

Learning innovation: Reconstruction laboratory activities design on respiratory air and designing a simple spirometer

Solikhah Isti Fadilah, Bambang Supriatno *, Alfyn Abdan Nurahman, Amprasto

Master Program of Biology Education, Faculty of Mathematics and Natural Science Education, Universitas Pendidikan Indonesia, Bandung, West Java, Indonesia.

* Corresponding Author Email: bambangs@upi.edu

Article Information

Keywords:

Laboratory activity design; Vee chart; Independent curriculum; Practice; Respiratory air

Kata Kunci:

Desain kegiatan laboratorium; Diagram vee; Kurikulum merdeka; Praktikum; Udara hasil pernafasan

History:

Received : 19/05/2024
Revised : 24/06/2024
Accepted : 28/06/2024
Published : 30/06/2024

Abstract

Laboratory practicum in science learning is considered important, especially in the context of the Independent Curriculum. Science-based learning is needed to encourage the development of students' skills and character, supported by practical activities. Good practical activities not only allow students to understand scientific concepts but also train students to apply scientific methods effectively. The aim of this research is to analyze, reconstruct, and design simple tools to improve Laboratory Activities Designed (LAD) on the respiratory air sub-material. The research method used is descriptive to show existing phenomena. Analysis was carried out using Vee Diagrams; then trials were carried out, reconstruction and design of simple tools, second trials, and revisions. The results of the analysis show that the five LAD samples are still in the very poor category, so improvements need to be made to avoid mistakes in the future. Researchers carried out LAD reconstruction, which included appearance, title, purpose, tools and materials, procedures, and questions. Reconstruction is supported by designing a tool in the form of a simple spirometer. The design of this simple tool can be assigned to students to train creativity and solve problems. It is hoped that the results of this analysis and reconstruction can help teachers in designing LAD for other materials in the future to suit learning objectives and the applicable curriculum.

Abstrak. Praktikum laboratorium dalam pembelajaran sains dinilai penting terutama dalam konteks Kurikulum Merdeka. Pembelajaran berbasis sains diperlukan untuk mendorong pengembangan keterampilan dan karakter siswa dengan didukung kegiatan praktikum. Kegiatan praktikum yang baik tidak hanya memungkinkan siswa untuk memahami konsep sains, tetapi juga melatih siswa dalam menerapkan metode ilmiah dengan efektif. Tujuan penelitian ini yaitu untuk menganalisis, melakukan rekonstruksi dan merancang alat sederhana untuk menyempurnakan Laboratory Activities Designed (LAD) pada sub materi udara hasil pernafasan. Metode penelitian yang digunakan yaitu deskriptif untuk menunjukkan fenomena yang ada. Analisis dilakukan menggunakan Diagram Vee, selanjutnya dilakukan uji coba, rekonstruksi dan perancangan alat sederhana, uji coba kedua, dan revisi. Hasil analisis menunjukkan bahwa kelima sampel LAD masih dalam kategori sangat buruk sehingga perlu dilakukan perbaikan untuk menghindari kekeliruan di masa yang akan datang. Peneliti melakukan rekonstruksi LAD yang mencakup tampilan, judul, tujuan, alat dan bahan, prosedur, dan pertanyaan. Rekonstruksi didukung dengan perancangan alat berupa spirometer sederhana. Perancangan alat sederhana ini dapat ditugaskan kepada siswa untuk melatih kreativitas dan memecahkan masalah. Hasil analisis dan rekonstruksi ini diharapkan dapat membantu guru-guru dalam merancang LAD materi lain di masa depan agar sesuai dengan tujuan pembelajaran dan kurikulum yang berlaku.

A. Introduction

Science is a knowledge-based discipline that focuses on experiments. One of the main components of science education is conducting science experiments (Rayment et al., 2023). This is in line with the Independent Curriculum currently implemented in Indonesia. Learning in the Kurikulum Merdeka emphasizes three aspects: 1) Pancasila character, implemented in project-based learning to develop students' soft skills and character by the character of the Pancasila youth profile. 2) Competency-based means focusing on essential material, thereby providing opportunities to deepen basic competencies such as literacy and numeracy. 3) flexible learning in the sense that teachers are free to carry out differentiated learning according to student's abilities and the context of local content (Nafi'ah et al., 2023).

Laboratory practicum prioritizes inquiry and problem-solving techniques that apply scientific methods. Effective scientific methods are very important in experiments to understand scientific concepts (Idris et al., 2022). The ability of scientific ideas is an individual's ability to record and reanalyze the information obtained to form an understanding of science (Fadilah et al., 2024). Scientific concepts can be mastered by analyzing phenomena, events, objects, or activities related to scientific material (Amanda et al., 2021). One of the activities that supports mastery of concepts is practical activity. Practical activities can encourage students to gain knowledge by analyzing scientific phenomena. Practicum activities can also support teacher-student relationships, build partnerships, guide student behavior, and encourage development and learning in the classroom (Lippard et al., 2024). It can be said that laboratory practice is an appropriate way to integrate theoretical and methodological knowledge and students' practical skills (Mosiienko et al., 2023). Another benefit students gain in the long term when applying this method is the student's ability to make decisions in real life. This activity will make students the center of learning because they are directly involved and play an active role in reconstructing knowledge (Ersalina et al., 2023).

Activities involving practical laboratory work are also not far from using pragmatic tools to train students' abilities in connecting real and idea domains (Novak & Gowin, 1984). The use of valuable tools is not limited to using available tools, but beyond that, teachers and students can also make tools intended for practical activities (Lestari et al., 2023). The use of simple tools in practical activities has a direct impact on student's academic achievement and attitudes toward science. Research conducted by Kirilmazkaya & Dal (2022) found that carrying out activities with essential equipment significantly improved academic performance and scientific attitudes. This can be used as an alternative solution for schools that do not have adequate equipment (Meristin et al., 2022).

The preparations that need to be made are not only limited to equipment but are also related to the Laboratory Activities Design (LAD). A teacher's or prospective teacher's abilities must be deepened to make practicum activities meet expectations (Beshir et al., 2023). Facts in the field show the need for improvements related to laboratory activities design and LKPD because they are not yet in line with expectations (Khasanah et al., 2021; Siregar et al., 2022; Darmawati et al., 2021; Faidah et al., 2022; Usmeldi & Amini, 2021). Hodson (1991) said this practical process can be complex and contributes little to their science learning. Therefore, teachers must analyze the laboratory activities designed to achieve learning objectives.

The analysis that needs to be carried out is related to the objectives, methods, and equipment used (Qisthi & Supriatno, 2023). Learning objectives must be clear and limited so that students stay focused on the learning process. Using explicit and planned methods to guide students' thinking productively in building relationships between the object and idea domains. Use of simple and cheap practical equipment (Millar, 2004). This analysis is used as a basis for reconstructing laboratory activities designed by a teacher to facilitate students in reconstructing their knowledge (Azzahra & Supriatno, 2023).

LAD analysis can be done using a Vee diagram (Ramadhayanti et al., 2020; Astika et al., 2020; Handayanie et al., 2020). The Vee diagram is a thinking framework that can help students understand the conceptual side (minds-on) and the methodological side (hands-on) (Hindriana, 2016). Vee diagrams can help students understand the structure of knowledge and how humans produce knowledge. The power of vee diagram analysis lies in the key elements that must be carefully considered in any investigation. The key elements that must be regarded are focus question, object/event, theory, principles and concept, record/transformation, and knowledge claim (Zumira et al., 2022). Another value of the Vee form is that because questions often need to be corrected at the bottom of the Vee diagram, it is more difficult to overlook relevant events, objects, or critical concepts (Novak & Gowin, 1984).

The importance of this study makes the author want to conduct analysis and reconstruction related to the laboratory activities design of respiratory air according to the Vee Diagram guidelines. It is hoped that this analysis and reconstruction can be used as an illustration for teachers to carry out similar reconstructions. Hopefully, teachers can carry out practical activities by learning objectives and helping students understand the concepts.

B. Materials and methods

The research method used is descriptive to explain the phenomena that are formed. The research was carried out at the Indonesian Education University Biology Laboratory from March 2024 to May 2024. The research samples used were five laboratory activity designs related to human breathing air. The design of the laboratory activities was obtained from searching several e-books and practical guidebooks in several high schools. This research followed the stages of analysis, trial, and reconstruction (Supriatno, 2013). Analysis of the design of laboratory activities using instruments (Novak & Gowin, 1984) is shown in Table 2. The analysis results are assessed using formula one, which is then categorized based on the criteria of Arikunto (2016), as shown in Table 1.

$$\text{Score percentage} = \frac{\text{Number of score}}{\text{Total Score}} \times 100\% \dots \text{Formula 1}$$

Table 1 Assessment criteria

Scale (%)	Indicator
80-100	Very good
70-79	Good
60-69	Medium
50-59	Deficient
0-49	Very poor

The next stage is trials carried out according to the sample LAD. The trial process is carried out to determine the suitability of the objectives with the focus questions, object, record of data obtained, theory, principles and concepts, and knowledge claims. The results of trials and analysis of laboratory activity designs are used as a basis for reconstructing laboratory activities and making simple tools for practical activities in accordance with the Independent Curriculum. Each stage is carried out repeatedly hoping to get maximum reconstruction results.

C. Results and discussion

Laboratory activities design analysis is carried out by looking at several aspects of the objectives of laboratory activities design according to Millar (2004), namely: To identify objects and phenomena, to learn facts, to learn a concept, to study a relationship, and to study a theory or model (Ekselsa et al., 2020). The analysis results were carried out on five samples of LAD obtained by researchers. The results of the analysis show that three types of laboratory activity design titles are found to be related to respiratory air. The three samples that were found discussed experiments on exhaled air in the form of CO₂ water vapor and how to calculate exhaled air. Researchers still find that laboratory activity design has two objectives with different work steps combined into one. For example, practicums regarding air in the form of CO₂ are combined with practicums for air resulting from respiration in water vapor. This should be

avoided because this combination will cause the research method and observation table to be in a different order.

General analysis can be done by examining the laboratory activities' design objectives. The five laboratory activity designs already have practicum objectives by the learning material but still need to be based on the basic competencies/minimum learning outcomes. Analysis related to objectives can be carried out by looking at the operational verbs used in designing laboratory activities. The results obtained were that all laboratory activity designs had lower operational verbs than basic competencies/learning outcomes. This must be paid attention to because the practicum aims to play a central role in practicum activities. Apart from that, the tools and materials usually need detailed specifications. The word "sufficiently" has a relative meaning, so students may experience problems doing practical work. The measurements used in valuable tools and materials must also be conveyed in more detail, and units for the materials used must be provided. Choosing tools and materials that are easy to use is also essential so students can search in a shorter and more affordable time (Setiawati et al., 2021). The critical points that need to be analyzed to produce appropriate phenomena are related to how things work. The work methods presented in the LAD should be sequential and provide clear and logical information. Most of the working techniques researchers found have yet to be explained in detail, and there are still illogical ways of working that can be carried out, confusing for practitioners. The way of working needs clear, sequential, and straightforward command sentences so students can follow them in practical activities.

Further analysis was carried out using the Vee diagram in Novak & Gowin (1984), which highlights the laboratory activities design related to several aspects: focus question, object/event, theory, principles, concept, record/transformation, and knowledge claim. This analysis is presented in Table 2.

The total scores obtained for the five LAD samples were 7, 2, 9, 8, 6. The percentage of analysis results obtained respectively were 41%, 12%, 53%, 47%, and 35%. The LAD analysis category can be seen using the criteria in Table 1. The research results show that the five LAD samples are still in the very poor category so improvements need to be made to avoid mistakes in the future. Previous research conducted by Putri et al. (2020) also stated that some LAD samples were not optimally designed. Further analysis was carried out using a Vee Diagram and showed that LAD did not meet expectations. Focus questions are identified but do not guide the acquisition of events/concepts, so they cannot build conceptual knowledge (thinking) or methodological knowledge (work) well in students. Novak & Gowin (1984) said that research questions are highly recommended because they determine the occurrence of the

phenomenon or event being observed. Objects in each LAD can be observed but are not yet consistent with the focus question. Most LADs have not been able to develop concepts based on relevant principles and theories. Even in LAD sample B, the concepts that can

be found in practical activities have not yet been identified. In addition, data recording or transformation is still difficult to analyze based on visible phenomena. An example of a data table can be seen in the LAD sample in Figure 1.

Table 2 LAD analysis

Score guide	Indicator	Score obtained				
		A	B	C	D	E
Focus question						
0	No focus question identified.					
1	Focus questions are identified but do not guide the acquisition of events/concepts.	1	1	1	1	1
2	The focus question identified and guided the generation of events/concepts; incorrect events result in incorrect data.					
3	Focus questions are identified and can be used to generate appropriate events and data.					
Object/event						
0	No objects/events identified.					
1	Key objects/events identified but not consistent with the focus question.	1	1	1	1	1
2	Key events identified and consistent with the focus question.					
3	Key events identified; consistent with focus question; can be used to record data.					
Theory/Principle/Concept						
0	No concepts identified.		0			
1	Concepts identified but without principles and theories.					1
2	Concept identified and one of the principles (conceptual/procedural); or relevant concept and theory identified.	2			2	
3	Concept and principles (conceptual and procedural) identified; or concept, one of the principles and relevant theory identified.			3		
Listing/Transformation						
0	No data recording/transformation identified.		0			
1	Data recording identified but not consistent with the focus question/event.	1		1		1
2	One (recording/transformation) identified and consistent with the focus question/event.				2	
3	Data recording/transformation identified; data record as per event; transformation inconsistent with a focus question.					
4	Recording and transformations identified; data recording appropriate to the event; transformations consistent with focus question; and lab activities appropriate to student level.					
Knowledge claims						
0	No knowledge claims identified.		0			
1	Knowledge claims do not relate to concepts, principles and theories.					
2	Knowledge claims include concepts that can be used to correlate but are inconsistent with recording and transformation.	2			2	2
3	Knowledge claims include concepts that can be used to correlate and are consistent with recording and transformation.			3		
4	Knowledge claims include concepts that can be used to relate; are consistent with recording and transformation; and can be used to create new focus questions.					
17	Total score	7	2	9	8	6

The tables contained in LAD are unable to combine the relationship between the actual domain and the idea domain. This is also ultimately related to the knowledge claims obtained by students. There are several notes related to the observation results table. First, records related to body weight (kg) information were not explained earlier in the procedure. Secondly, the observation table is combined with other activities

which can make students unfocused. This also applies to the procedures presented, they must be separated for one activity only.

The second stage is LAD sample testing. The first trial was performed using the original procedure before revision, and the second trial was performed based on the LAD reconstruction procedure. The results obtained in the first trial still encountered

obstacles, such as difficulties in determining the dosage of ingredients and collecting the data needed to achieve the practicum objectives. Even though the dosage is not specifically stated, the LAD sample can still produce phenomena. The tools and materials presented need to be improved because the lack of tools, materials, or procedures can result in different phenomena or even invisible phenomena. This is in line with Saputra & Supriatno (2024), who states that inappropriate design of laboratory activities can result in invisible objects/phenomena. Therefore, it is necessary to re-evaluate procedures and adapt them to students' abilities to minimize possible obstacles. The results of the analysis and trials became the basis for researchers to reconstruct the LAD related to breathing air.

Reconstruction is focused on correcting several deficiencies in the previous LAD. LAD updates include nearly every section, including appearance, purpose, tools and materials, procedures, and questions. The LAD was reconstructed into three parts related to the respiratory air content in the form of CO₂, O₂, and factors that influence the volume of respiratory air. Reconstruction begins with making a LAD cover, as shown in Figure 2.

The title taken for the LAD reconstruction is "What is contained in respiratory air, and what affects the volume of air produced by human breathing?". The title is the focus of the question that is adjusted to the learning objectives. This novelty was carried out to improve the previous LAD, which did not have a focus question. According to Novak-Gowin (1987), focus questions are central questions that direct the learning and understanding process to relevant and meaningful learning activities, guiding students in reflecting on and understanding their learning outcomes. Focusing students' attention on focus questions will help them develop a deeper understanding of air breathing and how to apply it in different contexts, strengthening student involvement in the learning process.

The title LAD is, of course, also adjusted to the learning objectives of the Independent Curriculum currently implemented. The purpose of LAD is the main part that needs to be understood in a laboratory activity, so it needs to be conveyed to students in accordance with the Curriculum. The learning achievement of phase F biology material related to respiratory organs is that students are expected to be able to analyze the relationship between organ structure in the organ system and its function and abnormalities or disturbances that arise in the organ system (Kemendikbud, 2023). Apart from that, the characteristics of laboratory work also aim to develop science learning in students and science practices in students (Gericke et al., 2023).

Reconstruction of objectives, tools, materials, procedures, and questions on the LAD can be observed in Figures 3, 4, 5, 6, and 7. Objectives are a central part that needs to be analyzed in a laboratory activity

design. The aim of the practicum in LAD reconstruction is "Students can analyze the air content of respiratory products through experimental and observational activities using limestone solution." The aim was made more specific, namely observing objects in the lime solution and breathing air. The operational verbs in the objectives are based on the curriculum and encourage students to learn to analyze visible phenomena. This is based on research by Zidan & Supriatno (2023), which states research objectives must be specific according to the phenomena observed in laboratory activities.

Reconstruction was also carried out regarding the procedures, tools, and materials. Tools and materials in LAD reconstruction are more measurable to ensure consistency of the phenomena formed. The reconstruction procedure has also been tested, and a phenomenon in the form of a color change in the limestone solution was produced. This phenomenon will produce data that is said to be fact. The observation table will record the facts obtained from the practicum process. The data collected can be used to analyze independently or in groups. Sequential and focused procedures will train students to think critically and actively learn (Al-hafidz et al., 2024). Analysis activities also require questions designed by the teacher to help students reconstruct knowledge. Valuable practical questions are part of directing focus, discussions, and training students' critical thinking skills (Alsaleh, 2020). The reconstruction of the laboratory activity design for question 1 is presented in Figure 4.

A. Judul : Udara Hasil Pernapasan		
B. Tujuan : Peserta didik mampu membuktikan udara hasil pernapasan melalui kegiatan percobaan dan pengamatan dengan tepat		
C. Alat dan Bahan		
1. Gelas plastik		
2. Sendok		
3. Sedotan		
4. Cermin		
5. Kapur gamping		
6. Spidol		
7. Air		
D. Cara kerja		
1. Siapkan dua gelas plastik yang bersih. Berilah label 1 dan 2 pada gelas plastik tersebut menggunakan spidol		
2. Masukkan kapur (gamping) ke gelas 1 dan masukan air secukupnya.		
3. Aduklah kapur (gamping) dan air tersebut hingga rata		
4. Tunggu larutan air sampai mengendap. Setelah larutan air kapur mengendap, tuangkan air kapur yang jernih pada gelas 2 hingga batas endapan		
5. Tiuplah air kapur pada gelas 2 menggunakan sedotan		
6. Amatilah perubahan yang terjadi pada air kapur dan catat perubahan tersebut		
7. Selanjutnya, siapkan cermin dalam keadaan bersih		
8. Embuslah napas melalui mulut di depan permukaan cermin selama beberapa saat		
9. Amatilah dengan cermat perubahan yang terjadi pada permukaan cermin		
10. Catat hasil pengamatan anda ke dalam bentuk tabel sebagai berikut		
No	Nama L/P	Berat badan (Kg)
1	Sebelum air kapur ditiup	
2	Setelah air kapur ditiup	
3	Sebelum diembuskan napas pada permukaan cermin	
4	Setelah diembuskan napas pada permukaan cermin	
11. Buatlah laporan sesuai dengan hasil pengamatan yang anda peroleh dan persentasikan di depan kelas		
E. Pertanyaan		
1. Bagaimana perubahan air kapur sebelum dan sesudah ditiup?		
2. Apakah yang mengakibatkan terjadinya perubahan air kapur sebelum dan sesudah ditiup?		
3. Apakah yang terjadi pada permukaan cermin setelah diembuskan napas selama beberapa saat ?		
4. Apakah kesimpulan anda dari kegiatan ini?		

Figure 1
Sample laboratory activity design (in Indonesian)

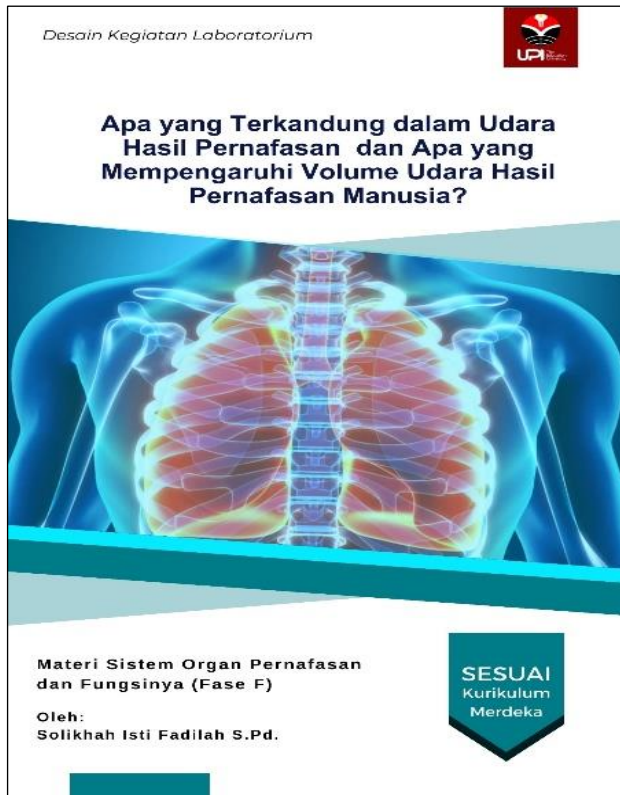


Figure 2
Cover of laboratory activity design
(in Indonesian)

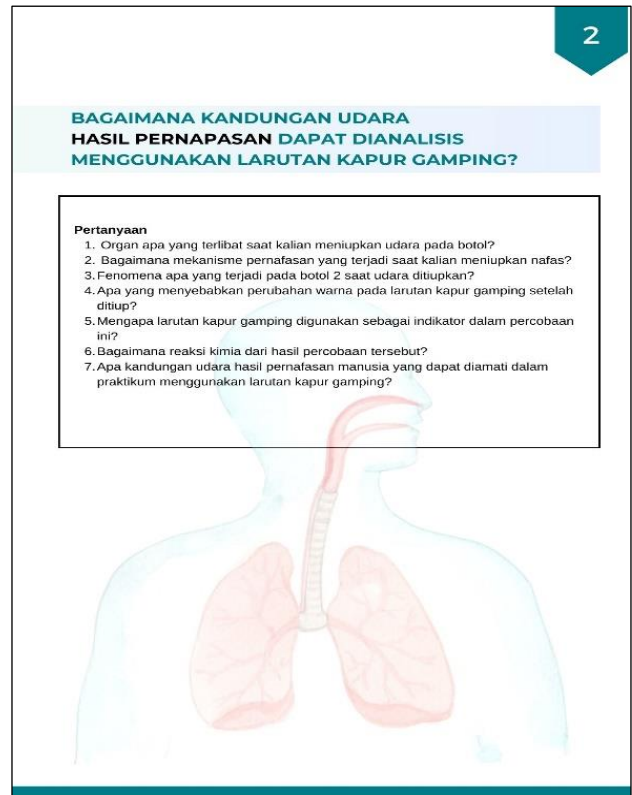


Figure 4
Laboratory activities design sheet two revision question section
(in Indonesian)

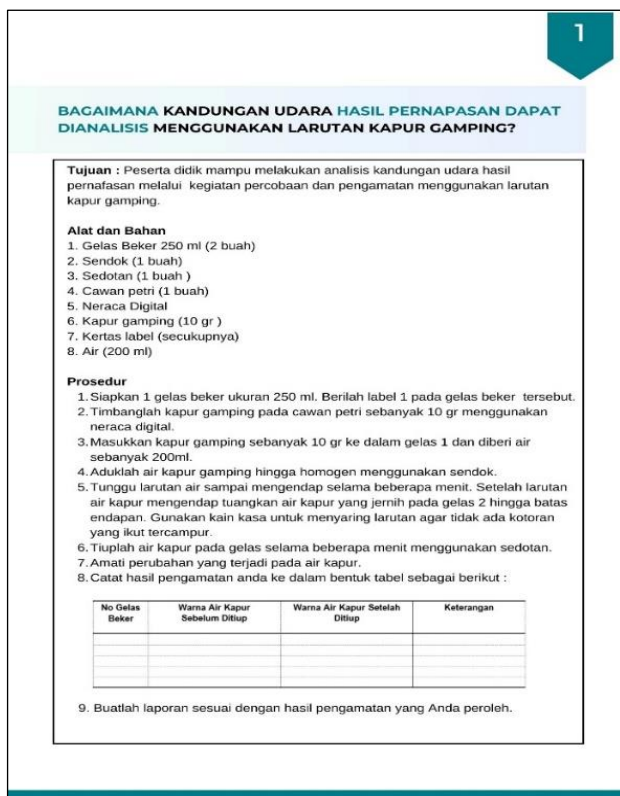


Figure 3
Laboratory activities design sheet one revision section objectives, tools, materials, and procedures (in Indonesian)

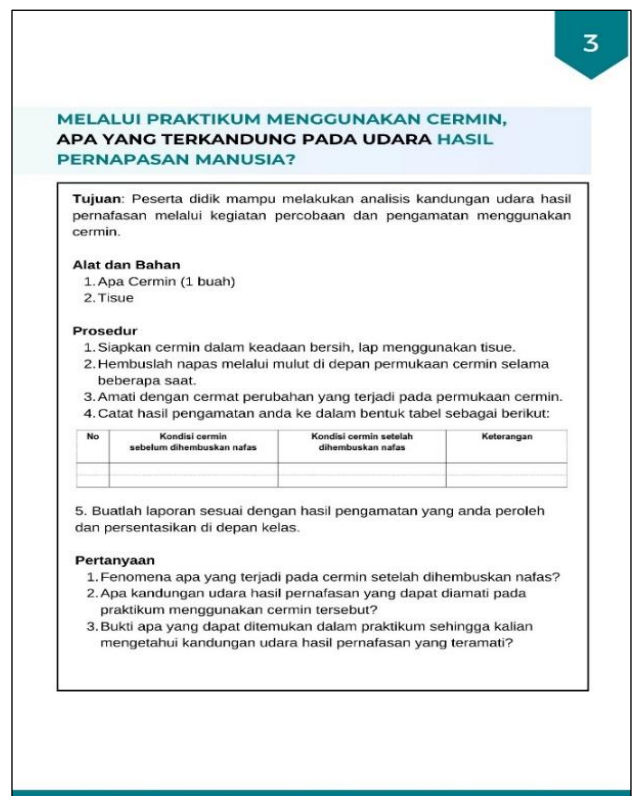


Figure 5
Laboratory activities design sheet three revision
(in Indonesian)

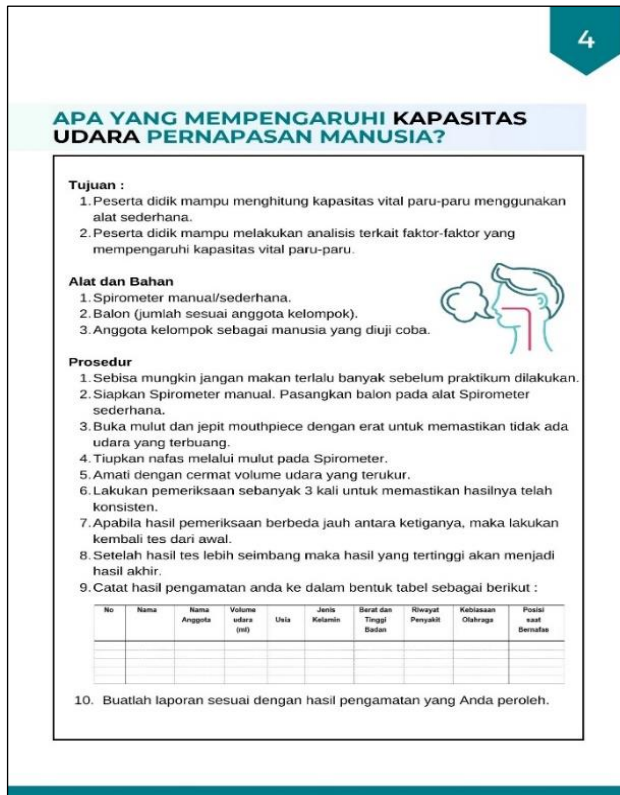


Figure 6
Laboratory activities design sheet four revision section objectives, tools, materials, and procedures (in Indonesian)

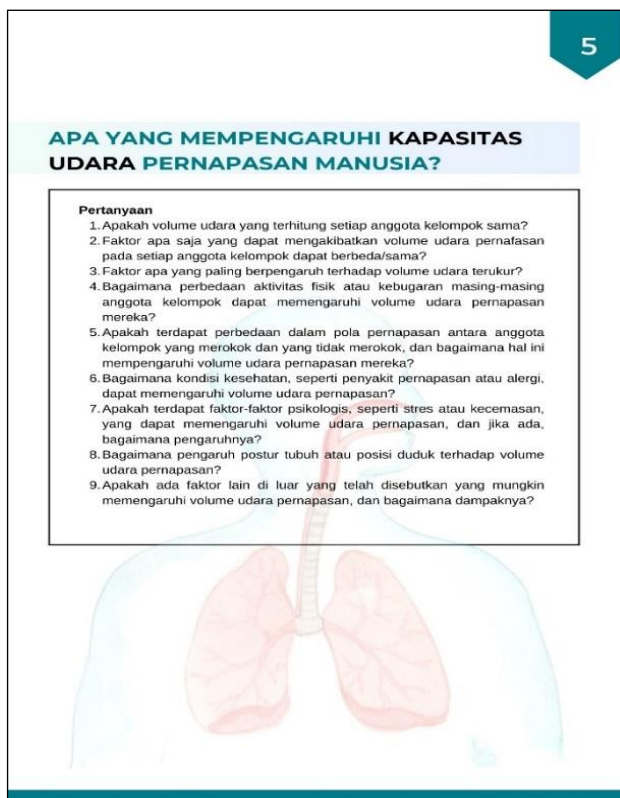


Figure 7
Laboratory activities design sheet five revision questions section (in Indonesian)

The second reconstruction is related to designing laboratory activities to test water vapor in inhaled air. The reconstruction was designed considering the focus of the practical questions presented in the title. The novelty is carried out to differentiate this title from previous practicum titles. This breaks the LAD habit of combining both practicum activities under one title. Combining the two activities in the previous LAD made procedures and data collection difficult for students to understand to form knowledge claims, so this reconstruction improves this. The reconstruction of the laboratory activity design is presented in Figure 5.

The third reconstruction was carried out in the practicum entitled "What Influences the Capacity of Human Respiratory Air?". Laboratory activity design reconstruction is adapted to students' conceptual construction and knowledge. The main goal of this reconstruction is to strengthen the connection between the theoretical concepts studied and practical experience in the laboratory. Researchers divide the practicum objectives into two: 1) Students can calculate the vital capacity of the lungs using simple tools. 2) Students can conduct analyses related to factors that influence the vital capacity of the lungs. The hope is that by doing this practicum, students can independently measure each group member's respiratory volume. Apart from that, they will carry out analyses related to various factors that influence human respiratory volume. Students can relate to the relationship between organ systems and respiratory diseases (Lutfi, 2017). This can also help increase students' awareness of adopting a healthy lifestyle so that the respiratory system is well maintained. The laboratory activities design is presented in Figure 6.

This laboratory activity design reconstruction is supported by several questions that encourage students to learn about relationships. The questions asked in the reconstruction include: 1) Is the calculated air volume for each group member the same? 2) What factors can cause the volume of respiratory air for each group member to be different or the same? 3) What factors have the greatest influence on the measured air volume? 4) How can differences in the physical activity or fitness of each group member affect the volume of air they breathe? 5) Are there differences in breathing patterns between smoking and non-smoking group members, and how does this affect the volume of air they breathe? 6) How can health conditions, such as respiratory illnesses or allergies, affect respiratory air volume? 7) How do psychological factors, such as stress or anxiety, influence respiratory air volume, and if so, how do they affect them? 8) How does body posture or sitting position affect respiratory air volume? 9) Are there other factors beyond those mentioned that might influence respiratory air volume, and how do they impact this?. Questions like this allow students to find the causes and effects that occur in the breathing process. The practical results

obtained can later be used to connect the concepts of lung structure, physiological processes, and disorders experienced in the human respiratory system. Laboratory activity design questions are presented in Figure 7.

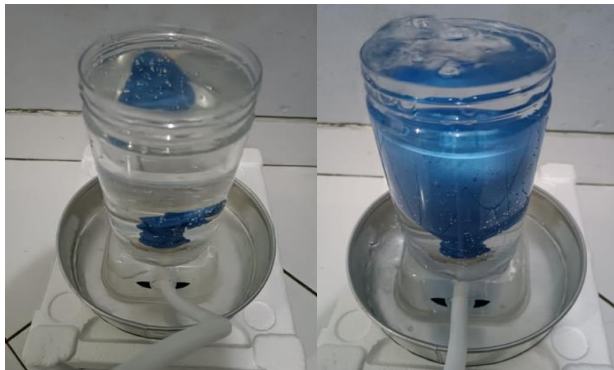


Figure 8
Equipment design: simple spirometer

The novelty of a simple spirometer design supports the LAD reconstruction results. The reason for making this simple tool is that not all schools in Indonesia have a spirometer, so it is necessary to make a simple tool that teachers can prepare before carrying out the practicum. Recommended simple tools are presented in Figure 8.

This simple spirometer was made by applying Archimedes' principle, where the air volume can be measured from spilled water. Inhaling the air blown into the balloon causes the previously full water to spill and fall into the container below. This tool can be used as an alternative to a spirometer. The design of this simple tool can also be assigned to students to train creativity and solve problems using the Think-Create-Learn (TCL) methodology (Calavia, 2021). The materials needed to make a simple spirometer are 1) a medium-sized balloon that is easy to inflate, 2) a Pianika hose, 3) a cylindrical jar with a toilet volume of 1 liter, 4) a jar base, 5) a glue burning tool and 6) a container for catching spilled water. The manufacturing process also does not require special skills, so high school teachers can apply them.

Based on the analysis results, laboratory design reconstruction activities and simple tool designs were carried out. We hope to help teachers create LAD aligned with Merdeka's learning objectives and curriculum. We also hope that this simple spirometer design can be a reference for making tools suitable for practical activities related to the air volume produced by human breathing.

D. Conclusion

The results of the analysis of five laboratory activity designs show that there are deficiencies. Several aspects need to be refined, such as fewer specific goals, less clear procedures, and material tools that need to be more detailed. Using Vee Diagrams as an analysis

tool helps identify weaknesses in existing LAD. Reconstruction was done to correct these deficiencies, including making simple tools such as spirometers to assist in practical work. This analysis and reconstruction provide a clear picture for teachers when designing laboratory activities based on learning objectives and applicable curricula. Hopefully, with these improvements, practical learning can be more effective in helping students understand science concepts and develop their scientific skills.

E. Acknowledgment

The researcher would like to thank the supervisors who have provided suggestions and input in this research. In addition, we would like to thank the Lembaga Pengelola Dana Pendidikan (LPDP), which contributed to funding our research and research publications.

F. References

- Al-hafidz, N. N. K., Fia, A., Zhafarah, A., & Suryanda, A. (2024). Pembelajaran biologi berbasis praktikum dan kemampuan berpikir kritis siswa: Sebuah kajian korelasi: Praktikum dalam pembelajaran dapat meningkatkan kemampuan berpikir kritis siswa. *DIAJAR: Jurnal Pendidikan dan Pembelajaran*, 3(1), 65-70. DOI: <https://doi.org/10.54259/diajar.v3i1.2250>
- Alsaleh, N. J. (2020). Teaching critical thinking skills: Literature review. *Turkish Online Journal of Educational Technology-TOJET*, 19(1), 21-39. Retrieved from <https://api.semanticscholar.org/CorpusID:211054783>
- Amanda, F. F., Sumitro, S. B., Lestari, S. R., & Ibrohim, I. (2021). Analysis of the relationship between concept mastery and problem-solving skills of pre-service biology teachers in human physiology courses. *Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education)*, 9(3), 421-432. DOI: <https://doi.org/10.24815/jpsi.v9i3.19956>
- Arikunto, S. (2016). *Prosedur penelitian; Suatu pendekatan praktik*, Jakarta: Rineka Cipta.
- Astika, E., Anggraeni, S., & Supriatno, B. (2020). Analisis komponen penyusun desain kegiatan laboratorium enzim katalase. *Biodik*, 6(3), 336-351. DOI: <https://doi.org/10.22437/bio.v6i3.9469>
- Azzahra, W., & Supriatno, B. (2023). Evaluasi desain kegiatan praktikum materi transpor zat dan implementasi hasil rekonstruksinya pada kurikulum merdeka. *BEST Journal (Biology Education, Sains and Technology)*, 6(1), 571-577. DOI: <https://doi.org/10.30743/best.v6i1.7104>
- Beshir, S., Kelkay, A. D., & Melesse, T. (2023). Perceptions of practicum actors in the primary teacher education practicum program. *Cogent Education*, 10(1), 1-21. DOI: <https://doi.org/10.1080/2331186X.2023.2206628>

- Calavia, M. B., Blanco, T., & Casas, R. (2021). Fostering creativity as a problem-solving competence through design: Think-create-learn, a teacher tool. *Thinking skills and creativity*, 39, 100761. DOI: <https://doi.org/10.1016/j.tsc.2020.100761>
- Darmawati, W. T., Suprianto, B., & Anggraini, S. (2021). Analisis dan rekonstruksi desain kegiatan laboratorium (DKL) materi spermatophyta melalui petunjuk praktikum. *EduMatSains: Jurnal Pendidikan, Matematika dan Sains*, 6(1), 163-174. DOI: <https://doi.org/10.33541/edumatsains.v6i1.3002>
- Ersalina, V., Yogica, R., Fajrina, S., & Fifendy, M. (2023). Pengembangan lembar kerja peserta didik (LKPD) elektronik berbasis pendekatan konstruktivisme pada materi sistem sirkulasi untuk peserta didik SMA. *Jurnal Biologi dan Pembelajarannya (JB&P)*, 10(2), 157-170. DOI: <https://doi.org/10.29407/jbp.v10i2.20903>
- Ekselsa, R. A., Anggraeni, S., & Supriatno, B. (2020). Rekonstruksi dan pengembangan lembar kerja siswa pada materi plantae submateri spermatophyta dengan pendekatan keterampilan proses. *BIODIK*, 6(4), 507-518. DOI: <https://doi.org/10.22437/bio.v6i4.9505>
- Faidah, S. T. R., Rohimah, T. R., Supriatno, B., & Anggraeni, S. (2022). Analisis dan rekonstruksi kegiatan laboratorium: Pengaruh konsentrasi karbondioksida pada laju fotosintesis Hydrilla verticillata. *Jurnal Basicedu*, 6(5), 8493-8505. DOI: <https://doi.org/10.31004/basicedu.v6i5.3634>
- Fadilah, S. I., Surakusuma, W., & Sanjaya, Y. (2024). Pengaruh kegiatan merancang alat sederhana dalam praktikum terhadap penguasaan konsep dan sikap ilmiah pada materi sistem pernafasan SMA. *ORYZA (Jurnal Pendidikan Biologi)*, 13(1), 7-17. DOI: <https://doi.org/10.33627/oz.v13i1.1729>
- Gericke, N., Högström, P., & Wallin, J. (2023). A systematic review of research on laboratory work in secondary school. *Studies in science education*, 59(2), 245-285. DOI: <https://doi.org/10.1080/03057267.2022.2090125>
- Handyanie, Y., Anggraeni, S., & Supriatno, B. (2020). Analisis lembar kerja siswa praktikum struktur darah berbasis diagram Vee. *Biodik*, 6(3), 361-371. DOI: <https://doi.org/10.22437/bio.v6i3.9408>
- Hindriana, A. (2016). The development of biology practicum learning is based on a Vee diagram to reduce student cognitive load. *Journal of Education, Teaching and Learning*, 1(2), 61-65. Retrieved from <https://www.learntechlib.org/p/209025/>
- Hodson, D. (1991). Practical work in science: Time for a reappraisal. *Studies in Science Education*, 19(1), 175-184. DOI: <https://doi.org/10.1080/03057269108559998>
- Idris, N., Talib, O., & Razali, F. (2022). Strategies in mastering science process skills in science experiments: A systematic literature review. *Jurnal Pendidikan IPA Indonesia*, 11(1), 155-170. DOI: <https://doi.org/10.15294/jpii.v11i1.32969>
- Kemendikbud. (2023). *Capaian pembelajaran biologi fase F*. Sistem Informasi Kurikulum Nasional, Pusat Kurikulum dan Pembelajaran. Retrieved from <https://guru.kemdikbud.go.id/kurikulum/referensi-penerapan/capaian-pembelajaran/sd-sma/biologi/fase-f/>
- Khasanah, M., Supriatno, B., & Anggraeni, S. (2021). Analisis LKPD dan alat ukur sederhana kapasitas paru-paru dalam mengembangkan HOTS (higher order thinking skills). *Bioscientist: Jurnal Ilmiah Biologi*, 9(2), 362-377. DOI: <https://doi.org/10.33394/bioscientist.v9i2.3799>
- Kirilmazkaya, G., & Dal, S. N. (2022). Effect of hands-on science activities on students' academic achievement and scientific attitude. *International Journal of Education and Literacy Studies*, 10(4), 56-61. DOI: <https://doi.org/10.7575/aiac.ijels.v10n.4p.56>
- Lestari, T. A., Karnan, K., & Kusmiyati, K. (2023). Pengembangan kegiatan praktikum menggunakan alat dan bahan sederhana untuk mahasiswa prodi pendidikan biologi. *Jurnal Ilmiah Profesi Pendidikan*, 8(1), 892-896. DOI: <https://doi.org/10.29303/jipp.v8i1b.1270>
- Lippard, C. N., Vallotton, C. D., Fusaro, M., Chazan-Cohen, R., Peterson, C. A., Kim, L., & Cook, G. A. (2024). Practice matters: How practicum experiences change student beliefs. *Journal of Early Childhood Teacher Education*, 1-25. DOI: <https://doi.org/10.1080/10901027.2024.2351471>
- Lutfi, M. F. (2017). The physiological basis and clinical significance of lung volume measurements. *Multidisciplinary Respiratory Medicine*, 12, 1-12. DOI: <https://doi.org/10.1186/s40248-017-0084-5>
- Meristin, A., Sunyono, S., & Marfu'ah, S. (2022). Pemanfaatan bahan sederhana pada praktikum mandiri: Kajian motivasi dan persepsi mahasiswa. *Orbital: Jurnal Pendidikan Kimia*, 6(1), 16-25. DOI: <https://doi.org/https://doi.org/10.19109/ojpk.v6i1.12041>
- Millar, R. (2004). *The role of practical work in teaching and science learning*. England: University of York.
- Mosiienko, H., Dziamko, V., Ievstigneieva, I., Kuninets, O., & Tsyganok, V. (2023). Laboratory practicums as the main form of integration of students' theoretical and methodological knowledge and practical skills. *Conhecimento & Diversidade*, 15(38), 306-326. DOI: <https://doi.org/10.18316/rcd.v15i38.11054>
- Nafi'ah, J., Jauhari Faruq, D., & Mutmainah, S. (2023). Karakteristik pembelajaran pada kurikulum merdeka belajar di madrasah ibtidaiyah. *Auladuna: Jurnal Prodi Pendidikan Guru Madrasah Ibtidaiyah*, 5(1), 1-12. Retrieved from <https://ejournal.uas.ac.id/index.php/auladuna/article/view/1248>
- Novak, J. D., & Gowin, D. B. (1984). *Learning how to learn*. England: Cambridge University Press.

- Putri, M. D., Anggraeni, S., & Supriatno, B. (2020). Analisis kegiatan praktikum biologi SMA materi sistem pernapasan manusia. *BIODIK*, 6(3), 290-301. DOI: <https://doi.org/10.22437/bio.v6i3.9454>
- Qisthi, N., & Supriatno, B. (2023). Analisis dan rekonstruksi desain kegiatan laboratorium berbasis diagram Vee pada materi pertumbuhan dan perkembangan. *JlIP-Jurnal Ilmiah Ilmu Pendidikan*, 6(12), 10109-10113. DOI: <https://doi.org/10.54371/jiip.v6i12.3326>
- Ramadhayanti, R., Anggraeni, S., & Supriatno, B. (2020). Analisis dan rekonstruksi lembar kerja peserta didik indra pengecap berbasis diagram Vee. *Biodik*, 6(2), 200-213. DOI: <https://doi.org/10.22437/bio.v6i2.9441>
- Rayment, S. J., Evans, J., Moss, K., Coffey, M., Kirk, S. H., & Sivasubramaniam, S. D. (2023). Using lessons from a comparative study of chemistry & bioscience pre-lab activities to design effective pre-lab interventions: A case study. *Journal of Biological Education*, 57(5), 1092-1111. DOI: <https://doi.org/10.1080/00219266.2021.2011771>
- Saputra, A. D., & Supriatno, B. (2024). Revolutionizing learning: Enhancing student worksheets on plant tissue structure through vee diagrams in alignment with the Merdeka curriculum. *Assimilation: Indonesian Journal of Biology Education*, 7(1), 25-38. DOI: <https://doi.org/10.17509/aijbe.v7i1.66426>
- Setiawati, E., Sopyan, T., & Maladona, A. (2021). Analisis pengelolaan laboratorium IPA dan alternatif praktikum IPA pada masa pandemi covid-19 di SMP Negeri 1 Ciamis. *J-KIP (Jurnal Keguruan dan Ilmu Pendidikan)*, 2(3), 229-236. DOI: <https://doi.org/10.25157/j-kip.v2i3.6290>
- 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. DOI: <https://doi.org/10.31004/basicedu.v6i4.3568>
- Supriatno, B. (2013). *Pengembangan program perkuliahan pengembangan praktikum biologi sekolah berbasis ANCORB untuk mengembangkan kemampuan merancang dan mengembangkan desain kegiatan laboratorium*. (Doctoral dissertation, Universitas Pendidikan Indonesia, Bandung). Retrieved from <https://repository.upi.edu/3661/>
- Usmeldi., & Amini, R. (2021). Pelatihan penggunaan KIT IPA dan pengembangan LKPD berbasis praktikum untuk guru IPA. *Jurnal Abdimas Prakasa Dakara*, 1(2), 56-65. DOI: <https://doi.org/10.37640/japd.v1i2.1010>
- Zidan, Z., & Supriatno, B. S. B. (2023). Analisis dan rekonstruksi desain kegiatan laboratorium mitosis akar bawang merah (*Allium cepa*) melalui model ANCOR. *Biodik*, 9(3), 37-49. DOI: <https://doi.org/10.22437/biodik.v9i3.25469>
- 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. DOI: <https://doi.org/10.31004/basicedu.v6i4.3474>