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Application of Vee Diagram in Reconstructing Laboratory Activity Design on Diffusion-Osmosis Concept

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Abstract: *Implementing the Merdeka curriculum is a record of Indonesia's long journey of education dynamics. One of the reforms visible from implementing the Merdeka curriculum is the existence of science process skills (KPS), as stated in the learning outcomes, especially in the skills element. Diffusion and osmosis are materials that are consistently included in the curriculum. As one part of science learning, diffusion-osmosis cannot escape the practicum learning method that involves science process skills and needs to contain aspects of Vee Diagram knowledge construction. The ideal Laboratory Activity Design (DKL) as a support for diffusion-osmosis practicum activities is still minimal, especially since the implementation of the Merdeka curriculum is still relatively new. Through the descriptive qualitative research method with an analysis-try-reconstruction (ANCOR) approach, this research aims to analyze the quality of diffusion-osmosis student worksheets (DKL) in high school textbooks and then test and reconstruct the DKL. The analysis and pilot test findings showed that DKL was unsuitable for knowledge construction. The results of DKL reconstruction use aspects of the Vee Diagram and Science Process Skills (KPS) to align with the expected competency achievements in implementing the Merdeka Curriculum.*

Keywords: *Vee Diagram, Laboratory Activity Design, Osmosis-Diffusion*

1. INTRODUCTION

Osmosis is the process of moving a solvent through a semipermeable membrane (Campbell, 2010). The process of osmosis, which is difficult to observe directly, often makes it difficult for students to distinguish it from the diffusion process. Previous research shows that students' understanding of diffusion-osmosis is less than satisfactory; most students only obtain KKM scores and show misconceptions (Ping *et al*., 2020). Although many compelling animations are available as learning resources (Awang Morsid *et al*., 2020), direct experience through a series of practical activities still needs to be done to provide meaningful experiences to students (Marquez, 2024). This is in line with the characteristics of material with abstract concepts that should not be separated from practical activities (Rahmah *et al*., 2020).

Practical activities are an integral part of the science learning process (Prajapati & Singhai, 2020; Toplis, 2012). Intensive practical work in science leads to a significant difference in attainment scores compared to traditional teaching methods (Shana & Abulibdeh, 2020). Practicum not only involves minds-on activities but also requires hands-on activities (Oliveira & Bonito, 2023) that directly provide student experience in activities to collect and process information, visualize problems, make graphs, maps, drawings, or work papers in mediating critical thinking processes and communicating (Laelasari & Supriatno, 2018). The importance of practicum activities needs serious attention so that

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the process can take place optimally and be able to develop students' skills such as scientific attitudes (Dewi *et al*., 2020), numeracy literacy (Sugianto & Darmayanti, 2022), and of course, student learning outcomes as a whole (Susantini *et al*., 2019). Practicum has an important role in building students' science process skills (KPS), including observing skills, hypothesizing, making predictions, interpreting data, communicating data, applying concepts, classifying objects, designing experiments, and conducting experiments.

Science process skills (KPS) are skills that can motivate student (Maison *et al*., 2019) and have a significant correlation with science achievement (Dolapçıoğlu & Subaşi, 2022). Science process skills can be developed to prepare students for the 21st century (Sisri *et al*., 2020) (Azzahra *et al*., 2024), specially now that KPS is explicitly included in the learning outcomes (CP) in the Merdeka curriculum. Science process skills can be developed through the use of appropriate and feasible students worksheet (LKPD) (Sanchia & Faizah, 2019).

Although hands-on activities/practicum/experimentation methods are important to develop learners' skills, in practice, these activities have several barriers such as 1) ineffective school administration; 2) the type of experiment is too simple; 3) irrelevant to students' interests and abilities; 4) experimental instructions; 5) lack of evaluation activities (Galve & Vela-Tafalla, 2020; Nugroho *et al*., 2019; Wirdawati, 2017). Other obstacles found in practicum activities are generally related to the need for a relatively long time allocation and the availability of adequate specialized equipment (Hudha *et al*., 2023).

A practicum-based student worksheet (LKPD) contains practicum instructions or Laboratory Activity Design (DKL). Some important aspects of DKL include focus questions, objects and events, data recording and transformation, and composition of theories, principles, concepts, and knowledge claims (Novak & Gowin, 2006). DKL is closely related to the curriculum because a good DKL must refer to clear learning objectives. The learning objectives are related to the competencies achieved by the demands of the applicable curriculum. However, various sources mention that there are still many problems in the practicum activities of osmosis diffusion. These problems include DKL's relevance and practical aspects that have not yet reached the maximum score, especially the lack of required content that does not train skills by the applicable curriculum (Tanfiziyah *et al*., 2021). Weaknesses in DKL were also found in several incomplete Vee diagram components (Azzahra & Supriatno, 2023).

The implementation of the Merdeka curriculum, which is still relatively new, and the limited number of DKL by the demands of the existing curriculum underlies the importance of improving DKL to become a reference in laboratory activities. The reconstructed DKL is expected to guide practicum activities that help students develop skills and construct knowledge. This study aimed to reconstruct DKL by implementing the applicable curriculum using the Vee Diagram scheme and evaluating the reconstructed DKL on fostering students' scientific processes skills. The analyzed DKL comes from online books that are spread on the internet, so it is considered to have high accessibility and is used by many students in Indonesia.

2. RESEARCH METHOD

This research method was conducted using a descriptive method to obtain an overview of the profile and quality of the Laboratory Activity Design (DKL) of osmosis diffusion. The analyzed DKL was then reconstructed based on the Vee diagram principle (Novak & Gowin, 2006) which are consisted of five aspects such as: 1) focus question, 2) objects/events, 3) theory, principles, and concepts, 4) records/transformations, and 5) knowledge claim. The sampling technique was carried out purposively. The sample had to include diffusion-osmosis student laboratory activities (DKL) represented in biology textbooks used in the KTSP, 2013, and Merdeka Curricula. The books had to be publicly accessible and available online. Based on these criteria, three textbooks were selected and compared to determine which best aligned with the aspects of the Vee Diagram for further analysis.

DKL development in this study uses the Analysis, Trial, and Reconstruction (ANCOR) approach. The research flow consists of: 1)

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analyzing aspects of the relevance of DKL competencies to the curriculum and Vee diagrams. 2) After the analysis, a trial was conducted by performing all the practicum activities included in the DKL. This stage aimed to assess the feasibility of the analyzed DKL. The trial followed every instruction in the DKL strictly, without any modifications or manipulation of the practicum activities, including the use of materials and tools, work procedures, data recording in observation tables, and answering questions (if any). 3) The findings from the analysis and trial were recorded, followed by the reconstruction and revision of the DKL to address the identified issues. The reconstruction was carried out to improve the DKL following the aspects of the Vee Diagram, such as refining the focus question, clarifying the observed phenomena, and improving data transformation

3. RESULTS AND DISCUSSION

Analysis of Competency Aspects in the Curriculum

The first step taken before reconstructing the DKL is analyzing the alignment between the competency achievements of the current curriculum and the Vee diagram used in DKL analysis. This is important because the reconstructed DKL, in addition to incorporating key aspects of the Vee diagram, must also align with the competency achievements outlined in the applicable curriculum. Table 1 presents the competencies and topics related to diffusion-osmosis derived from the basic competencies (KD) and competency achievements (CP) found in the content standard documents of the KTSP curriculum, the 2013 curriculum, and the Merdeka curriculum. The data shows the existence of diffusion-osmosis material in each applicable curriculum.

Table 1. Competency Aspects of Diffusion-Osmosis Topic in the Curriculum

Curriculum	Competence
KTSP	• Compare transport mechanisms in membranes (diffusion, osmosis, active transport, endocytosis, exocytosis)
Curriculum 2013	• Analyze various bioprocesses in cells including mechanisms of membrane transport, reproduction, and protein synthesis. • Model the bioprocesses that occur in cells based on literature studies and experiments.
Merdeka Curriculum	• Learners have the ability to describe the structure of cells and the bioprocesses that occur such as cell transport and cell division. • Science Process Skills (KPS)

The curriculum has been developing for the last 10 years, starting from the end of the implementation of the KTSP curriculum in 2015, followed by the 2013 curriculum, which was refined with the implementation of the Merdeka curriculum starting in 2022. The development of the curriculum certainly has an impact on the content of different learning content standards and off course it will impact student outcomes (Roblin *et al*., 2018).These differences can be in the form of changes in the nomenclature of learning strategies, minimum standards of learning outcomes, and the complexity/breadth of material students will take. It can be seen that, from the three applicable curricula, the material of member transfer (including diffusion and osmosis) is consistently included in the content of the competencies that must be achieved. Implementing an Merdeka curriculum frees teachers to choose materials that are considered essential so that the competency analysis carried out across the curriculum can be a reference for selecting diffusion-osmosis material to be considered essential.

Diffusion and osmosis sub-materials are part of the material that is generally juxtaposed with the material of cell structure and function. In its development, the diffusion and osmosis sub-material with cell structure and function material content were made separately (content standards of the KTSP curriculum and the 2013 curriculum). However, these two materials have the same learning outcomes in the Merdeka curriculum. The author analyzes the dimensions of cognitive and psychomotor processes, content depth, and learning strategies in each curriculum. The analysis is presented in Table 2.

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Table 2. Analysis of Competency Level and Depth of Diffusion-Osmosis Topic in the Basic Competencies of Curriculum in Indonesia

Competence	Curriculum		
	KTSP	**2013**	**Merdeka**
Level of thinking ability (cognitive)	C2	C4	C2
Psychomotor ability level	P4	P6	KPS
Depth of Material	Membrane transport bioprocess	Bioprocesses include membrane transport, reproduction and protein synthesis	Membrane transport and cell division (can be adjusted as needed)

The author analyzed operational verbs in the knowledge and psychomotor dimensions of the revised version of Bloom's taxonomy. The analysis results show that the dimensions of the cognitive process of basic competencies expected in this material tend to fluctuate. The expected cognitive process dimensions range from only comparing and describing (C2 level) in the KTSP curriculum and Merdeka curriculum to analyzing (C4) in the 2013 curriculum. Of course, this change in cognitive level must be aligned with the teacher's learning strategies, especially since analyzing (C4) is a higher-order cognitive process that requires a more complex learning process, including activities involving data and information processing.

Meanwhile, at the psychomotor ability level, students are expected to have the skills to compare (P4) in the KTSP curriculum and model (P6) in the 2013 curriculum. However, in the Merdeka curriculum, the achievement of skill elements explicitly directs the development of science process skills (KPS), which include observing, hypothesizing, making predictions, interpreting data, communicating data, applying concepts, classifying objects, designing experiments, and conducting experiments.

Based on the three curricula we analyzed, the member transport sub-material (diffusion-osmosis) did not show substantive changes. The consistency of the diffusion-osmosis sub-material in each curriculum shows the relevance and essence of the material needed as a knowledge base for students. Although the dimensions of cognitive processes and skills have changed in each curriculum, the rules still use Bloom's revised taxonomy. Meanwhile, in the Merdeka curriculum, the skills dimension is directed towards more holistic scientific skills, namely science process skills (KPS). This shows that implementing learning in the Merdeka curriculum is expected to train science process skills to help students find and construct their knowledge.

Vee Diagram Aspect Analysis of DKL Components

Laboratory activities are a part of the learning process to construct students' knowledge. The DKL should reflect the activities, from observable objects and information processing to the generalizations that form new knowledge structures. The Vee Diagram is a visualization of the structure of knowledge and how humans produce knowledge. The Vee Diagram was first developed to help students and instructors clarify the nature and purpose of laboratory work in science. Therefore, a DKL that fulfills the aspects of the Vee diagram can facilitate students in actively constructing their knowledge through data and information processing. These aspects include: 1) focus question, 2) objects/events, 3) theory, principles, and concepts, 4) records/transformations, and 5) knowledge claim.

The pilot test analysis of the selected diffusion-osmosis DKL shows discrepancies in several indicators that should ideally appear in the practicum. The assessment of each indicator in the DKL is presented in Table 3 below.

Table 3. DKL Assessment Results According to Indicators on the Vee Diagram

No.	Indicator	Score
1.	***Focus question*** "Questions are clearly identified, covering concepts that can support objects and events"	3
2.	***Object/event*** "Objects and events are identified and related to the question"	2
3.	***Theory, principles, and concepts*** "A concept and two principles or one each of a concept, principle, and relevant theory are identified"	3

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No.	Indicator	Score
4.	***Records/transformation*** *"Records* or data transformation activities may be identified but not both"	2
5.	***Knowledge claim*** *"Knowladge claims* include concepts used in inappropriate contexts OR generalizations that are inconsistent with records and transformations"	2
	Score	**67% (**medium**)**

Overall, the analysis results show that DKL still has many weaknesses. The percentage of achievement indicators that are important to help students construct knowledge only reaches 67% (medium). This can be seen from the suitability of the focus question and the fact that the data recording that is carried out does not have a connection. The title and basic competencies contain the concepts of diffusion and osmosis. At the same time, the objectives and procedures described in the DKL have not led to the discovery of facts and phenomena needed by students. At the next point, the questions in DKL should guide students in connecting the facts and phenomena that arise with the concepts to be constructed (Novak & Gowin, 2006). However, the questions in DKL are not practical enough to guide students in linking the facts and phenomena that learners find (Chin & Chia, 2004). Objects/phenomena, recording, and transforming data are used as meaningful evidence/information that can be processed to construct new knowledge (Novak & Gowin, 2006). However, the facts, data, and phenomena found are insufficient to lead learners to discover the expected new concepts.

Figure 1. shows a vee diagram of the diffusion-osmosis DKL component. The theories, concepts, and principles illustrated in the DKL only emphasize the concept of osmosis. This is not by the DKL title, which also requires the concept of diffusion. The objects and phenomena that appear also do not describe the process of diffusion-osmosis; only the impact of osmosis is due to differences in solution concentration. Data recording activities are not facilitated by tables of observations and guidelines for transforming data contained in DKL so the meaning of the phenomena that occur becomes diverse, and it is not easy to get the same understanding of construction. Knowledge claims are also unclear enough to involve the observed data, objects, and phenomena. Knowledge claims should be able to direct students to answer focus questions based on the meaning of data obtained from observing objects and phenomena (Novak & Gowin, 2006).

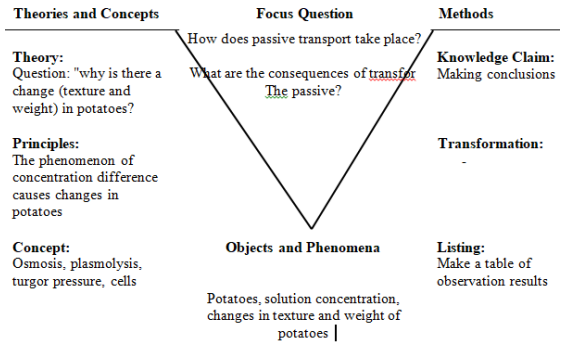


Figure 1. Vee Diagram based on DKL Components of Diffusion-Osmosis Material. It is illustrated that the transformation aspect is not included in the DKL analysis results

The deficiencies found in DKL will undoubtedly hinder students' interpretation of data and synthesizing conclusions/knowledge. Some of these things become a strong foundation for the author to reconstruct DKL and adjust it to the proper criteria.

DKL Trial Results

The Laboratory Activity Design (DKL) trial was conducted to see the readability and applicability of the DKL guide when used. The practicum steps were tested using the stages listed in DKL. Based on the results of the DKL trial in terms of content and competence, it has not met the minimum standards of KD in the 2013 revised curriculum that was in effect when the DKL was published. There was a mismatch between the objectives and the competencies achieved.

In the DKL, the tools/materials do not align with the steps of the activity, and the quantities/sizes used are not specified, making the instructions less informative. When the trial was conducted, the procedure steps contained missing or incorrect instructions, which could affect the accuracy of the observation results. For example, the steps for measuring the mass and length of objects were swapped. Additionally, the

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measurements taken are quite time-consuming as they require high precision, and any errors can significantly impact the observation results—for instance, when measuring the length, width, and height of a potato slice. The objects/phenomena observed and the data processed are insufficient to answer the guiding questions that lead students to construct new knowledge or concepts. The objects and phenomena are not concrete enough to indicate that the observed event is osmosis caused by the movement of water molecules. The recorded data only include changes in mass and length, which could be interpreted as other phenomena unrelated to osmosis.

DKL Reconstruction

After analyzing and testing the DKL, the researcher tried to reconstruct the DKL for osmosis diffusion based on the DKL assessment rubric adopted from the vee diagram. The reconstruction carried out is based on the findings of the analysis and trial, which contains the weaknesses found in DKL (figure 1) and adjustments to implement the Merdeka curriculum. This reconstruction aims to make the DKL used more practical, effective, and relevant to the intended competency achievements. The reconstructed DKL is also arranged based on aspects of science process skills (KPS) designed so that students can identify facts and develop concepts and theories in the learning carried out. The hope is that the compiled DKL can act as a guide in developing science skills and knowledge construction for high school students in the applicable Merdeka curriculum.

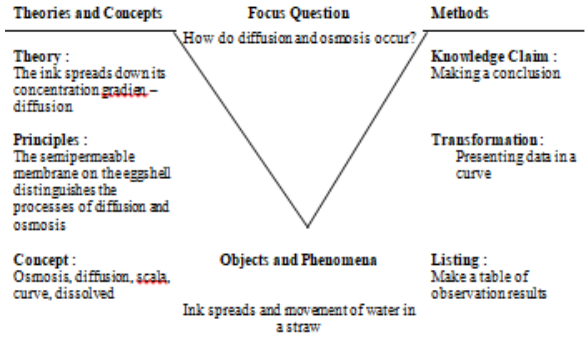


Figure 2. Vee Diagram Based on Reconstructed DKL Components of Diffusion-Osmosis Material. Each component illustrated represents an aspect of the Vee diagram

Figure 2 summarises the reconstructed DKL based on the Vee diagram's aspects. Several adjustments and improvements have been made compared to Figure 1. The transformation aspect, which was previously missing, is fulfilled in Figure 2. The fulfilment of the Vee diagram aspects is expected to support the development of science process skills in alignment with the learning outcomes of the Merdeka curriculum.

4. CONCLUSIONS

The Osmosis Diffusion DKL that was analyzed and tested still had shortcomings in various aspects. This deficiency will undoubtedly make the practicum unable to support the formation of student knowledge by the learning objectives. The most often found shortcomings are mainly related to the suitability of facts and phenomena to answer the focus of the question and lead to knowledge claims. The findings from the results of the analysis and trial of DKL became the basis for researchers to reconstruct DKL. DKL reconstruction is carried out by holistically integrating aspects of science process skills based on the competency achievements in the Merdeka Curriculum. Disclosure of the Diffusion and Osmosis phenomena is also presented simultaneously to reinforce so that knowledge construction can be formed as a whole. In addition to enhancing learning effectiveness, a well-designed laboratory activity (DKL) can improve science process skills, thereby optimizing students' construction of new knowledge. Hopefully, this reconstruction DKL can be an alternative teaching material that is suitable and representative of the applicable curriculum standards and can guide students in practicum activities.

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