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Examination of Pre-service Science Teachers' Opinions on Vee Diagrams

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ABSTRACT

This study examines pre-service science teachers' perceptions regarding the Vee Diagram. The descriptive survey method was utilized in the study since it was intended to reveal the students' perceptions about the Vee Diagram implementation. The study was conducted with 36 pre-service science teachers who were studying in the first year of the Department of Science Teaching and enrolled in the Chemistry I laboratory practices course over a period of 14 weeks. In the experiments conducted in the second and third weeks, the students were expected to prepare their experiment reports in the classical experiment report format. In the fourth week, the students were asked to prepare the reports of nine experiments in Vee diagram format. 'Attitude scale towards Vee diagram' and 'Semi-structured opinion form on the utilization of Vee diagram' were employed to determine the opinions of pre-service science teachers about the studies they carried out in laboratory practices. In analyzing the quantitative data collected in the study, percentage and frequency were calculated from descriptive statistics. Qualitatively collected student responses were subjected to content analysis. In the quantitative findings of the study, 80% of the pre-service teachers responded positively to the statement, "Vee diagrams are a very helpful tool for observing the experimental process as a whole." In the study's qualitative findings, most of the pre-service teachers stated that they prefer to prepare their experiment reports in "Vee diagram format." The pre-service teachers stated that utilizing the Vee diagram as an experiment report was beneficial in "demonstrating the relationship between theory and practice, eliminating misconceptions, learning new information and facilitating meaningful learning".

Keywords: Experiment reports, Vee diagram, pre-service science teachers' opinions.

Introduction

In the current education system, students are aimed to provide a qualified service in line with their abilities and to carry out practical studies. The most important environments that come to mind in the teaching of science courses are laboratories (Alkan, Çilenti & Özçelik, 1991; İlhan, 2013). Student-centered laboratory practices that focus on learning by making and experiencing provide meaningful and lasting science teaching (Tobin, 1990; Telli, Yıldırım, Şensoy & Yalçın, 2004; Hofstein & Lunetta, 2004; Hofstein & Mamlok-Naaman, 2007; Tatar, Korkmaz & Ören, 2007). The written presentation of results and comments obtained as a result of an experiment or an activity is called an "experiment report". The reports include the name of the experiment, the experiment's purpose, its execution, tools and materials, theoretical information about the experiment, a graphical or tabular representation of the data, the experiment's result, and comments (Yenice & Aktamış, 2004). At the end of the experiment, the benefits of expressing what was accomplished in written form were as follows (Ergin, Şahin-Pekmez & Öngel-Erdal, 2005). Experiment reports provide a holistic view of each stage of the study.

a) Students acquire the ability to express their knowledge, process steps, and results in written and visual form while preparing an experiment report.

b) Experimental reports can be utilized as an assessment tool.

c) Students can observe their progress through experiment reports.

The evaluation of science experiments in our country is usually carried out using classical experiment reports. Classical experiment reports include the name, purpose, tools and equipment, theoretical information, conduct, graphical or tabular representation of data, result, and comments about the experiment (Yenice & Aktamış, 2004). When the classical laboratory sheets are examined, the aim is to achieve learning as a result of guiding the students, by listing what should be carried out at each step (Tamir, 1977; Kyle, 1979; Shymansky & Penick, 1979). This situation prevents students from structuring information in their minds and establishing connections between old and new knowledge (Nakiboğlu & Meriç, 2000; Atılboz & Yakışan, 2003). The most important purpose of laboratory studies is to provide a real learning environment by forming meaningful relationships between the theoretical knowledge students learn in class and the phenomena they observe in the laboratory. In the 1970s, Gowin and his students developed the Vee diagram to better understand and structure knowledge and laboratory practices. The Vee diagram is utilized as an experimental report in laboratory studies.

In Novak and Gowin's (1984) study that the first documented source on Vee diagrams was the book "Learning How to Learn. In the book, the Vee diagram was discussed extensively. In the literature, this instrument is called "Vee heuristic", "Vee diagram" (Novak & Gowin, 1984), Vee map (Roth & Roychoudhury, 1993; Roth & Bowen, 1993; Roehrig, Luft & Edward, 2001), or V-diagram (Nakiboğlu & Meriç, 2000). Nakhleh (1994) emphasized the importance of Vee diagrams and concept maps by stating that active learning, responsibility, and encouragement are essential for students to construct knowledge in the laboratory environment.

According to Ausubel (1968), learning occurs when linked to the student's existing knowledge. Therefore, before conducting laboratory experiments, students must associate the new information with concepts or generalizations they already know. In this sense, Vee diagrams allow students to research the concepts they will learn before the experiment. Like other cognitive theories, the theory of meaningful learning proposed by Ausubel (1968) focuses on the cognitive processes involved in learning rather than how knowledge is formed. Ausubel's (1968) view is based on the concepts of "learning" and "meaningful learning." According to Ausubel's (1968) theory of meaningful learning, instructional tools are necessary for meaningful learning. In their study, Novak and Gowin (1984) invented two learning tools called "Concept map" and "Vee map" based on Ausubel's Meaningful Learning theory to help students understand scientific concepts and construct knowledge (Ebenezer & Connor, 1998). Various teaching tools, such as Vee and concept maps, enable theoretical knowledge to be put into practice (Ramahlape, 2004).

Novak and Gowin (1984) define a concept map as an instructional tool that both taps into students' cognitive structures and expresses them. A concept map can be used with a Vee diagram. The Vee diagram, invented by Gowin, is a heuristic tool that has been proven to be effective in helping people understand complex concepts or relationships. A Vee diagram is both a teaching and a learning tool. According to Novak and Gowin (1984), concept maps and Vee diagramming allow educators and students to generate new ideas. With a Vee diagram, students can make connections between the results of the experiment and what they already know. Thus, systematically learning information enhances the permanence of learning (Novak & Gowin, 1984). Since the preparation of the Vee diagram takes place before the experiment, students conduct detailed research on the subject of the experiment and achieve more efficient learning (Roth & Bowen, 1993). The Vee diagram is an instrument that connects theoretical knowledge and practice and leads to results in a systematic way (Tatar, Korkmaz & Ören, 2007). The Vee diagram provides a significant benefit in understanding and evaluating the relationship between the observed and interpreted situations (Aydoğdu & Kesercioğlu, 2005). There are scientific studies in which Vee diagrams, which allow theoretical knowledge and practice to be combined, are utilized in laboratories (Atılboz & Yakışan, 2003; Morgil, Seçken & Karaçuha, 2005; Thoron & Myers, 2007). While creating the Vee diagram, five effective questions were emphasized to reveal the knowledge, (Novak & Gowin, 1984). These questions can be sorted as follows (Torres and Marriott, 2010).

What is an influencing question?

a) What is a keyword?

b) Which methods are employed in the research?

c) What are the main knowledge claims?

d) What are the valuable claims?

The main epistemological components of the Vee diagram are illustrated in Figure 1 (Novak and Gowin, 1984).

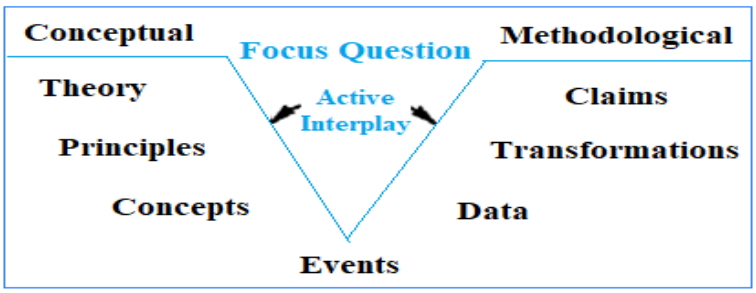


Figure 1. Vee heuristic

As shown in Figure 1, the Vee diagram consists of three main parts. It starts by drawing a large letter V. The focus question in the middle space is intended to connect the left and right sides of the Vee diagram (Gurley Dilger, 1992). The left part of the Vee diagram is called the conceptual part. This part consists of the student's knowledge before starting the experiment (Gurley Dilger, 1992). The conceptual part includes "theories, principles, and concepts. The right part of the Vee diagram is called the methodological part. The methodological part consists of empirical claims; knowledge claims; data transformations; and records. First, objects and events are identified. Answers to the focus question are sought. Afterward, they are asked what they need to know about the study. "What do I need to know to answer the focus question?" is the basis of the conceptual part on the left (Mintzes & Novak, 2005). The Vee diagram ensures a proper understanding of the basic concepts by establishing a connection between theoretical knowledge and methodology (Karamustafaoğlu, Yaman & Karamustafaoğlu, 2005). The parts of the Vee diagram to be filled in by the student are explained below (Nakiboğlu & Meriç, 2000).

Focus Question: Questions indicating the starting point and purpose. It should interact with the conceptual and methodological parts. There may be one or two focus questions.

Tools and Materials: It is placed at the bottom of the Vee diagram at the pointed end of the **V-shape**. This section includes the tools and materials used in the experiment.

Theory and Principles: It assists in determining which tools and materials will be utilized in the experiment.

Concepts: This is the part where the concepts, symbols, and expressions necessary for understanding the experiment are written. This part was prepared before the experiment.

Knowledge Claims and Experimental Claims: The answers to the focus questions are knowledge claims. These claims provide ideas about new questions that can guide research. The practical details, that is, those related to the experiment, are included in the empirical claims section.

Valuable Claims: These are considered valuable in research produced in or outside the field.

Data Transformations: These are the sections where the information obtained as a result of the experiments and the observations obtained beforehand are compared and converted into tables and graphs.

Registrations: This is where all the results, measurements, and observations gathered during the experiment are recorded.

Roth and Verechaka (1993) state that the Vee diagram can be regarded as a map illustrating the path to be followed in reaching new knowledge from previous knowledge, and that when students look at this diagram, they will understand how and why the experiment was conducted and what results were achieved. In their study, Roth and Verechake (1993) expressed the Vee diagram as a Vee map. In this context, the concepts relevant to understanding the experiment in the Vee diagram can also be expressed using concept maps (Roth and Verechake, 1993). In the Vee map, students learn the relationships between concepts by creating a map in the concepts section before the experiment. With this feature, the concepts section provides meaningful learning (Tekeş, 2011). The Vee map utilized by Luft, Tollefson, and Roehrig (2001) in their study is displayed in Figure 2.

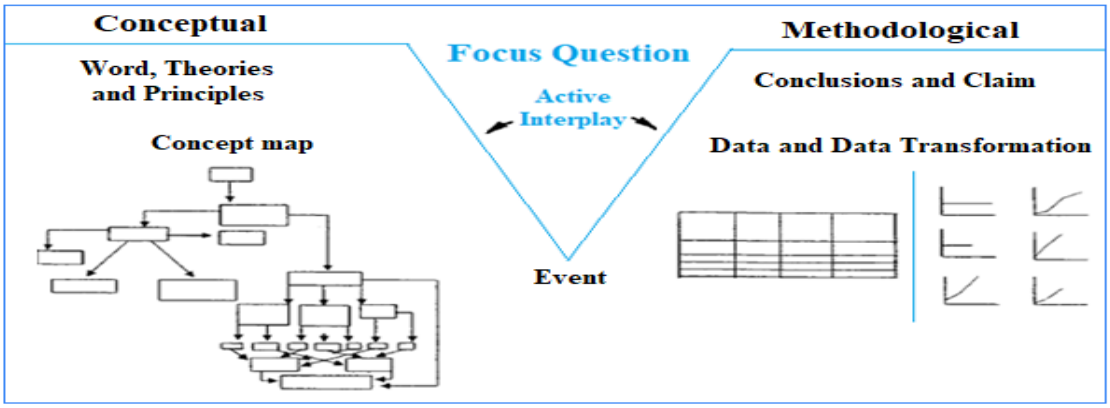


Figure 2. Vee map components

The advantages of utilizing the Vee diagram can be summarized as follows.

a) Vee diagrams are effective in structuring knowledge by providing a standardized format (Roehring, Luft & Edward, 2001).

b) Students improve their discussion skills by working in groups while preparing Vee diagrams (Nakiboğlu & Meriç, 2000).

c) Constructing a Vee diagram is more practical and less time-consuming than the classical experiment format (Novak & Gowin, 1984).

d) Vee diagrams effectively develop communication skills by allowing students to work together (Luft, Tollefson & Roehrig, 2001).

e) The Vee diagram can also be employed as an evaluation tool (Novak & Gowin, 1984; Roehring, Luft & Edward, 2001).

f) Vee diagrams can be useful in concept learning and identifying misconceptions (Ault, Novak & Gowin, 1984; Passmore, 1998; Nakiboğlu, Karakoç Topal & Benlikaya, 2002; Nakiboğlu & Özkılıç Arık, 2006; Alvarez & Risko, 2007).

In the studies conducted on laboratory practices, it was concluded that having students conduct classical experiment reports had no impact on learning except for psychomotor behavioral changes and that there was no relationship between the theoretical part of the experiment and observations (Nakiboğlu & Meriç, 2000). This study examines pre-service science teachers' perceptions regarding the Vee diagram. For this purpose, the study seeks answers to the following research questions.

1. What are the opinions of pre-service science teachers regarding the Vee diagram utilized in the laboratory?
2. What are pre-service science teachers' opinions regarding utilizing the Vee diagram?

Methods and Materials

In this study, the descriptive survey method was preferred since it aimed to reveal the students' perceptions, regarding the implementation of the Vee Diagram (Karasar, 1991). In the field of education, the descriptive survey model is adopted to learn people's attitudes, opinions, and beliefs (Johnson & Christensen, 2014).

Sampling

In the fall semester of the 2021-2022 academic year, a total of 36 first-year students studying in the Department of Science Teaching at Alanya Alaaddin Keykubat University, and enrolled in the Chemistry I laboratory practices course were included in the study. Within the scope of this study, it is important to ensure that students create and finalize Vee diagrams in different experiments (pre-experiment and post-experiment) in the laboratory practices course.

Applications process

This study was carried out for 14 weeks. Within the scope of the laboratory practices course, in the first week, the students were informed about the functioning of the course, laboratory safety rules, tools and equipment used in the laboratory, laboratory reports, including classical reports, and Vee diagrams. Pre-service teachers were also trained in the concept maps in the concepts section of the Vee diagram. In the experiments conducted in the second and third weeks, the students were expected to prepare their experiment reports in the classical experiment report format. In the experiments conducted after the fourth week, the students were asked to prepare their experiment reports in the Vee diagram format. The Chemistry I laboratory practices course was considered suitable for preparing Vee diagrams as it includes basic chemistry topics and involves preparing experimental reports. In the Chemistry I laboratory practices course, 9 experiment reports, "Separation of Mixtures, Separation by Distillation, Types of Reactions, Law of Conservation of Mass, Physical States of Matter, Ionic Solids and Conductivity, Comparison of Propagation Rates of Gases, Surface Tension of Liquids, Fluidity and Viscosity in Liquids", were prepared in Vee diagram format.

Data collection tools

"Attitude Scale Towards Vee Diagram" was administered to determine pre-service teachers' opinions regarding the Vee diagram. The 18-item, five-point Likert-type questionnaire specified intervals as "Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree. Based on the data from this study, Cronbach's Alpha value was calculated as 0.902. In the literature, Cronbach's alpha value is defined as "a scale is highly reliable if $0.80 \leq \alpha < 1.00$" (Terzi, 2017). According to these values, the reliability of the scale utilized in the study is high. Semi-structured Student Opinion Form on the Utilization of Vee Diagram" was utilized to determine pre-service teachers' views on using the Vee Diagram. The "Semi-structured Focus Group Interview Questions Vee Diagrams" form prepared by Savran Gencer, Sevim, and Kaska (2015) was adapted by the researcher to be suitable for the study and renamed as the "Semi-structured Opinion Form on the Use of Vee Diagram. The questions posed to the prospective teachers in the study are as follows.

1. In which format do you prefer to prepare your experiment reports (Vee diagram-Classical experiment format? Did you prepare the Vee diagram every week? If not, can you explain why?

2. Did you research while preparing the Vee diagram? Which sources did you consult?

3. Did you have any difficulties while preparing the Vee diagram? What are the challenging points?

4. Did preparing a Vee diagram influence the learning process?

5. How did utilizing Vee diagrams in laboratory practices contribute to your learning?

6. Will you likely use the Vee diagram when you become a teacher?

Data analysis

The pre-service teachers' responses to the quantitative scale were coded separately in Excel for each question. The Jamovi (jamovi.org) software was employed to calculate the scale's reliability. In the study, percentage and frequency calculations from descriptive statistics were made during data analysis. The Tableau 2021.1 program was used to visualize the data. In the qualitative dimension of the study, pre-service teachers' views on laboratory practices were revealed through content analysis. Student responses collected qualitatively in the study were subjected to content analysis. Content analysis is generally a form of interpretation that enables the transition from qualitative data to quantitative insights to reveal the common aspects of a large number of text contents, structuring and classifying the important meanings (Gökçe, 2006). A code was formed for the students' comments when they were . For example, it was expressed according to S1.

To ensure the validity and reliability of the qualitative dimension of the study, student opinions were analyzed by experts in the field. The consistency of the codes used by the researchers, independently of each other, was determined by marking "Consensus" or "Disagreement. The codes the researchers made, in conjunction with student opinions, were accepted as unanimity of opinion, while different codes were accepted as disagreement. In the sections where there were contradictions among researchers, the opinions of different researchers were gathered, and coding was carried out. The reliability of the study conducted in this way was calculated using the formula: Agreement/(Agreement + Disagreement) x 100. To ensure reliability, the agreement between the researcher and the expert should be at least 90% (Miles & Huberman, 1994). In this study, the average reliability was found to be 92%.

Ethical Considerations

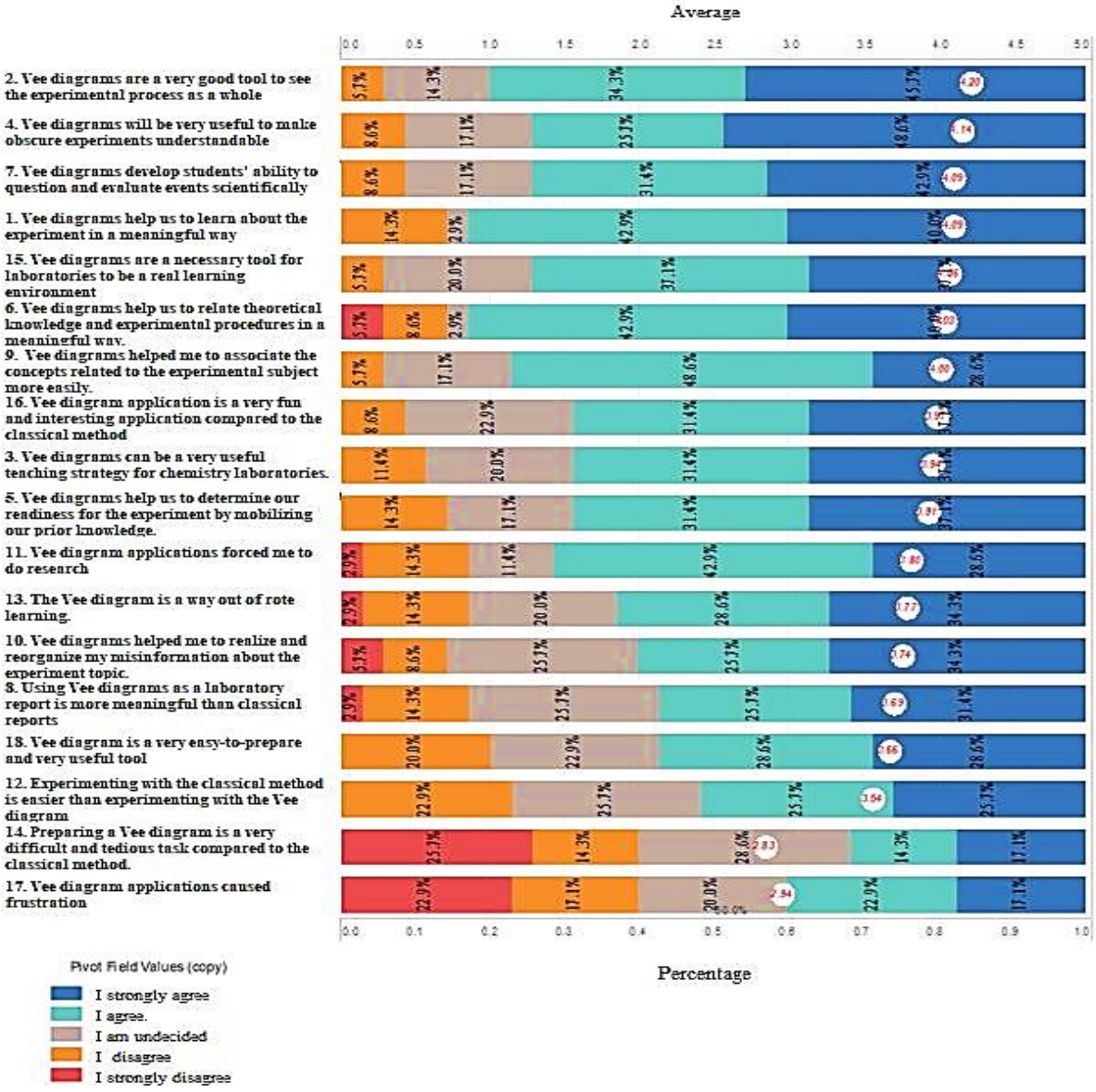
In this study, all rules within the scope of the "Higher Education Institutions Scientific Research and Publication Ethics Directive" were followed. None of the actions stated under the title "Actions Against Scientific Research and Publication Ethics," which is the second part of the directive, were not taken. Ethical review board name: Alanya Alaaddin Keykubat University Social and Human Sciences Scientific Research Ethics Committee Decision
Date of ethics review decision: 30.09.2021
Ethics assessment document issue number: 2021/06

Findings

Quantitative Findings

The results of the scale administered to determine the views of pre-service science teachers on Vee diagrams are presented in Table 1.

Table 1. The views of pre-service science teachers on Vee diagrams



When Table 1 is analyzed, the majority of the pre-service teachers, accounting for 45.7% and 34.3% respectively, responded positively to the item "Vee diagrams are a very useful tool for understanding the experimental process as a whole. In this item, 5.7% of them chose the option to disagree. No one chose the option of disagreeing. The highest mean was calculated as 4.2. The mean was 4.14 for the item "Vee diagrams will be very useful for making difficult experiments understandable." The rate of pre-service teachers who expressed positive opinions (strongly agree and agree) in this item was 74.3%, while that of those who expressed disagreement was 8.6%.

In the item "Vee diagrams develop students' ability to question and evaluate events scientifically.", the mean was 4.09. The rate of pre-service teachers who expressed a positive opinion on the item was 74.3%, while those who expressed disagreement was 8.6%.
In the item "Vee diagrams assist us in learning the subject of the experiment in a meaningful way," the mean was 4.09. The percentage of those who expressed a positive opinion in this item was 82.9%, while the percentage of those who disagreed was 14.3%. In the item "Vee diagrams are a necessary tool for laboratories to be a real learning environment.", the mean was 4.06. For this item, 74.2% expressed a positive opinion, while 5.7% disagreed. In the item "Vee diagrams assist us in establishing a meaningful relationship between theoretical knowledge and experimental procedures," the mean was 4.03. In this item, 82.9% of the pre-service teachers selected strongly agree, and agree, while 14.3% selected strongly disagree, and disagree.

The mean of the item "Vee diagrams enabled us to associate the concepts related to the subject of the experiment more easily" was 4.00, and the rate of pre-service teachers who agreed with the statement was 77.2%. In comparison, the rate of those who disagreed with the statement was 5.7%. In the item "Vee diagram implementation is a very enjoyable and interesting practice compared to the classical method," the mean was 3.97. At the same time, the rate of those who agreed was 68.5%, and the rate of those who disagreed was 8.6%. The mean score for the item "Vee diagrams can be a very useful teaching strategy for chemistry laboratories." was calculated as 3.94. While 68.5% agreed with this item, disagreed with it was 11.4%. The mean of the item "Vee diagrams assist us in determining our readiness for the experiment by stimulating our prior knowledge." was 3.91. At the same time, the rate of those who agreed was 68.5%, and the rate of those who disagreed was 14.3%.

"Vee diagram implementations encouraged me to conduct research." The mean was calculated as 3.80. In this item, the rate of pre-service teachers who strongly agreed on options was 71.5%, while the rate of pre-service teachers who strongly disagree was 17.2%. The mean for the item "Vee diagram is a way to get rid of rote learning." was 3.77, while the rate of those who expressed positive opinions was 62.9%, and the rate of those who expressed negative opinions was 17.2%. The mean of the item "Vee diagrams assisted me in realizing and reorganizing my misinformation about the experimental subject" was 3.74. At the same time, the rate of those who agreed was 60%; the rate of those with negative opinions was 14.3%. The mean of the item, "The utilization of Vee diagrams as a laboratory report is more meaningful than classical reports," was calculated as 3.69. In this item, 57.1% of the pre-service teachers selected either strongly agree or agree, while 17.2% selected either strongly disagree or disagree.
"The Vee diagram is a very useful tool that is prepared quite easily"; the mean was 3.66, while the rate of those who expressed positive opinions was 57.2%. The rate of negative opinions expressed was 20%. In the item "It is easier to conduct experiments with the classical method than with the Vee diagram," the mean was calculated as 3.54. The rate of pre-service teachers choosing strongly agree and agree options was 51.4%, while those choosing disagree options was 22.9%. In the item "Preparing a Vee diagram is a very difficult and boring task compared to the classical method," " the mean was calculated as 2.83. The proportion of pre-service teachers who selected strongly agree and agree options for this item was 31.4%, while the proportion of pre-service teachers who selected strongly disagree and disagree options was 40%. The mean of the negative item "Vee diagram implementations caused disappointment" was calculated as 2.94. The proportion of pre-service teachers who selected strongly agree and agree options for this item was 40%, while those who selected strongly disagree and disagree options was also 40%.

Qualitative Findings

The findings obtained as a result of the qualitative data analysis were supported by the statements of the pre-service teachers and shared accordingly.

Findings and Comments on Experiment Report Preference

The frequency distributions of the categories and codes belonging to the theme of experiment report preference are presented in Table 2.

Tablo 2. Frequency distributions related to the theme of experiment report preference

Theme	Category	Code	Frequency
Experiment report preference	Vee diagram format	Instructive	15
		Entertaining	6
		Consolidating	5
		Aesthetic	5
		Seeing the whole	4
		Permanence	4
		Comprehensive	4
		Summarized	3
		Detailed research	2
		Repetitive	2
	Classic experiment format	Easy	4
		Time-saving	3
	Vee diagram ve Classic experiment format	All of them	4
		None of them	1

To determine in which format the pre-service teachers prepared their experiment reports, the question "In which format would you prefer to prepare your experiment reports (Vee diagram–Classical experiment format?)" was asked when examining Table 2. When the answers to this question were analyzed, it was observed that the pre-service teachers expressed different preferences. It was determined that pre-service teachers mostly preferred the Vee diagram format. Most of the pre-service teachers (f=6) stated that they preferred the Vee diagram because it was "instructive." For example, one pre-service teacher (S16) answered, "It is a study format in which I can best explain why and how I prepared the experiment because it establishes a relationship between concepts and is instructive"; another pre-service teacher (S26) stated, "It makes the subjects more explanatory and instructive by doing extensive research on the experiment. After the concept of "instructive", it was observed that the pre-service teachers emphasized that Vee diagrams were mainly (f=4) entertaining, (f=4) effective for viewing the whole, and (f=4) offered permanence. For example, S22 stated that Vee diagrams were "more instructive and entertaining than the classical experiment format," S25 stated that Vee diagrams were "both more entertaining and more effective for learning purposes," and S23 stated that Vee diagrams were "more informative and entertaining.

In the case of "seeing the whole" of Vee diagrams, S35 stated that 'it enables us to learn all the terms related to the subject in detail.' S35 stated that "*it makes it easier to repeat the subjects by thinking about them in their entirety*". The "permanence" of Vee Diagrams was expressed by S30 as "I need additional information while preparing Vee diagrams, and writing by researching becomes more memorable. It presents the subject in a richer form in terms of theoretical, experimental, and visual aspects, and makes it more permanent. Other concepts emphasized by the pre-service teachers in their statements were (f=2) "aesthetics", (f=2) "detailed research" and (f=2) "connection between concepts". For example, the "aesthetics" of Vee diagrams were expressed by S7, one of the pre-service teachers, as follows: "It looks

more beautiful, I enjoy drawing it, and it allows us to explain the experiment better in terms of information, and it prevents us from getting tired. S13, one of the pre-service teachers, stated: "I prefer the Vee diagram because it is more informative and more visually appealing, as it provides versatile learning opportunities.

It was determined that some of the pre-service teachers (f=7) preferred to prepare their laboratory reports in the classical experiment report format because it was easy to prepare (f=4) and did not take a long time (f=3). For example, E6 of the pre-service teachers stated that "*the classical experiment report is easier than the Vee diagram, and we spend less time*." 26 of the pre-service teachers stated that "it is easier to prepare, and makes the subjects more permanent". It was determined that pre-service teachers (f=4) preferred various report formats in preparing an experiment report. For example, S29 of the pre-service teachers stated that "I would prefer to use the classical experiment report when covering the subject in less detail, but if I wanted to reinforce the subject by doing detailed research, I would prefer the Vee diagram format. 36% of the pre-service teachers expressed their opinions as "I would decide according to the content of the subject. S31, one of the pre-service teachers, stated that he would not prefer any of them with the following statement: "*The Vee diagram is too complicated, and the classical experiment format is contrary to my learning style*".

In the interview form, pre-service teachers were asked, "Which experiment report format do you prefer the most? Can you explain why?" The question was directed to the pre-service teachers. When the answers were analyzed, it was found that the pre-service teachers preferred to prepare the Vee diagram format, the classical experiment report format, and both formats. The pre-service teachers who preferred the Vee diagram justified their preference by using expressions indicating that it was enjoyable and visually beautiful to prepare, that it had a good level of comprehensibility, that they did detailed research, and that it enabled them to see the whole subject. The pre-service teachers who preferred the classical experiment report emphasized that it was practical and did not consume much time. The pre-service teachers who preferred to prepare both experiment reports stated that the two should complement each other.

When the preferences of the pre-service teachers are analyzed, findings highlight that Vee diagrams are a learning tool and that detailed research is required for their preparation. The pre-service teachers said they learned the subject with Vee diagrams and emphasized that Vee diagrams facilitated thinking. Reflecting on the idea of facilitating thinking, S10, says, "The Vee diagram gives more detailed and instructive information and has the quality of a book; it facilitates thinking." S8 "The Vee diagram helps us understand the subject more clearly and easily." S33: "I prefer the Vee diagram because it facilitates shaping my students' thoughts." S34 The Vee diagram makes it easier to review the topics by thinking about them in their entirety. Stating that Vee diagrams are a comprehensive tool, S19 explained that, "I think Vee diagrams will be more comprehensive and useful," and S32 said, "Vee diagrams are more comprehensive and instructive. S16 stated their opinions: "I would prefer it because it touches every point of the subject matter and gives us a better view of what we need to pay attention to.

Findings and Comments on the Vee Diagram Preparation Process

The frequency distributions of the categories and codes related to the Vee diagram preparation process—"Preparing every week, doing research while preparing, and having difficulty while preparing"—theme is presented in Table 3.

Table 3. Frequency distributions related to the theme of the Vee diagram preparation process

Theme	Category	Code		Frequency
Vee diagram preparation process	Regular preparation	Yes (Referenced sources)	Internet and experiment sheet	31
			Book	7
			Notebook	2
			Friend	2
			Slide presentation	1
			Previous knowledge	1
		Partially prepared	Absenteeism	3
			Not completely understanding the subject	2
			Lacking of time	1
			Forgetting	1
	Hardship and its cause	I did struggle	Concept mapping	8
			Figure drawing	3
			Excessive time consuming	2
			Disconnection in subject coherence	1
			Paper layout	1
			The distinction between theory and empirical principle	1
			Data transformations	1
			Generating theoretical knowledge	1
		I did not struggle		18

Regarding the process of preparing a Vee diagram, the pre-service teachers were asked, "Did you prepare a Vee diagram every week?". When Table 3 is analyzed, almost all of the pre-service teachers (f=29) stated that they prepared Vee diagrams regularly every week. Some pre-service teachers (f = 7) stated that they could sometimes be prepared. Some of the pre-service teachers (f=3) stated that they could not prepare it because of absenteeism (f=2). They could not fully understand the subject (f=1) due to forgetting and a lack of time. Another question related to this theme was about the sources of research conducted while preparing the Vee diagram. Almost all of the pre-service teachers (f=31), indicating frequency, stated that they benefited from the internet and the experiment sheet. In contrast, two participants stated that they used notebooks and friends, while one participant stated that they used slides and previous knowledge.

The pre-service teachers were asked whether they had difficulty preparing the Vee diagram, and half of the pre-service teachers (f=18) stated that they had difficulty . In contrast, the other half (f=18) stated that they did not have difficulty. The pre-service teachers stated that the most common reason for difficulty (f=8), was creating the concept map within the Vee diagram. One of the pre-service teachers, S17, stated, "I had difficulty in *creating a concept map in the Vee diagram*." Another reason stated for having difficulty by the pre-service teachers (f=3), was drawing shapes. S14 of the pre-service teachers stated, "*I had difficulty in creating the shapes of the experiment in the Vee diagram*," and S14 stated, *"I had difficulty in drawing the shape of the Vee diagram*". Some pre-service teachers stated that the difficulty was due to the activity taking too much time. S33 expressed this, "I did not have difficulty in preparing the Vee diagram, but it was a study that required us to spend a lot of time. Some pre-service teachers stated the reasons for difficulty as '(f=1) disconnection from the coherence of the subject, (f=1) paper layout, (f=1) theory-experimental principle distinction, (f=1) data transformations, (f=1) creating theoretical knowledge'.

Findings and Comments on the Impact of Utilizing the Vee Diagram

The frequency distributions of the categories and codes belonging to the theme "Theory-practice relationship; meaningful learning; learning new information; and eliminating misconceptions" are presented in Table 4.

Table 4. Frequency distributions related to the theme of the impacts of utilizing the Vee diagram

Theme	Category	Code	Frequency
Impacts of utilizing the Vee diagram	Learning	Theory-practice relationship	34
		Elimination of misconceptions	32
		Learning new information	31
		Meaningful learning	27
	Willingness to use it as a teacher	Yes	31
		No	5

The pre-service teachers were asked "In which aspect did utilizing the Vee diagram contribute to your learning?" about the effects of using the Vee diagram with the question, "In which aspect did utilizing the Vee diagram contribute to your learning? When Table 4 is analyzed, pre-service teachers are evaluated using the Vee diagram in laboratory practices in terms of 'theory-practice relationship, elimination of misconceptions, learning new information, and meaningful learning.' The majority of pre-service teachers (f=34) thought that the use of the Vee diagram was a beneficial learning tool for demonstrating the relationship between theory and practice, eliminating misconceptions (f=32), learning new information (f=31), and achieving meaningful learning (f=27).

Another question combined under the same theme, "Are you willing to use Vee diagrams when you become a teacher?," was asked. When the answers of the pre-service teachers were analyzed, it was determined that most of them (f=31) wanted to employ Vee diagrams. Very few pre-service teachers (5) stated they did not want to use it. An important finding is that although half of the pre-service teachers had difficulty preparing Vee diagrams, they wanted to use them while teaching.

Discussion and Results

The Vee diagram was introduced to the literature by Gowin and his students in the 1970s to improve the understanding and structuring of knowledge in the laboratory (Novak & Gowin, 1984). This distinctive teaching tool, which appears in the literature as "Vee heuristic", "Vee diagram", and "Vee map", has been the subject of important scientific studies. This study aimed to reveal pre-service science teachers' views on the use of Vee diagrams, prepared as an experiment report in the laboratory. For this purpose, many of the quantitative and qualitative findings utilized in the study were similar.

In the study, most of the pre-service teachers concentrated on the items expressed as "Vee diagrams are a very useful tool for us to observe the experimental process as a whole," and "Vee diagrams will be very helpful for making difficult-to-understand experiments understandable. From these results, it is evident that Vee diagrams are beneficial for students' learning processes. There are studies in the literature that corroborate these findings. In his study, Roth (1990) reveals that Vee diagrams can be used together with concept maps as an effective tool for students to understand the experiments in laboratories and to change their attitudes towards laboratory courses in a positive way. Roth and Browen (1993) stated that Vee diagrams help in organizing information, researching, and learning. Nakiboğlu and Meriç (2000) revealed "Reports prepared with Vee diagrams will enable students to learn the experiment very well. In Afamasaga-Fuata'i's (2004) study that concept maps and Vee diagrams effectively facilitated students' understanding and learning processes. Calais (2009) reported that Vee diagrams as a pedagogical technique greatly benefit students in understanding and transferring

knowledge. In addition, Çelikler, Güneş, Güneş and Şendil (2008) reported that "Vee diagrams make complex experiments more understandable". Thoron and Myers (2010) determined that learning was more productive in classes where Vee maps were employed than in classes where traditional experiment reports were employed. Ameyaw and Kyere (2019) found that using Vee maps in biology lessons provided students with a better understanding of the subject and explained that this was because the concepts in the Vee maps were based on concept maps. James and Yunana (2020) stated that Vee maps enhance students' learning performance in analytical chemistry teaching because they are a formative medium that guides students through the processes they will undergo in their scientific reasoning. Kusumawati and Lesmono (2020) reported that Vee maps included in students' worksheets facilitated their learning processes. Mohammed and Shraikh (2020) stated that the Vee-shaped diagram can be useful for cognitive development in students to enhance learning. Mohammed and Samuel (2021) reported that Vee maps had a very favorable effect on students' learning of genetics. Thamarasseri (2022) stated that Vee maps are a means of supporting the higher-order thinking skills of students and facilitating learning.

In the study, the majority of pre-service teachers supported the item "Vee diagrams support us to establish a meaningful relationship between theoretical knowledge and experimental procedures" from the quantitative findings. They expressed this agreement through the qualitative findings as "A Vee diagram is a useful tool in determining the relationship between theory and practice" . Studies similar to those described here were encountered in the literature. Novak and Gowin (1984) argued that the Vee diagram can make laboratory reports more understandable and useful by enabling students to establish a relationship between theoretical knowledge and laboratory work. Nakhleh (1994) investigated various methods to examine how learning occurs in the laboratory and stated that the Vee diagram is an effective tool that enables students to make connections between what they learn in lectures and laboratory practices. Knaggs and Schneider (2012) stated that tools such as Vee maps can encourage students to make connections with science. Olivares, Merino, and Quiroz (2014) reported that Gowin's heuristic Vee could assist students in systematizing knowledge and acquiring different perspectives in laboratory work. Gencer (2014) characterized Vee diagrams as a metacognitive tool that helps students learn the nature and structure of knowledge. Handayani (2020) stated that implementing the Vee diagram helps students comprehend the experiment better because the conceptual and methodological parts guide each other. Olalere and Chado (2021) reported that Vee maps positively impact teaching organic chemistry to students, because they encourage the interaction between the conceptual and methodological parts. Handayani, Hindriana, Widiantie, Lismaya, and Satianugraha (2022) reported that Vee diagrams improved students' science process skills and contributed significantly to designing experiments.

In the study, the majority of the pre-service teachers supported the item "Vee diagrams facilitate meaningful learning of the experiment subject" from the quantitative findings through qualitative findings, stating that "Vee diagram is a helpful tool in providing meaningful learning .", It has been stated in the literature that using Vee diagrams in science education is one of the tools that facilitate meaningful learning (Novak, 1990; Novak, 1998; Passmore, 1998). Tamir (1989) emphasized the importance of using learning tools such as Vee diagrams and concept maps so that science teachers can use the laboratory as a place where meaningful learning occurs. Nakhleh (1994) argued that tools such as Vee diagrams and concept maps should be utilized to ensure "meaningful learning" in general chemistry laboratory courses. In his study, Passmore (1998) observed that meaningful learning occurred in students utilizing Vee diagrams and concept maps because they examined the conceptual, relational, and hierarchical structure of the subject they studied. Nakiboğlu, Benlikaya, and Karakoç (2001) emphasized in their study that the Vee diagram is effective in realizing meaningful learning in chemistry laboratory courses. Novak (2010) emphasized that in scientific research, Vee diagrams serve as a road map showing where students are in the process and how they should proceed, while for teachers, they serve as a graphical guide that helps the research process turn into a meaningful learning environment. In his study, Demirtaş (2006) stated that Vee diagrams "facilitate students in connecting theory and practice, are an efficient tool in providing a real learning environment and are effective in learning the experimental subject in a meaningful way". Safdar, Hussain, Shah, and Tasnim (2013) stated that

concept maps and Vee diagrams in physics laboratories contribute to improving students' performance and making learning more meaningful. Hindriana (2020) stated that Vee diagram-based experiment worksheets developed in laboratory activities contributed positively to students' meaningful learning.

In the study, some of the pre-service teachers supported the quantitative finding, "Vee diagrams enabled us to associate the concepts related to the subject of the experiment more easily", by expressing a similar perspective in the qualitative findings. They described it as "a study format in which I can best explain why and in which ways I prepared the experiment because it establishes a relationship between concepts and is instructive." Some studies in the literature have similar results. For example, in their study on molecular concepts, Ault (1984) observed a significant improvement in some children's conceptions of molecules due to employing the Vee diagram in interviews. In their research on energy concepts, Ault et al. (1988) reported that students' construction of Vee diagrams helped them to learn the concepts. Okebukola (1992) stated that teachers perceived concept maps and Vee diagrams as effective cognitive tools that facilitate concept teaching. Al-Zaanen (2010) reported a significant difference in concept teaching in the student group working with Vee diagrams. Tekeş (2011) reported that students learned better the relationships between concepts through Vee diagrams. Ayvacı and Akbulut (2012) stated that the Vee diagram contributed to conceptual learning in the cognitive domain. Polancos (2013) emphasized that Vee diagrams and concept maps are significant teaching instruments in learning chemistry concepts and making connections between concepts. Mutai (2015) reported that Gowin's Vee heuristic strategy significantly improved students' conceptual understanding and contributed significantly to the higher-order cognitive development of students who used this strategy. Yerima, Mu'azu, and Hamidu (2017) reported that Vee maps had a favorable effect on students' learning of concepts. Kurniasih and Irpan (2019) stated that implementing the Vee diagram in biology teaching effectively provides students with conceptual comprehension. Fitakurahmah, Sambodo, Karyanto, Astorini, and Oetomo (2020) stated that the Vee-supported E-module is a beneficial tool for students to learn concepts. Kipkazi (2022) emphasized that Gowin's Vee teaching strategy is effective for student concept learning and easier to employ than traditional methods.

In the study, some of the pre-service teachers supported the item "Vee diagram practices encouraged me to do research" from the quantitative findings by expressing it as "Vee diagram makes the subjects more explanatory and instructive by doing extensive research on the experiment" from the qualitative findings. In the literature, Roth and Roychoudhury (1993) stated that utilizing Vee diagrams and concept maps facilitated the structuring of knowledge. Roth and Verechaka (1993) state that the Vee diagram illustrates the path to be traced in reaching new knowledge from previous knowledge. Roth and Bowen (1993) stated that Vee diagrams can help students understand the research process. Leibowitz (1998) demonstrated that the Vee diagram encourages students to think and learn more effectively compared to the traditional laboratory approach. Nakiboğlu and Meriç (2000) observed that the Vee diagram encouraged students to research during pre-laboratory preparation. Luft, Tollefson, and Roehrig (2001) reported that students using the Vee diagram were more successful in organizing the experiment, generalizing, and in their thinking and learning processes. Åhlberg, Äänismaa and Dillon (2005) observed that using concept maps and Vee diagrams effectively advanced pre-service teachers' thinking and professional development. Evren, Bati, and Yilmaz (2012) stated that there was a significant difference in the self-confidence dimension of pre-service teachers who used Vee diagrams compared to pre-service teachers who did not. Thoron and Rubenstein (2013) suggested that Vee maps are a useful instrument in developing students' higher-order thinking skills that Vee diagrams should be used. Suprapto (2017) reported that Vee diagrams positively affect students' reasoning and judgment. Musa, Ozoji, and Duru (2018) suggested using Vee maps to improve the thinking capacities of students in basic sciences.

In the study, most of the pre-service teachers supported the quantitative finding that "Vee diagram implementation is a very entertaining and interesting practice compared to the classical method." They expressed this sentiment in the qualitative findings, stating, "Vee diagrams are more instructive, entertaining, and more comprehensive in terms of addressing the subject in its entirety compared to the classical method." These findings may indicate that it is easier and more entertaining for students to

use Vee diagrams in the laboratory, than using the classical method. In Tekeş's (2011) study, it was determined that the students mostly answered "Yes" to the items "I enjoyed working with the Vee diagram,", "The classical experiment reports you used before did not contribute as much as Vee diagrams in understanding and learning the subject of the experiment," and "It would be much better to use Vee diagrams instead of classical experiment reports in laboratories. Doğru, Selvi, Köklükaya, and Güven Yıldırım (2015) stated that the positive aspects of Vee diagrams for pre-service teachers are that they are practical and visual, enabling research, facilitating understanding, and are organized. Kayacan (2018) stated that most pre-service teachers expressed positive opinions about preparing Vee diagrams. The most frequently mentioned feature was that it was easier to prepare than a classical experiment report. In Kırılmazkaya and Zengin's (2016) study, it was determined that the majority of the students preferred the Vee diagram to the question "Can you compare the Vee diagrams with the experiment reports you prepared before? Which one would you prefer to use when you become a teacher ?" Kayacan (2018) stated that the majority of pre-service teachers expressed positive opinions about preparing Vee diagrams, and the most frequently mentioned feature was that it was easier than a classical experiment report.

In the study, some of the pre-service teachers supported the item "Vee diagram is a very beneficial tool that is prepared quite easily" from the quantitative findings with statements indicating that they prefer Vee diagrams "in terms of visuality, better understanding of the subject and ensuring the integrity of the subject" from the qualitative findings. Most pre-service teachers stated that they did not have hardship while constructing Vee diagrams. In his study, Günaydın (2019) stated that the students did not have difficulty transferring the data to the graph in the interviews and that they could easily create the data transformations part. Çınkı (2007) reported that students stated that they did not encounter any problems creating Vee diagrams and improved their experimental observation and explanation skills. In Tekeş's (2011) study, some students stated that they had difficulty in creating Vee diagrams at firs. Still, they eliminated this problem with the Vee diagram exercises before the implementation. In Okebukalo's (1992) study, science teachers stated that Vee diagrams were easy to comprehend.

The item "Preparing a Vee diagram is a challenging and boring task compared to the classical method," was the most undecided item among the quantitative findings regarding the thoughts of pre-service science teachers about Vee diagrams. This was supported by the qualitative findings, which revealed that they preferred the traditional experiment format because the preparation of the Vee diagram is more difficult and time-consuming. These findings may indicate that students considered the Vee diagram very useful or thought it took a long time to develop. Keleş and Özsoy (2009) stated that most pre-service teachers expressed positive opinions about Vee diagrams. Still, some pre-service teachers stated that preparing Vee diagrams was challenging and time-consuming. In Kırılmazkaya and Zengin's (2016) study, some of the students stated that preparing a Vee diagram was time-consuming and difficult, that they did not have difficulty in the "theory-principles" part, but making a general inference from the data in the "results-claims" part was challenging.

In this study, it was observed that Vee diagrams were more effective than classical experiment reports in terms of observing the connections between theory and practice. They made students aware of the ways of obtaining information by participating in the scientific research process and encouraged students to engage in meaningful learning. It was reported that utilizing Vee diagrams as reports in laboratories is not very widespread (Morgil, Seçken & Karaçuha, 2005). It is believed that this study will benefit researchers, teachers, and students, and will encourage the implementation of learning instruments such as Vee diagrams and concept maps that promote meaningful learning in science laboratories.

As a result of the study, having the experiment reports, which are an important part of the laboratory course, prepared in Vee diagram format is a very valuable practice for pre-service teachers. The pre-service science teachers stated that they would teach, and have this method applied by their students when they become teachers.

Limitations and Recommendation

Considering the limited number of studies prepared with Vee diagrams in Turkey, such studies should be expanded and diversified, especially from the primary school to the university level. This technique should be introduced to prospective teachers in departments such as physics, chemistry, and biology, not only in faculties of education but also in faculties of science and literature. Since there are insufficient studies on Vee diagrams in Turkey, especially at the primary education level, teachers should be provided with extensive information through in-service training programs and be enabled to use it in their lessons. The use of laboratory applications supported by Vee diagrams should be widespread as they encourage students to conduct research and provide meaningful learning. Today, the importance of innovative educational orientations is increasing day by day. Using such innovative educational practices in laboratory courses will surely contribute to training more qualified teachers.

Implications

This study is a descriptive study, and its evaluation was done using descriptive and content analysis methods. Future studies will be conducted on experimental and control groups. The study was conducted at the university level. It can also be conducted at primary, secondary and high school levels. This studywas conducted in the field of science education and can be repeated in different fields.

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