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Original Research Article

Measuring meaningful learning through the experience of chemistry education students' in the basics of analytical chemistry practicum

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ABSTRACT

Chemistry Education students often engage in laboratory practicums to develop scientific process skills and enhance the meaning of chemistry learning, as seen in the course basic analytical chemistry. Previous research indicates that the basics of analytical chemistry practicum frequently focus solely on confirming basic knowledge, thus only leading to an improvement in basic experimental skills. This study aims to measure the level of meaningful learning achieved through the experiences of chemistry education students in in the basics of analytical chemistry practicum as evidence to improve the practicum curriculum in order to create more meaningful learning. The research method involves both quantitative and qualitative descriptive approaches, with quantitative data collected using the Meaningful Learning in the Laboratory Instrument (MLLI), which has been modified to measure students' affective and cognitive experiences after learning in the chemistry laboratory. The study involved 60 third semester students who had completed the basics of analytical chemistry practicum course. The results indicate that all aspects were rated as good, with percentage scores of 67% for affective aspects, 74% for cognitive aspects, and 69% for affective-cognitive aspects, yielding an overall average percentage score of 70%. These findings suggest that chemistry education students have achieved significant meaningful learning through their experiences in the basics of analytical chemistry practicum.

Introduction

One field of science that has an important role in human life is chemistry (Baunsele et al., 2020). Chemistry is a branch of science that studies in detail various aspects of matter, including its properties which include physical and chemical properties, molecular structure and particle arrangement, changes that occur in matter through chemical reactions, and the energy involved in these processes (Artini and Wijaya, 2020). Chemistry involves a deep understanding of seemingly simple everyday processes, such as phase changes when boiling water, chemical reactions in making drinks, and various other phenomena (Junaidi et al., 2017; Melati and Hadinugrahaningsih, 2024).

As prospective educators, chemistry education students must have a good understanding of chemistry (Sumanik et al., 2021). One method that can help chemistry education students improve their understanding of chemistry is practicum (Hamidah et al., 2014). Practical activities are a very effective means of developing science process skills and increasing student interest and making chemistry learning more meaningful (Nugraha et al., 2021; Anggraeni and Moersilah, 2024). This is necessary in order to fulfill teacher competencies which include teaching chemical concepts clearly, facilitating practicums, and teaching strategies for handling environmental impacts resulting from human activities (Alhayat et al., 2022).

One of the courses that carries out practicum activities in the Tanjungpura University Chemistry Education Study Program is the basics of analytical chemistry. This course is very important in measuring students' science process skills through experiments that support the development of these skills (Murlia et al., 2020). However in the implementation process, it was found that when carrying out activities in the laboratory, the basics of analytical Chemistry practicum only

focused on verifying knowledge, so that the results only improved basic skills in conducting experiments (Pursitasari and Permanasari, 2012). The expected increase in understanding of concepts has not yet been achieved in the core curriculum in the basics of analytical chemistry practicum course (Haryani et al., 2010).

The results of interviews conducted at the beginning of June 2023 with six chemistry education students from the class of 2021 who had carried out the practicum activities on the basics of analytical chemistry revealed that they also had similar experiences. While undergoing this practicum, students faced difficulties in assembling the equipment correctly, especially in titration experiments. Lack of in-depth understanding of the basic concepts of analytical chemistry is also the main factor causing the difficulties they experience. This shows that students have not achieved meaningful learning, but instead only rely on rote learning, so that their understanding is temporary and easily forgotten (Basyir et al., 2020; Hutahaean et al., 2024).

Identifying the challenges faced by students in the basics of analytical chemistry practicum requires the introduction of learning strategies that can encourage meaningful learning. Thus this will help students link relevant concepts in their cognitive structure, so that they can gradually help strengthen their understanding and abilities in the basics of analytical chemistry concepts (Najib and Elhefni, 2016; Amirudin and Widiati, 2017). Through meaningful learning, even though some information is forgotten, the knowledge structure formed still helps students understand similar concepts that they will learn later (Iwani, 2022; Pardiana, 2024).

Therefore to measure meaningful learning in practical activities in the chemistry laboratory, the Meaningful Learning in the Laboratory Instrument (MLLI) developed by (Galloway and Bretz, 2015a) modified to suit the practical context of the basics of analytical chemistry to be studied. The MLLI was designed to be a tool that can be used to evaluate evidence of meaningful learning at the undergraduate level in the chemistry laboratory context. With a clear approach to operationalizing learning theory, MLLI is the first instrument to specifically evaluate the learning process in chemistry laboratories (Galloway and Bretz, 2015a).

Although laboratory activities are emphasized to teach direct skills and the proper and correct use of tools, there is no clear evidence-based information regarding how and how important laboratory activities are for students (Galloway and Bretz, 2015a; Galloway and Bretz, 2015b). So far the practicum has been more oriented towards developing the psychomotor domain (Talino et al., 2022; Rakhmalinda et al., 2024). Meanwhile aspects such as cognitive processes, the role of the affective domain and the integration of affective, cognitive and psychomotor learning to provide meaningful learning experiences for students are rarely paid attention to (Galloway and Bretz, 2015b). If laboratories are considered to provide the unique learning experiences that many people consider them to be, then research evidence is needed to show the extent to which students gain meaningful learning from these laboratory activities (Galloway and Bretz, 2015a).

This research specifically aims to measure the level of meaningful learning achieved through the experiences of chemistry education students in in the basics of analytical chemistry practicum as evidence to improve the practicum curriculum in order to create more meaningful learning. Through analysis of students' direct experiences during practicums, this research will explore the extent to which this learning can contribute to students' understanding of the basic concepts of analytical chemistry and the development of students' practical skills. Thus it is hoped that this research will provide a more comprehensive insight into the role of the chemistry laboratory in the learning process, as well as show the extent to which the practicum can provide a meaningful learning experience for students.

Methods

Sample

The number of sample studied consisted of 60 students from the chemistry education study program, semester 3 class of 2022 academic year 2023/2024 at the Faculty of Teacher Training and Education Tanjungpura University. Sample were divided into two classes, namely class A1 which consisted of 31 students and class A2 which consisted of 29 students. All sample who took part in this research had taken practicum courses the basics analytical chemistry.

General Procedure

Data collection in this research was carried out in two ways, namely using measurement techniques Meaningful Learning in the Laboratory Instrument (MLLI) for quantitative data and interviews for qualitative data. The MLLI given this study aims to measure the level of meaningful learning achieved through the experiences of chemistry education students in in the basics of analytical chemistry practicum. The MLLI used in the research was prepared by (Galloway and Bretz, 2015a) with slight modifications to each statement to suit the practical context the basics analytical chemistry. MLLI consists of 30 statements, including 8 items focusing on affective aspects, 16 items on cognitive aspects, and 6 items covering both aspects, with 16 items being positive and 14 items being negative. The reliability coefficients used in this MLLI instrument are Cronbach's α and Ferguson's δ as presented in Table 1.

Table 1. Reliability coefficients of the MLLI instrument

No	Aspect	Cronbach's α	Ferguson's δ
1	Affective	0.80	0.98
2	Cognitive	0.78	0.97
3	Affective-Cognitive	0.62	0.98

Cronbach's α measures the internal reliability or the consistency of students' responses to the test items. An α value greater than 0.7 was found on the affective and cognitive scales indicating good reliability, while the affective-cognitive scale had an α value of less than 0.7 indicating lower consistency. Ferguson's δ which measures the test's ability to differentiate

student responses, showed an excellent value exceeding 0.96 meaning that the instrument effectively distinguishes between students' expectations and experiences. In this study, the MLLI was translated and validated by two language experts who are English lecturers and one lecturer from FMIPA Tanjungpura university with expertise in chemistry, to ensure the language's alignment with the research context. The validation results from the three validators confirmed that the previously modified MLLI was valid and suitable for data collection.

The second data collection technique used in this research was interviews. The interviews aimed to gather more in-depth information regarding the meaningful learning experiences of chemistry education students in in the basics of analytical chemistry practicum course. A total of 12 chemistry education students were selected based on their previous practicum report scores in the Non-Metal Element Chemistry practicum. The students were grouped into three categories high, medium, and low report scores, with each category represented by 4 students selected randomly. The purpose of this categorization was to identify and differentiate students' perceptions from each category regarding the implementation of in the basics of analytical chemistry practicum. In addition, interviews were also conducted with 8 laboratory assistants, 1 laboratory head, and 2 lecturers in charge. Each group of respondents was asked to provide responses to five prepared interview questions, with the expectation of obtaining a more comprehensive understanding of the practicum's effectiveness and quality from the perspectives of both students and teaching staff as well as laboratory management. The interview questions were validated by two lecturers from the chemistry education study Program at Tanjungpura University. The validators evaluated each interview question and selected those deemed most relevant, representative, and effective for each group of respondents. The validation results from both validators indicated that the interview questions were deemed suitable for research after revisions were made based on the suggestions provided by the validators.

Data Analysis

The MLLI data were then analyzed using a 5 category Likert scale (Strongly Disagree = 1, Disagree = 2, Neutral = 3, Agree = 4 and Strongly Agree = 5). Next, the score data is converted into percentages using the following formula:

$$Value = \frac{Score\ Obtained}{Maximum\ Score} \text{ x } 100\%$$

The percentage values obtained are then categorized according to the interpretation criteria as shown in Table 2.

Table 2. Interpretation criteria

Persentase (%)	Kategori
≤25	Not good
26 – 50	Enough
51 – 75	Good
76 – 100	Very good

Table 2 shows the criteria for interpreting students' meaningful learning which is divided into 4 categories, namely poor, fair, good and very good. Based on this table, meaningful learning as measured by students' experience in in the Basics of Analytical Chemistry practicum can be achieved if it is categorized as good or very good with a minimum percentage range of 51% and a maximum of 100%.

Results and Discussion

This research data was obtained through MLLI results and interviews. Every student who fills out the MLLI will be grouped based on a certain percentage range in each aspect. Statements in the MLLI are grouped based on their aspects, namely affective, cognitive, and affective-cognitive which is then calculated using a previously established formula. The percentages for each aspect are grouped by range and category, as presented in Table 3.

Table 3. Proportion of students in all aspects

Percentage Range (%)	Affective		Cognitive		Affective-Cognitive		Category
	Class A1	Class A2	Class A1	Class A2	Class A1	Class A2	
≤25	-	-	-	-	-	-	Not good
26 – 50	-	-	1	-	1	-	Enough
51 – 75	27	27	24	22	24	22	Good
76 – 100	4	2	6	7	6	7	Very good

Based on data from Table 3, the 60 students in this study were classified into four categories, namely not good, enough, good and very good based on the percentage range for each aspect. These students are divided into two classes, namely classes A1 and A2. In the affective aspect, not a single student from class A1 or A2 was included in the poor or good enough category. The good category is the dominant category in the affective aspect seen from the number of students who fall into that category. In the affective aspect, there are 4 students from class A1 and 2 students from class A2 who are in the very good category. This shows that classes A1 and A2, on average, are included in the good category in the affective aspect. In the cognitive aspect, there are no students who are included in the poor category. However, there was 1 student from class A1 who obtained a percentage score below 50% so that he was in the adequate category in the cognitive aspect. The good category dominates the cognitive aspect, seen from the number of students who fall within that percentage range. The final

aspect, namely affective-cognitive, has results and categories that are similar to the cognitive aspect, with the good category dominating. There was 1 student from class A1 who obtained a percentage score below 50% so it was included in the sufficient category.

Further analysis was carried out to identify the comparison of the percentage values for each aspect between classes A1 and A2. Data from the comparison of the percentage values for all these aspects are presented in Table 4.

Table 4. Comparison of percentages of all aspects

Class	Aspect Type			Average (%)	Category
	Affective (%)	Cognitive (%)	Affective-Cognitive (%)		
A1	68	74	68	70	Good
A2	66	75	69	70	Good

Table 4 shows a comparison of the percentage of overall aspects between classes A1 and A2. From this table it can be seen that the affective aspect of class A1 has a higher percentage value, namely 68% in the good category compared to class A2 with a percentage value of 66% in the good category. However even though the percentage score for class A2 is lower in the affective aspect, in the cognitive aspect the percentage score for students in class A2 looks higher, namely 75% in the good category than in class A1 with a percentage score of 74% in the good category although the difference is not significant. Likewise in the affective-cognitive aspect class A2 shows a higher percentage value, namely 69% in the good category than class A1 with a percentage value of 68% in the good category. Even though there are differences in the percentage scores for each aspect both classes A1 and A2 have the same average percentage score, namely 70% in the good category. Comparison of percentage scoreson the affective aspect is presented in Fig-1, comparison of percentage scores on the cognitive aspect is presented in Fig-2, and comparison of percentage scores on the affective-cognitive aspect is presented in Fig-3.

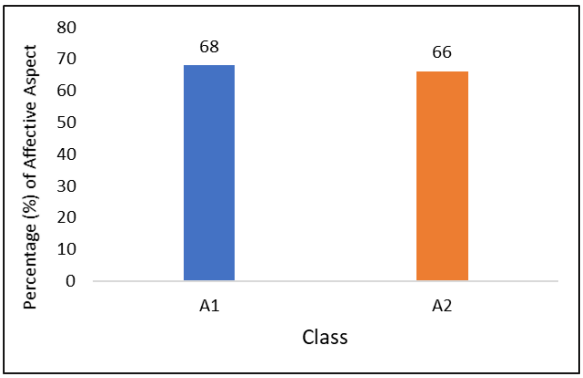

Fig-1. Comparison of percentage scores on the affective aspect for students in classes A1 and A2 (NA1= 31) (NA2= 29)

Fig-1 displays a comparison diagram of percentage scores for affective aspects students in classes A1 and A2. From the results of the image analysis, it can be seen that class A1 obtained a percentage score of 68% in the good category for the affective aspect, while class A2 obtained a percentage score of 66% in the good category. This difference shows that overall, class A1 students show slightly better achievements in the affective aspect compared to their peers in class A2. However the percentage difference is not significant, which means that there is almost no difference in quality between the two classes in the affective aspect. This is because in the affective aspect both classes A1 and A2 receive similar attention in developing the affective aspect, which leads to comparable performance between the two.

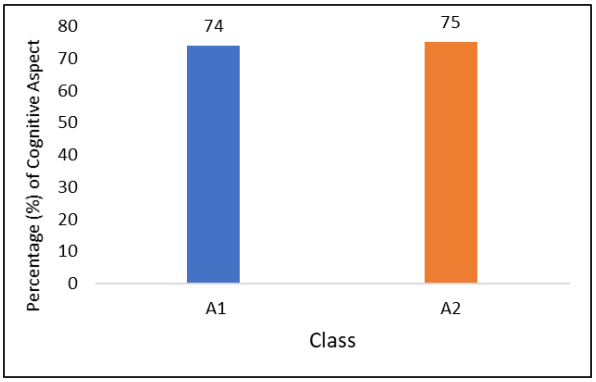

Fig-2. Comparison of percentage scores on the cognitive aspect for students in classes A1 and A2 (NA1= 31) (NA2= 29)

Then the results of interviews conducted with lecturers and laboratory assistants in the practicum the Basics Analytical Chemistry shows that the practicum process supports increased meaningful learning in the affective aspect. This can be seen from the implementation of the rolling system during team work in practicum implementation. The rolling system in practicum team work allows group members to take turns in various positions every week. This can increase student

involvement and responsibility in learning in the laboratory. This system aims to optimize the use of tools and materials used in practical activities by giving students the opportunity to change positions. In this way, students can experience a more varied and useful learning experience from a variety of different assignments (Rizqiyana et al., 2023). Apart from that, the laboratory assistant also explained that the practical group was in the practicum the basics analytical chemistry is divided into small groups, with each group consisting of 4-5 practitioners and one laboratory assistant whose job is to supervise. With this rolling system and small group divisions, practitioners can carry out experiments optimally. Practitioners have the opportunity to understand the practicum process, get to know the equipment used, and how to use it better. This happens because the practitioner is involved in a small scope and experiences various positions during the practicum the Basics analytical chemistry. This is in line with research (Marom and Kurniawan, 2022) which states that practical learning with a rolling system can improve student learning outcomes. The research reported that of the 35 students involved, all managed to achieve an average score above the passing limit or could be said to have passed.

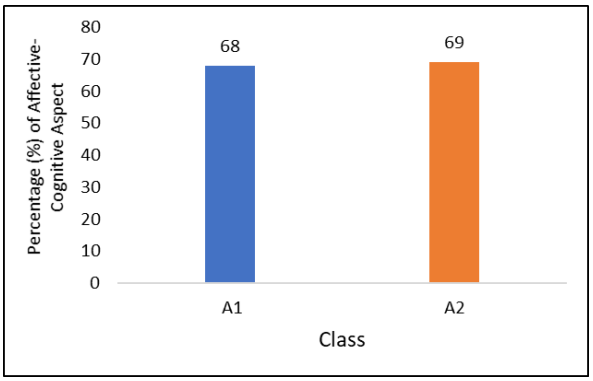

Fig-3. Comparison of percentage scores on the affective-cognitive aspect for students in classes A1 and A2 (NA1= 31) (NA2= 29)

In the cognitive aspect seen in Fig-2, it shows that the percentage scores in class A1 was 74% in the good category and class A2 obtained a percentage value of 75% in the good category. This shows that in general both classes have achieved a good category in the cognitive aspect. However a difference of one percentage between the two classes is not significant, it is possible that this difference may reflect the learning patterns of each individual in class A2 or the emphasis of certain concepts that are more successful in one class than the other. In this context, the learning emphasis and strategies applied by students in class A2 may be more effective in supporting conceptual understanding and cognitive achievement compared to students in class A1. Effective learning behavior has an important role in improving individual abilities in accordance with the desired goals. There are three learning motivation factors that significantly influence student learning achievement namely learning methods, learning strategies, and the level of independence in the learning process so that they will provide maximum learning results (Yulianti and Fitri, 2017).

The results of interviews with lecturers, laboratory assistants and students showed that the percentage scores were high in the cognitive aspect of the practicum the basics analytical chemistry is due to conformity with the concepts that have been taught in class. The lecturer explained that the concepts taught in class were applied directly in the practicum the basics analytical chemistry, such as the use of tools and materials in accordance with theoretical explanations. This opinion was also supported by students who stated that practicum the basics analytical chemistry is closely related to the material taught in previous classes by the lecturer. This gives students a good understanding and becomes a provision before they are involved in practical activities in the laboratory. Furthermore, in carrying out the practicum, students have achieved the practicum objectives the basics analytical chemistry develops practical skills, such as reacting solutions and carrying out titrations, although some students still need further guidance. However, overall the majority of practitioners have been able to achieve the practicum objectives the basics analytical chemistry, as presented by a laboratory assistant in an interview.

The results of the assessment of the affective-cognitive aspect in Fig-3 show that the percentage scores obtained from class A1 was 68% with a good assessment category. Meanwhile for class A2 the percentage value is 69%, also in the good category. This indicates that overall both classes show similar achievements in the affective-cognitive aspect. Based on the results of interviews with laboratory heads, every practicum carried out in the laboratory trains students in affective and cognitive aspects not just psychomotor. In the affective aspect practitioners are involved in discussions to ensure experiments or activities are completed on time, communicate with fellow practitioners, design work schemes, and interact with friends in their group. From a cognitive perspective, at the end of each semester practitioners complete an evaluation in the form of a written exam and a practical exam. This is done to evaluate students' understanding of the practicum that has been carried out and their ability to use the tools properly and correctly. With this students can improve their understanding of the concepts that have been taught. Students are not only skilled in psychomotor aspects but can also develop their attitudes and knowledge in the context of practical work in the laboratory.

Furthermore, analysis to measure the meaningful learning obtained by students is carried out thoroughly. Data on the percentage values of the overall affective, cognitive and affective-cognitive aspects are presented in Fig-4. The diagram in the image above displays the percentage scores for all aspects, namely affective, cognitive and affective-cognitive aspects which will be indicators for evaluating the extent of students' meaningful learning through their experiences after completing the practicum the Basics Analytical Chemistry. In the diagram above, it can be seen that the affective aspect which reflects emotional responses and attitudes towards learning material received a percentage score of 67% in the good category. This shows that students show positive engagement and good attitudes towards learning in the laboratory. Meanwhile the cognitive aspect measures understanding and application of concepts the Basics Analytical Chemistry obtained a percentage score of 74% in the good category. This shows that students have been able to understand the subject matter well and apply

it in the practical context in the laboratory. Then in the affective-cognitive aspect which combines the two previous aspects, the percentage result was 69% in the good category. This shows that students not only have a strong understanding of the material but also show a positive emotional response to the learning. With this the average score obtained in all aspects is 70% in the good category.

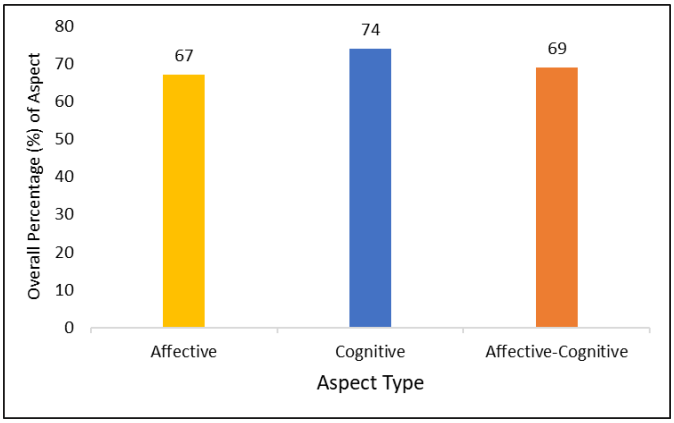

Fig-4. The overall percentage scores for the affective, cognitive, and affective-cognitive aspects (NA1 and NA2= 60)

Judging from these three aspects, the cognitive aspect is the aspect that has the highest percentage value, namely 74% in the good category. The cognitive aspect dominates with the highest percentage because there is a statement in the MLLI which emphasizes that laboratory experience can increase students' understanding so that many students feel this statement is relevant. Previous research, as presented by Ning and Downing (2012) that learning experiences can influence self-regulation and motivation in students' academic performance. On the other hand, the affective aspect received the lowest percentage score because several statements on the MLLI expressed students' anxiety when doing laboratory practicums.

Affective aspects, which include individual attitudes, behavior, emotions and values, are very relevant in the context of laboratory learning (Ulfah and Arifudin, 2021). Hidayatullah (2020) emphasizes that the affective aspect is closely related to attitudes and values. In this study, the affective aspect recorded the lowest percentage value because based on the results of interviews with students, many of them expressed feelings of anxiety when undergoing practicum the Basics Analytical Chemistry. Students also emphasized that tools used in practicum the Basics Analytical chemistry is very varied and has high prices, which raises concerns for students when using it. Apart from that, anxiety also arises when students complete practicum reports because they are worried that they will not be able to complete them on time and are afraid that the results will not match their expectations.

Bretz et al. (2013) states that the cognitive domain is often the main focus, and the affective domain is often ignored in practicum activities. Lack of attention to these affective aspects hinders the achievement of meaningful learning in the laboratory. In planning laboratory curricula, chemists tend to pay more attention to what students will do than how they will engage emotionally and mentally in the learning process (Sevian and Fulmer, 2012). The affective domain in laboratory curricula is often limited to group work and its relevance to the real world (Bretz et al., 2013). Therefore, it is necessary to emphasize the importance of paying attention to the affective dimension in laboratory learning, remembering that learning is not only about cognitive exercises. Learning requires integration between actions (psychomotor) and feelings (affective) with thinking (cognitive) so that meaningful learning occurs (Novak, 2010).

Thus, based on the diagram in Figure 4, it can be concluded that students from the Chemistry Education Study Program have taken part in the practicum the Basics Analytical Chemistry in the 2023/2024 academic year shows a meaningful learning process in the good category. This is reflected in their experience after participating in the practicum which is measured through Meaningful Learning in the Laboratory Instrument (MLLI) (Galloway and Bretz, 2015a). This finding is in line with research conducted by (Apriani et al., 2020) which found that the majority of students experienced positive learning experiences after participating in practicum activities, as reflected in aspects of the student learning experience. However, the research results reported by (Galloway and Bretz, 2015c) shows a difference in that students have high cognitive expectations for chemistry laboratory courses, but their practicum experiences do not always match these expectations.

Factors that support student experiences to be more meaningful according to Syahreni and Waluyanti (2007) is when students have been given clear directions, received appropriate feedback on the activities they carry out, and demonstrated good attitudes, appearance and submission of reports during the learning process. This finding is in line with the results of interviews conducted with lecturers and laboratory assistants which showed that before carrying out practical activities, lecturers and laboratory assistants gave detailed directions to students and interacted with them through questions regarding the experiments to be carried out, resulting in an exchange of information and effective feedback.

Muthathi et al. (2017) adding that other factors that can support a good learning experience are the preparation stage, demonstration techniques, and optimizing study groups. This implementation is also carried out in practicum the Basics Analytical Chemistry. One of the strategies used is to form small groups with 4-5 members who are monitored by laboratory assistants so that each group can be more optimal in carrying out the practicum. This finding is consistent with the results of interviews with laboratory assistants, which indicate that this strategy has been an important part of ensuring a meaningful learning experience for students.

Crookes et al. (2013) revealed that the meaningfulness of learning occurs when the information or knowledge obtained by students is relevant to the competency framework and learning objectives. Meaningful learning is reflected in students' understanding of the learning context and their understanding of the reasons why certain material must be studied. Effective

laboratory learning shows clarity of purpose, positive feedback from the teacher, deep understanding of the learning material, as well as awareness of the goals and distribution of learning objectives (Jeppesen et al., 2017). Thus, meaningful learning experiences can be generated when students feel connected to the learning material and the material is relevant to their academic and professional goals.

Conclusion

The research results show that the 2021 cohort of Chemistry Education students achieved meaningful learning in the good category in the Basics of Analytical Chemistry practicum, with a cognitive aspect percentage of 74%, an affective-cognitive aspect percentage of 69%, and an affective aspect percentage of 67%. These findings emphasize that meaningful learning in the laboratory is not solely dependent on cognitive understanding but also on how students respond emotionally and connect their learning to their academic and professional goals. This research can also serve as an evaluation for educators to pay more attention to the integration of cognitive and affective aspects in laboratory learning. Therefore, special attention to the affective aspect needs to be enhanced in the laboratory learning process to improve the overall quality of students' learning experiences and create more meaningful and relevant learning for their academic and professional development.

Conflict of Interests

The author declares that there is no conflict of interest in this research and manuscript.

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