroom (Wahidah et al., 2018), through the process of explaining the concepts studied with real understanding obtained during practicum (Hofstein & Mamlok-Naaman, 2007; Setiawan et al., 2020). In accordance with (Agustina, 2015) which states that practicum-based learning can provide concrete experiences to students (Suryani et al., 2014), so that students can acquire new concepts and ideas (Putri et al., 2018; Wahidah et al., 2018). According to (Sanjaya, 2011), direct experience in learning is very beneficial for students because they gain knowledge from their own activities, so they can minimize the misconceptions (Suryani et al., 2014).

Practical activities can be carried out well if there is a laboratory activity design (Mila Putri et al. 2018). Laboratory activity design (DKL) can direct students to construct their knowledge based on emerging phenomena (Wahidah et al., 2018). DKL contains instructions for practical activities (Seprianto et al., 2022). According to (Meyhandoko, 2013) DKL has several roles such as: 1) helping students achieve learning mastery, 2) cultivating scientific work habits, 3) providing feedback to teachers in preparing more varied learning plans (Putri et al., 2018; Wahidah et al., 2018). A good DKL should have several aspects such as: 1) Practicum objectives, 2) theoretical basis, 3) availability of tools and materials, 4) work procedures, 5) how to use tools, 6) interpretation of observation data, 7) data analysis, and 8) conclusion of practicum activities (Seprianto et al., 2022).

Practicum implementation still has many obstacles, especially related to the availability of DKL (Seprianto et al., 2022). According to Kurniasih et al. (2020) and Supriatno (Siregar et al., 2022) several obstacles were identified and often arose, including greater emphasis on cognitive aspects rather than psychomotor aspects in practicum objectives, use of a deductive approach with an expository model, closure of structures in practicum procedures, and selection of practicum material that does not consider its essence, similarities and complexity (Supriatno, 2022). Apart from that, practicum activities are often purely verification in nature, without building new constructs of understanding (Capah & Fuadiyah, 2021; Siregar et al., 2022).

Thus, this study aims to analyze and reconstruct the DKL of Fruit's DNA isolation. Fruit is often chosen in DNA isolation practicals for several scientific and practical reasons. First, the fruit has a high DNA content, which makes the extraction process easier compared to other plant parts such as leaves or stems (Saghai-Maroof et al., 1984). The cell structure in fruit is also relatively simple, making it easier to break down during the isolation process (Doyle & Doyle, 1987). In addition, fruit is usually available in a variety of varieties and has a clear ripening time, making sampling easier. The lower cellulose and lignin content in fruit also contributes to the ease of DNA isolation, as other parts of the plant often have high contents of these substances, complicating the process (Murray & Thompson, 1980). Lastly, fruit is generally freer from contaminants such as microorganisms and chemicals often found in plant and animal parts, resulting in cleaner DNA. All these factors make fruit an ideal choice for DNA isolation practicals in educational laboratories.

The main aim of this research is to improve and enhance the existing DKL (carried by several textbook biologies that used), with the hope of optimizing the knowledge claim process during practicum implementation. Through this analysis and reconstruction, it is hoped that the updated DKL can provide more effective and relevant guidance for students and contribute to efforts to improve the quality of practical learning in the context of DNA isolation.

METHOD

This research uses qualitative research methods with descriptive analysis which aims to analyze and reconstruct the design of fruit DNA isolation laboratory (DKL) activities. The sampling technique used was purposive sampling by analyzing the DKL in the Biology book written by (Omegawati et al., 2015). This Biology book adopts the revised 2013 curriculum which was written specifically to develop creative and critical thinking skills in high school students.

The instrument used is a vee diagram developed by (Novak & Gowin, 1984). This vee diagram assesses relevance, competence, practice, and knowledge construction (Siregar et al., 2022). The relevance in question is the relationship between the focus of the DKL question and the objects and phenomena observed. The competencies provided are presented in a practical procedure. However, the procedure is related to the theories, principles, and concepts in the material being studied. Competency also indicates the ability to collect and transform experimental data into conclusions. The experimental practice can be relevant to knowledge claims in a coherent manner. The following are the components of the vee diagram assessment used below:

Table 1. Vee diagrams Assessment

Indicator	Assessment Criteria
Focus Question	There are focused questions that can guide the occurrence of a phenomenon and can lead students to knowledge claims
Object / Event	There are objects and phenomena that contain facts and can be observed
Theory & concept	The concepts, principles and theories trained can be identified and are relevant to the practicum objectives
Record and Transformation data	There is a process of recording and transforming data from facts to concepts, and is relevant to students' lab skills
Knowledge claims	There are directions for concluding and generalizing concepts obtained from the practicum process

The use of vee diagrams will help to analyze DKL components which include main questions, objects and events, theories, principles and concepts, records, and knowledge achievements (Yusni & Supriatno, 2023). In the context of practicum activities, Vee diagrams can help in planning and implementing practicum activities in a more structured and efficient.

RESULTS AND DISCUSSION

DNA is the main component that contains chromosomes in eukaryotic cells. DNA is found in several places such as in the cell nucleus (chromosomal DNA), outside the cell nucleus (chloroplast DNA and mitochondrial DNA) and in plasmid DNA (extrachromosomal DNA) (Alberts, et al., 2002; Setiawan et al., 2021). DNA is a compound that stores all the genetic information of living things. The function of DNA is to regulate biological activities (Setiawan et al., 2021). DNA isolation is the process of separating DNA from cells through an extraction or lysis process. In isolating DNA, using a buffer solution can prevent DNA damage (W. Setiawan et al., 2021; Yuwono, 2008). The principle of DNA isolation consists of lysing the cell wall, removing DNA components, and purifying the DNA. The method commonly used in DNA isolation is the filter method (filter-based kit) (Seprianto et al., 2022). Based on (Setiawan et al., 2020), are 50% of schools in Yogyakarta carry out DNA isolation practicum activities in Biotechnology learning materials. This practical material and activities are provided to class XII high school students. The DKL used in this analysis was taken from the high school biology book.

1. Analyze The Original DKL

DKL was analyzed using the Vee Diagram component developed by (Novak & Gowin, 1984). The knowledge construction involves the process of developing conceptual understanding through observing objects/phenomena, recording and transforming data, as well as connecting theory with observation results. The following are the results of DKL analysis of DNA isolation based on the vee diagram principle:

Table 2. Analyze DKL result

Indicator	Point	Assessment Criteria
Focus Question	1	Focus questions are identified but do not guide the acquisition of events/concepts.
Object / Event	3	Key events identified; consistent with the focus question; can be used to record data
Theory & concept	4	Relevant concepts and principles (conceptual and procedural) and theories are identified.
Record & Transformation data	3	Record/transformation identified; record according to event; transformation is inconsistent with the focus question
Knowledge claims	2	The concept is identified and there is one principle (conceptual/procedural); or relevant concepts and theories are identified.
Total	**13**	**72 % good category**

The DKL being analyzed already has an implied focus question on the objective. However, the objectives of the DKL do not yet have verbs that can guide students in acquiring the event or concept being studied. According to (Novak & Gowin, 1984) DKL with focus questions can be identified and contains a conceptual part. However some DKL cover conceptual principles while others do not. Different focus questions lead us to observe different aspects of the event or object the student is observing. The object observed was DNA in ripe fruit. The formulation of tools and materials will influence the identified objects and phenomena. Meanwhile, DKL the tools and materials listed were not yet equipped with specifications. Practicums must be able to help students develop knowledge and skills in understanding biological phenomena (Millar, 2004; Wahidah et al., 2018). In the data recording process, a table of observation results has been presented, but units are not yet equipped to measure the time and thickness of the observed DNA. In the data transformation process, only concluding activities are carried out optimally. Therefore, it is necessary to reconstruct the DKL DNA isolation of the fruit.

2. Reconstruction DKL

Reconstruction is intended for DKL by adjusting certain components to optimize the knowledge claim process. This reconstruction process involves a thorough examination of the existing DKL to identify areas that need repair and refinement. By paying close attention to DKL components, such as focus questions, conceptual sections, and procedural instructions, educators can adjust the guidelines to better align with learning goals and facilitate a more effective knowledge acquisition process for students.

a. Focus Questions

Focus questions can be seen in the title and objectives of a practicum. The practicum objective should have verbs that are equivalent to or one level higher than the learning objective. This practice is included in strengthening the concepts given after learning. The concept in question is the structure of DNA. So the objective of the practicum was reconstructed to "*Observe and Analyze the structure of DNA in fruit*".

b. Objects and Phenomena

Through practical activities, students can observe and analyze the structure of DNA in fruit. The structure that is understood is not microscopic, but a collection of DNA that forms a lump. In this case, students can see the phenomenon of fruit DNA clumping which is visible in the test tube in the form of white lumps. The white lump phenomenon occurs due to a reaction between the buffer solution and the fruit aliquot. In this practicum, students are asked to see how long it takes for DNA to coagulate in the various types of fruit being observed.

Objects and phenomena are influenced by the tools and materials used and the procedures carried out. Tools and materials in practical instructions need to have clear specifications. Several tools need to be replaced, as follows: 1) Using a blender is not efficient, because it will damage the DNA of the fruit due to the heat produced by the blender blade, 2) Using filters, filter paper and filter cloth is not necessary because only the extract water is taken. A more efficient filter tool is neeeded, 3) Spatulas are not recommended because the NaCl measurement must be clear in grams, 4) A ruler is needed to measure the thickness of the observed DNA, 5) Fruit selection should use perfectly ripe fruit, to make grinding easier. using a mortar and pestle. 6) The amount of distilled water should be adjusted to the number of types of fruit used for the practical and a 1:1 ratio should be applied to maximize extract extraction. The 3 types of fruit for practical time efficiency. 7) Measuring NaCl and detergent should use clear comparison units, so that the required concentration can be known with certainty.

Figure 1. Stacked filter design

The purpose of creating a multi-layered filter design is to prevent fruit dregs from being carried along with the aliquot to be used, thereby ensuring that the results of DNA analysis are easier to identify. This multilayered filter design involves combining several filtration stages; first, using a plastic ziplock with the ends cut off, then pouring it onto cotton, and finally using gauze for the last filtration. The use of a funnel is intended so to prevent the filtration results from spilling neater the process. This approach avoids the squeezing process with a cloth filter which is prone to carrying fruit pulp.

c. Theories, Principles, and Concepts

In the fruit DNA isolation practicum, students will obtain data showing that each fruit has a different time in the DNA clumping process. This variation is caused by difference in DNA length, fruit maturity level, and concentration of aliquots used (Seprianto, et al., 2022). The concepts studied include the basic structure of DNA, steps in the DNA isolation process, selection of materials and reagents, principles of DNA separation, DNA purification, DNA quality analysis, and practical applications of DNA in various fields such as genetic engineering and medical diagnostics. Students can learn the relationship between the physical structure of DNA and its function as genetic material that carries genetic information. Additionally, students can compare the natural process of DNA isolation in cells with the processes they apply in the laboratory, allowing them to understand the principles of cellular biology used in the lab.

During the practicum, students will see how the various materials and reagents used have different roles in the DNA isolation process. For example, detergent solutions are used to destroy cell membranes, while salt solutions are used to precipitate proteins (Mardiah, 2023). The importance of the DNA purification process is also emphasized, as it helps the purity of isolated DNA. This is a valuable opportunity for students to understand firsthand how the principles of molecular biology are applied in laboratory practice.

d. Data Recording and Transformation

The process of recording and transforming data is listed in the observation results table and also in DKL questions (Indrawati, et al, 2024). In the analyzed DKL, the table of observation results does not provide standard units for the thickness and time of DNA formation. The Revisions are needed in the observation results table. Data transformation activities can be carried out by instructing students to make a line diagram that shows the relationship between time and DNA clumping in those forms. Additionally, the data transformation process can be carried out through instructions for concluding (Zumira, et al., 2022).

e. Knowledge Claims

Knowledge claims can be addressed in the DKL discussion section, Where DKL will guide students in processing information or facts into structured knowledge. Studying the topic of inheritance can provide an in-depth explanation of the theories underlying the practice of DNA isolation. Providing practice aims to support students' understanding of concepts through demonstrations, presentations, and direct student interaction during practicum activities. By changing the discussion questions in the DKL, the knowledge-claiming process can be maximized. The results of the DKL reconstruction are attached.

Based on reconstructed DKL, this practicum is designed to extract DNA from various types of fruit and observe the DNA clumping process and the timing of this process in detail. This practicum begins with the process of weighing 20 grams of each type of fruit separately. After weighing, the fruit is put in a plastic or ziplock along with 20 ml of distilled water. This stage is important to ensure that each fruit sample has consistent quantities and conditions, which will influence the extraction results. Next, the fruit is crushed by pressing the plastic carefully, ensuring there are no leaks and achieving a soft and homogeneous consistency. The results of this refinement are then filtered using a multi-stage filter to remove large particles, thus producing a clean extraction liquid. In the next stage, a mixture of NaCl (salt), detergent, and distilled water in a ratio of 1:3:10 is mixed in a container and stirred gently for 15 minutes. This step aims to break down the cell walls and membranes of the fruit cells so that the DNA can be released into the solution. This process is important to ensure that the resulting DNA can be extracted optimally. After mixing was complete, 2 ml of buffer liquid was added into each test tube, then stirred gently for 3 minutes. This buffer fluid functions to stabilize the pH and ionic conditions required for DNA extraction, maintaining the quality and quantity of extracted DNA.

Then, cold alcohol was added drop by drop into each test tube in the amount of 6 ml. The addition of alcohol is very important because DNA is not soluble in alcohol, so the alcohol functions to precipitate the DNA. At this stage, we need to observe the formation of DNA strands which appear as fine white lumps. This observation was carried out carefully to measure the thickness and quality of the DNA threads formed in each type of fruit. The results of the observations are recorded in a systematic observation table, including data regarding the shape and characteristics of the DNA obtained, as well as the time required for each type of fruit to form DNA. In addition, we must also answer analytical questions that focus on the shape and characteristics of the resulting DNA, the time required for DNA formation, and the reasons behind the differences in thickness of the resulting DNA. These questions help in understanding the DNA extraction process in more depth and the factors that influence the results obtained, as well as providing further insight into the quality and quantity of DNA from each type of fruit tested.

Based on table 3, the question focus criterion obtained a score of 3, which reflects excellent identification of the focus question. This focus question has been formulated clearly and precisely, so that it can be used to produce appropriate and relevant phenomena and data. Identifying a good focus question is very important because it will guide the entire research and analysis process, ensuring that each subsequent step is consistent and targeted according to the research objectives. Success in setting effective focus questions also allows research to focus on key aspects of the topic under study, so that the results obtained can be more focused and useful.

In the object or phenomenon aspect, the assessment also received a score of 3, indicating that the key phenomena have been identified accurately and are in accordance with the focus questions that have been set. Identification of appropriate and relevant phenomena is essential for effective data recording. These phenomena must be consistent with the focus question so that the data collected can provide useful and in-depth information. With a good assessment in this section, it is hoped that all important phenomena can be monitored and recorded carefully, which will ultimately enrich the analysis results and help in drawing appropriate conclusions.

Table 3. Measuring criteria of DKL's reconstruction

Indicator	Point	Assessment Criteria
Focus Question	3	The Focus Question has been identified and can be used to generate appropriate events and data
Object / Event	3	Key events identified; consistent with the focus question; can be used to record data
Theory & concept	4	Relevant concepts and principles (conceptual and procedural) and theories are identified.
Record & Transformation data	4	Records and transformations are identified; record according to event; transformation consistent with the focus question; and laboratory activities appropriate to the student's level
Knowledge claims	2	The concept is identified and there is one principle (conceptual/procedural); or relevant concepts and theories are identified.
Total	**16**	**88 % Very good category**

In terms of theories and concepts, the assessment received a score of 4, indicating that all relevant concepts, principles and theories have been identified very well. This includes both conceptual and procedural concepts that are directly related to the focus of the question and the object of the phenomenon that has been determined. Identification of appropriate theories and concepts is key to understanding and explaining the phenomenon under study. With a deep understanding of applicable theories and concepts, researchers can make stronger and more thorough arguments in their analysis. It also enables the effective application of relevant principles in the research process.

In the data recording and transformation section, a score of 4 indicates that the data recording and transformation process was carried out very well. Recording is carried out carefully according to the ongoing phenomenon, and data transformation is carried out consistently with the predetermined focus questions. The laboratory activities carried out are also appropriate to the student's level of ability, ensuring that the procedures implemented are relevant and manageable by students at their level of education. With excellent assessment in this section, the data collection and analysis process can be carried out effectively, supporting the integrity and accuracy of research results.

However, in the knowledge claims section, the score obtained is 2. This indicates that although the basic concept has been identified, only one principle (conceptual or procedural) has been applied or the relevant concepts and theories may not have been fully identified or explained. A decrease in scores in this section indicates that there are areas that need further development to achieve a more comprehensive understanding and application. Improvements in the identification and application of broader concepts and principles will improve the quality of proposed knowledge claims.

Overall, with a total score of 16 out of 18, equivalent to 88%, this rating is in the very good category. This reflects that most aspects of the assessment have been carried out very well, although there are still several areas that require improvement to achieve a more comprehensive evaluation. Success in most criteria indicates significant achievement in the research and analysis process, however, attention to detail in areas where we were less strong would have further enhanced the overall quality of this evaluation.

CONCLUSION

Practicum is an important component for developing students' understanding of concepts and skills. However, the available DKL still has several shortcomings, such as focused questions that do not effectively guide students, a lack of clarity in tool and material specifications, and efficient data recording and transformation processes. Therefore, it is necessary to reconstruct the DKL DNA isolation to increase the effectiveness of practical learning. This study aims to analyze and reconstruct the DKL for DNA isolation in fruit using the Vee diagram principle to optimize the process of students' knowledge acquisition. Analysis of the existing DKL shows that although there are important components such as theories and concepts, objects and phenomena, as well as data recording and transformation, there are several deficiencies in the focus questions, equipment and material specifications, and the data recording process. Therefore, DKL reconstruction was carried out by clarifying the focus question, improving the specifications of tools and materials, and optimizing the data recording and transformation process. It is hoped that this reconstruction can increase students' understanding of the structure and process of DNA isolation in fruit, as well as help them connect theoretical concepts with observed phenomena more effectively.

REFERENCES

Abrahams, I., & Millar, R. (2008). Does practical work work? A study of the effectiveness of practical work as a teaching and learning method in school science. *International Journal of Science Education*, 30(14), 1945–1969. https://doi.org/10.1080/09500690701749305

Agustina, P. (2015). Persepsi mahasiswa calon guru biologi tentang pengembangan praktikum biologi sekolah menengah: Studi pengembangan pembelajaran pada mahasiswa pendidikan biologi FKIP Universitas Muhammadiyah Surakarta. *Jurnal BIOEDUKATIKA*, 3(2). http://dx.doi.org/10.26555/bioedukatika.v3i2.4151

Alberts B, Johnson A, Lewis J, Raff M, Robert K, & Walter P. (2002). Molecular biology of the cell (4th ed.). *Garland Science*.

Capah, J., & Fuadiyah, diatul. (2021). Journal for lesson and learning studies analisis kualitas lembar kerja praktikum pada materi sel menggunakan diagram Vee. *Journal for Lesson and Learning Studies*, 4(2), 238–245. https://doi.org/10.23887/jlls.v4i2.38271

Doyle, J. J., & Doyle, J. L. (1987). A rapid DNA isolation procedure for small quantities of fresh leaf tissue. *Phytochemical bulletin*.

Hofstein, A., & Mamlok-Naaman, R. (2007). The laboratory in science education: The state of the art. *Chemistry Education Research and Practice*, 8(2), 105–107. https://doi.org/10.1039/B7RP90003A

Indrawati, L., Supriatno, B., & Gusti, U. A. (2024). Analisis dan rekonstruksi desain kegiatan laboratorium (DKL) pada materi protista kelas X SMA. *Eduproxima (Jurnal Ilmiah Pendidikan IPA)*, *6*(1), 127-135. https://doi.org/10.29100/.v6i1.4239

Mardiah, H. D. (2023). Evaluasi fisikokimia formula sabun cair pembersih tangan dengan kandungan ekstrak etanol daun petai cina: Leucaena leucocephala (Lam.) de Wit (*Doctoral dissertation, Universitas Islam Negeri Maulana Malik Ibrahim*). http://etheses.uin-malang.ac.id/id/eprint/52964

Meyhandoko, A. (2013). Pengembangan petunjuk praktikum kontekstual dengan pemanfaatan kondisi lingkungan lokal dalam pembelajaran materi pencemaran di SMA 2 Rembang. [Skripsi]. UNS. http://lib.unnes.ac.id/id/eprint/18951

Millar, R. (2004). The Rrole of practical work in the teaching and learning of science. *National Academy of Sciences*. https://doi.org/10.12691/wjce-5-5-5

Murray, M. G., & Thompson, W. (1980). Rapid isolation of high molecular weight plant DNA. *Nucleic acids research*, *8*(19), 4321-4326. https://doi.org/10.1093/nar/8.19.4321

Novak and Gowin. (1985). Learning how to learn. Cambridge : *Cambridge University Press*.

Omegawati, W., H., Sukoco, T., dan Hidayah, S.N. (2015) Biologi XII Peminatan IPA & Ilmu Alam. Klaten; PT. Intan Prawira. http://repository.unpas.ac.id/id/eprint/62004

Putri, M Z., Hasnunidah, N., Yolida Pendidikan Biologi, B., Universitas Lampung, F., Soemantri Brojonegoro No, J., & Lampung, B. (2018). Pengembangan buku penuntun praktikum struktur dan fungsi tumbuhan dengan model Argument-Driven Inquiry (ADI). *Jurnal Bioterdidik: Wahana Ekspresi Ilmiah*, 6(2). http://repository.lppm.unila.ac.id/id/eprint/10384

Sanjaya, W. (2011). Strategi pembelajaran berorientasi standar proses pendidikan. *Kencana Prenada Media Group*.

Saghai-Maroof, M. A., Soliman, K. M., Jorgensen, R. A., & Allard, R. (1984). Ribosomal DNA spacer-length polymorphisms in barley: mendelian inheritance, chromosomal location, and population dynamics. *Proceedings of the National Academy of Sciences*, *81*(24), 8014-8018. https://doi.org/10.1073/pnas.81.24.8014

Seprianto, O., Saraswati, H., Wahyuni, F. D., Novianti, T., Nora, A., Naroeni, A., & Handayani, P. (2022). Workshop isolasi DNA dan pengenalan alat laboratorium bioteknologi bagi guru biologi SMA/MA se-Jakarta. *Jurnal Pengabdian Kepada Masyarakat*, 2(3). https://doi.org/10.53625/jabdi.v2i3.2780

Setiawan, Maliza, R., & Putri, D. A. (2020). Pengenalan media bahan ajar praktikum jarak jauh kepada guru MGMP Biologi SMA/MA Kota Yogyakarta di masa pandemi Covid-19. In Seminar Nasional Hasil Pengabdian kepada Masyarakat (Ed.), Seminar Nasional Hasil Pengabdian kepada Masyarakat.

Setiawan, W., Handayani, K., & Kanedi, M. (2021). Pelatihan analisis DNA secara sederhana untuk praktikum biologi bagi guru IPA SMA di Bandar Lampung. https://dspace.uii.ac.id/handle/123456789/33950

Siregar, N. F., Sholihah, R. N., Supriatno, B., & Anggraeni, S. (2022). Analisis dan rekonstruksi desain kegiatan laboratorium alternatif bermuatan literasi kuantitatif pada praktikum fotosintesis Ingenhousz. *Jurnal Basicedu*, 6(4), 7532–7543. https://doi.org/10.31004/basicedu.v6i4.3568

Suryani, Rudyatmi, E., & Agung Pribadi, T. (2014). Pengaruh experiential learning KOLB melalui kegiatan praktikum terhadap hasil belajar biologi siswa info artikel. *Unnes Journal of Biology Education*, 3(2), 50229. http://journal.unnes.ac.id/sju/index.php/ujbe

Toplis, R., & Allen, M. (2012). “I do and I understand?” Practical work and laboratory use in United Kingdom schools. Eurasia Journal of Mathematics, Science and Technology Education, 8(1), 3–9. https://doi.org/10.12973/eurasia.2012.812a

Wahidah, N. S., Supriatno, B., & Kusumastuti, M. N. (2018). Analisis struktur dan kemunculan tingkat kognitif pada desain kegiatan laboratorium materi fotosintesis (The analysis of cognitive structure and level on design of laboratory activities of photosynthesis concept). Assimilation: Indonesian Journal of Biology Education, 1(2), 70–76. https://doi.org/10.17509/aijbe.v1i2.13050

Yuwono, T. (2008). *Biologi Molekuler*. Erlangga.

Yusni, D., & Supriatno, B. (2023). Analisis, uji coba, dan rekonstruksi lembar kerja peserta didik pada materi sel untuk meningkatkan keterampilan proses sains. *Jurnal Basicedu*, *7*(3), 1493-1506. https://doi.org/10.31004/basicedu.v7i3.5340

Zumira, A., Salsabila, A., Nurzeha, F., Supriatno, B., & Anggraeni, S. (2022). Desain kegiatan praktikum pengaruh intensitas cahaya terhadap laju proses fotosintesis bermuatan literasi kuantitatif. *Jurnal Basicedu*, *6*(4), 7474-7485. https://doi.org/10.31004/basicedu.v6i4.3474