Profile of Chemistry Students' Laboratory Activities: Pre-lab, Lab-Work, and Post-lab Overview

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Abstract. To be able to design optimal laboratory activities at the university, it is necessary to first carry out an assessment of the profile of laboratory activities that have been conducted by students. This study aims to analyze the laboratory activity profile of chemistry students in pre-lab, lab work, and post-lab activities. A quantitative approach is used to achieve the research objectives. Research respondents were first, second, and third-year chemistry students in semesters 2, 4, and 6 (N = 89) who participated in offline practicum activities. The research data was obtained from the distribution of Likert scale questionnaires about respondents' perceptions during practicum activities. The results of the data analysis show that students have high knowledge, experience, and a sense of comfort in pre-lab activities, but they are low in lab work and post-lab activities. Furthermore, the lowest student knowledge was shown in procedural skills (2.17) and the preparation of practicum reports (3.05), and the lowest experience and comfort were shown in practicum report preparation activities (2.16). Therefore, the design of practicum activities should focus more on training lab work and post-lab activities.

Keywords: Chemistry lab activity · pre-lab · lab work

1 Introduction

Today's 21st-century education demands learning that provides more opportunities for students to explore their knowledge [1]. In line with constructivism theory, learning chemistry is related to the process of obtaining concepts and constructing concepts so that students are able to relate them to new concepts [2]. This process requires teachers to apply learning processes that strengthen prior knowledge and give students more experience in learning [3]. Implementation of learning activities in the laboratory is a method that must be distinct from chemistry learning. Laboratory activities are activities that train many skills, such as communication, problem-solving, and many other skills [4–6]. In chemistry learning, there are four basic principles of the importance of laboratory activities [7]:

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1. Teach students scientific skills in science
2. Laboratory activities are important in preparing students to learn science in a structured way.
3. Teach proper working techniques in the laboratory.
4. Develop good motivation and expectations from laboratory activities for students.

Laboratory activities are generally divided into three stages, namely pre-laboratory work, laboratory work, and post-laboratory work [8]. It is still common that the implementation of laboratory activities is more focused on data collection activities, namely at the investigation stage [9, 10], and pre-laboratory and post-laboratory activities have received less attention. It is noted that investigation activities will be successful if students have good pre-laboratory activities and are able to connect the results of the investigation with new concepts through reflection activities on post-laboratory activities [4, 11, 12].

One of the reasons that the three stages in laboratory activities still need to be optimal is that there is no serious effort yet in mapping the objectives of the practicum. The lack of clarity of objectives causes the skills that are measured after students carry out the practicum also to become more balanced. Moreover, in this regard, the cognitive aspect still dominates the assessment and final achievement of the practicum [9, 10, 13]. Non-cognitive studies such as attitudes, experiences, or feelings of students while participating in activities have yet to become an important assessment [4]. This reason underlies the importance of research related to the profile of learning activities in improving and developing learning innovations in the future [14].

Information related to laboratory activity profiles is very important to provide information to teachers and is useful as part of improving the learning process. Students' perceptions as part of a non-cognitive assessment can help teachers and students prepare better laboratory activities at the university level [15]. This assessment can be done using a survey or self-assessment to describe the condition of students in carrying out practical activities. This study aims to analyze the laboratory activity profile of chemistry students in pre-lab, lab work, and post-lab activities.

2 Methods

2.1 Situation Analysis

Some courses in the Chemistry Education study program have been carried out normally in class since the even semester of 2021/2022. The practicum is fully carried out offline in the laboratory. There are five courses that are integrated with practicum, which are given the opportunity to carry out learning activities in the laboratory on as many as 4–5 topics according to the guidelines during the COVID-19 pandemic.

2.2 Sample

The research sample is all students of the Chemistry Education study program at the University of Mataram in the even semester of 2021/2022. The demographics of the sample are shown in Table 1.

Table 1. Demographics of the sample (N = 89)

Background	Number of Respondent	(%)
Gender		
Men	8	9.0
Women	81	91.0
Semester		
2	23	25.8
4	32	35.0
6	34	38.2

Table 2. Laboratory activities of students

No	Stage	Activity
1.	Pre-lab	a. Explore the material put into practice
		b. Prepare practical tools
		c. Prepare practical materials
		d. Carry out a pretest
		e. Prepare preliminary reports
2.	Lab Work	a. Procedural skills
		b. Observing the experimental results
		c. Recording experimental data
		d. Interpreting observations
		e. Teamwork
3.	Post-lab	a. Prepare final reports
		b. Delivering practical results during lectures
		c. Connecting practical results with the existing theory learned

2.3 Data Type

The data was collected in the form of student laboratory activities consisting of pre-lab, lab work, and post-lab activities. The three activities are described in several activities, as shown in Table 2 [8].

The indicators measured in laboratory activities are knowledge, experience, and comfort [16–18]. This assessment is a self-assessment with modified instruments [3]. The results of the assessment are integrated with the pretest scores and student report scores using standardized instruments. The rating scale used is a scale of 1–4. Supporting data is in the form of open responses related to the experiences and feelings of students in participating in practicum activities.

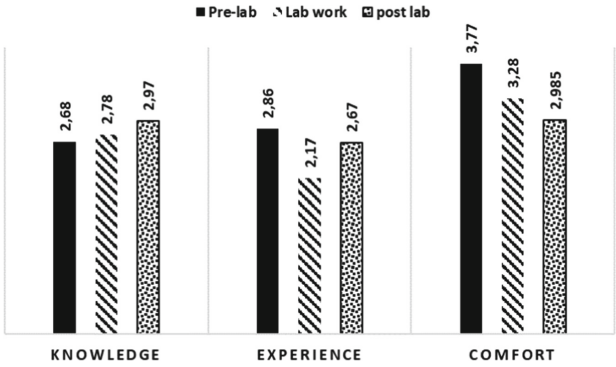

Fig. 1. The Average Score of Chemistry Students' Laboratory Activities

2.4 Data Analysis

The data obtained were collected and tabulated by calculating the average and standard deviation of each indicator in each activity. Open response data were tabulated and described by calculating the percentage of respondents who gave the same response in every aspect that emerged.

3 Results and Discussion

The results of students' self-assessment of laboratory activities showed varying scores on each indicator. In the pre-lab activity, the highest score was shown on the comfort indicator, with an average score of 3.77 (SD = 0.481), while the lowest score was on the knowledge indicator, with an average score of 2.68 (SD = 0.735). As shown in pre-lab activities, the comfort indicator also got the highest score in lab work and post-lab activities, with scores of 3.28 (SD = 0.623) and 2.985 (SD = 0.897), respectively. In contrast to pre-lab activities, lab work and post-lab activities gave the lowest score on the experience indicator, with an average score of 2.17 (SD = 0.529) and 2.67 (SD = 0.779). Figure 1 shows the average laboratory activities on the indicators of knowledge, experience, and comfort.

Analysis of the assessment scores for each activity showed a low average score on the indicators of knowledge and experience in each laboratory activity (Table 3). In the pre-lab activity, the activity of preparing practicum materials and preliminary reports showed the lowest score compared to other activities. However, the comfort indicator had a high score in every pre-lab activity. Activities at the lab-work stage showed low average scores on knowledge related to procedural skills. As it is indicated in pre-lab activities, the comfort indicator still shows a higher score compared to knowledge and experience. Compiling a practicum report is an activity with a low average score at the post-lab stage, especially on indicators of experience and comfort. While on the knowledge indicator, the activity of connecting the results of the investigation with the theory that has been studied shows a low score.

Open responses related to students' opinions regarding pre-lab, lab work, and post-lab activities showed results that were in line with the results of the self-assessment

Table 3. Average score of chemistry students' laboratory activities

Stage	Activity	Knowledge	Experience	Comfort
Pre-lab	a. Explore the material put into practice	2.966	3.112	3.820
	b. Prepare practical tools	2.685	2.809	3.753
	c. Prepare practical materials	2.506	2.741	3.786
	d. Carry out initial response	2.674	2.989	3.719
	e. Prepare interim reports	2.595	2.663	3.775
Lab-Work	a. Procedural skills	2.506	1.944	3.247
	b. Observing the experimental results	2.685	2.034	3.461
	c. Recording experimental data	2.764	2.079	3.191
	d. Interpreting observations	2.674	2.034	3.146
	e. Teamwork	3.281	2.786	3.371
Post-lab	a. Prepare practical reports	3.056	2.157	2.135
	b. Delivering practical results during lectures	3.416	3.416	3.416
	c. Connecting practical results with the theory that has been learned	2.427	2,427	3,404

analysis (Table 4). In pre-lab activities, the statements that often become the attention of students are the discrepancy of the material practiced with the pretest questions, the lack of an explanation of the functions and how to use laboratory equipment, the lack of an initial explanation of the work steps, and difficulties in compiling a preliminary report.

Lab-work activities that concern students are difficulty following work steps, the unbalanced proportion of team members, often making mistakes in determining the quantity of materials needed, and practicum assistants who need help understanding the topics being practiced. Meanwhile, post-lab activities show more attention to the preparation of practicum reports. Students think that the practicum report is too burdensome because it has to be handwritten. It is found that students have needed help finding the literature for the last five years and the difficulty in compiling the discussion.

Pre-lab activities are an important stage in carrying out investigations at the University level. This activity aims to focus students' attention on the investigation to be carried out [19, 20]. If the pre-lab is carried out optimally, then this will provide benefits in all domains [21]. In the conceptual domain, pre-lab may stimulate students to develop ideas related to the concept of inquiry so that they become more independent in completing their investigative activities [22, 23]. The psychomotor domain is related to students' understanding of practicing various skills so that they can use time as efficiently as possible [24]. Comfort and self-confidence can be built through pre-lab activities so that they may reduce negative feelings that will arise in students [25]. This is why the selection of pre-lab activities needs to be an important consideration in the investigation process at the University level.

Table 4. Free response data related to laboratory activities

Stage	Students' Response	Percentage
Pre-lab	a. The discrepancy between the material being practiced with the pretest questions	50.56
	b. Lack of explanation about the function and how to use laboratory equipment	46.07
	c. Lack of initial explanation of the working steps	29.21
	d. Difficulty in compiling preliminary reports	58.43
Lab-Work	a. Difficulty following work steps	23.6
	b. The unbalanced proportion of team members	16.85
	c. Often make mistakes in determining the quantity of materials needed	41.57
	d. The practical assistant who does not understand the topic being practiced	7.86
Post-lab	a. The practicum report is too burdensome because it has to be handwritten	64.04
	b. Difficulty in searching the literature for the last five years	55.06
	c. Difficulty in arranging discussions	76.40

In this study, the pre-lab activities with the lowest scores on the knowledge and experience indicators were in carrying out a pretest and preparing preliminary reports. This is in line with the free response data, which describes students' difficulties in making pictures/charts that illustrate the summary of the investigation procedures they will carry out. The pretest has a low score because the students' responses are related to the discrepancy between the pretest questions and the topic of investigation. A report by Smerdel & Hajric [20] claims that the use of quizzes is a less attractive option in pre-lab activities. The use of quizzes has begun to be replaced with learning videos or pre-lab discussions that stimulate students' interest and knowledge of the investigation to be carried out [26–28].

The comfort indicator shows the highest score for all pre-lab activities. In line with the research of Jolley et al. [6] and Chaytor et al. [29], a sense of comfort is a response that is often given by students in pre-lab activities. This is due to high motivation to initiate investigations and the existence of social interactions with peers [30].

Pre-lab activities can be a determinant of the success of investigation activities carried out by students [21]. Based on the results of this study, pre-lab activities that have not been optimal may be the cause of the low self-assessment scores on lab-work activities. Procedural skills are a problem that is often encountered in investigative activities. Several studies have shown that procedural skills such as designing tools, selecting reagents, and following investigation procedures show the lowest scores of knowledges and experience [3].

Problems found by students during the investigation process can be minimized through the introduction of laboratory techniques before the investigation process begins [21]. The use of videos and discussions may be applied to first-year students. On the other hand, final-year students are better given the opportunity to design their own experiments [31], or alternatively, the use of online modules can also have a positive influence on the investigation process [32].

Compiling an investigation report on post-lab activities still needs to be solved in investigative activities [33]. The results of this study indicate that the preparation of the investigation report gave the lowest score on the three indicators. In line with the opinion of Duzor [34] and Hofstein et al. [35], the investigation report mostly only duplicates what is written in the practicum instructions and does not contain arguments against the results of the investigation. Students' responses related to the difficulty of obtaining appropriate literatures may be an obstacle to their analytical and argumentative abilities.

Overcoming problems in the preparation of practical reports can be done by familiarizing students with writing from the lowest level of difficulty to the highest. According to Rosenthal [36], the preparation of the discussion chapter is the most difficult part of the investigative report because it contains analysis and arguments. To overcome this, lecturers can provide opportunities for students to express the results of their investigations and analyzes, and arguments related to these results. Through class discussions, students will be trained to express their opinions and be motivated to give appropriate arguments [37]. Class discussions need to be accompanied by feedback from the lecturer so that students are able to learn to analyze properly [38]. In addition to feedback during discussions, lecturers need to provide feedback on reports prepared by students. This aims to help them improve the writing they have compiled in the next report [39].

4 Conclusion

The results of the study indicated that students experienced several problems in pre-lab, lab-work, and post-lab activities. The lowest assessment score at the pre-lab stage was shown in carrying out the pretest and preparing research tools and materials. At the lab-work stage, procedural skills become the main problem. Scores on the comfort indicator in pre-lab and post-lab indicate that students want to improve their investigative skills. The preparation of the investigation report had the lowest score on the three indicators assessed. This indicates that compiling investigation reports is part of laboratory activities that need to be better designed to increase the comfort of students at the university level.

5 Recommendation

These findings provide several recommendations to improve the quality of learning by involving laboratory activities, including:

1. The pre-lab implementation is adjusted to the level of students where first year students can use videos or class discussions, while final year students use modules that train them to design investigations independently.

2. The pre-lab content focuses on the skills needed in the laboratory during the investigation process. Through optimal pre-lab activities, it is hoped that students can be better prepared to carry out the investigation process.
3. Provide opportunities for students to report the results of the investigation through discussion in class so that they can practice their analytical and argumentation skills.
4. Designing an investigation report preparation technique that is easier and able to train students' writing skills. Reports need to be given feedback by the lecturer so that students can correct the shortcomings of the writing that has been prepared.

6 Research Limitation

This study has limitations related to student self-assessment. Some students may have high confidence or feel insecure in giving an assessment. This causes supporting data to be needed in the interpretation process (Towns et al., 2015). It is recommended that further research can be accompanied by the results of accompanying interviews to dig deeper regarding the indicators of activities carried out during practicum activities.

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References

1. A.R. Saavedra and V.D. Opfer, *Teaching and learning 21st century skills: lessons from the learning sciences* (RAND Corporation, London, 2012), pp. 6–10.
2. M.M. Cooper and R.L. Stowe, Chem. Rev. **118**, 6053–6087 (2018).
3. N, Mistry and S.G. Gorman, Chem. Educ. Res. Pract. **21**, 823–838 (2020).
4. S. Altowaiji, R. Haddadin, P.Campos, S. Sorn, L. Gonzalez, S.M. Villafan and M.N. Groves, Chem. Educ. Res. Pract. **22**, 616–625 (2021).
5. B.K. DeKorver and M.H. Towns, J. Chem. Educ. ***92*(12)**, 2031–2037 (2015)
6. D.F. Jolley, S.R. Wilson, C. Kelso, G. O'Brien and C.E. Mason, J. Chem. Educ. **93(11)**, 1855–1862 (2016).
7. M.K. Seery, A.B. Jones and T. Mein, J. Chem. Educ. **96(1)**, 53–59 (2019).
8. N. Reid and I. Shah, Chem. Educ. Res. Pract. **8(2)**, 172–185 (2007).
9. G. Reynders, E. Suh, R.S. Cole and R.L. Sansom, J. Chem. Educ., **96(10)**, 2109–2119 (2019).
10. M.K. Seery, J. Chem. Educ., **97(6)**, 1511–1514 (2020)
11. K. Ho, S.R. Smith, C. Venter and D.B. Clark, Chem. Educ. Res. Pract. **22**, 973–84 (2021)
12. J. Tashiro, D. Para, J. Pollard and V. Talanquer, Chem. Educ. Res. Pract. **22**, 662–682 (2021)
13. R. Sansom and J.P. Walker, J. Chem. Educ. **96(2)**, 193–195 (2019)
14. B. Ng, New Wav. Educ. Res. Dev. **22(1)**, 1–13 (2019).
15. S.R. George-Williams, A.L. Ziebell, R.R.A. Kitson, P. Coppo, C.D. Thompson and T.L. Overton, Chem. Educ. Res. Pract. **19**, 463–473 (2018)
16. M. Towns, C.J. Harwood, M.B. Robertshaw, J. Fish and K. O'Shea, J. Chem. Educ. **92**, 2038–2044 (2015).
17. S. Hensiek, B.K. DeKorver, C.J. Harwood, J. Fish, K. O'Shea and M. Towns, J. Chem. Educ. **93**, 1847–1854 (2016).
18. M.K. Seery, H.Y. Agustian, E.D. Doidge, M.M. Kucharski, H.M. O'Connor and A. Price, Chem. Educ. Res. Pract. **18**, 403–419 (2017).

19. T. Costello, P. Logue and K. Dunne, AISHE-J. **14(2)**, 1–34 (2022).
20. S. Smerdel and M.Z. Hajric, Acta Chem. Slov. **67**, 435–444 (2020).
21. H.Y. Agustian and M.K. Seery, Chem. Educ. Res. Pract. **18**, 518–532 (2017).
22. A.H. Johnstone, R.J. Sleet and J.F. Vianna, Stud. High. Educ. **19(1)**, 77–87 (1994)
23. J.A. Schmidt-McCormack, M.N. Muniz, E.C. Keuter, S.K. Shaw and R.S. Cole, Chem. Educ. Res. Pract. **18**, 749–762 (2017)
24. T.M. Winberg and C.A.R. Berg, J. Res. Sci. Teach. **44(8)**, 1108–1133 (2007).
25. D. Spagnoli, C. Rumey, N.Y. Man, S.S. Wills and T.D. Clemons, "Designing online pre-laboratory activities for chemistry undergraduate laboratories", in *Teaching Chemistry in Higher Education: A Festschrift in Honour of Professor Tina Overton*, edited by M.K. Seery and C. Mc Donnell (Trigonal Planar Press, Edinburgh, 2019), pp. 1–18.
26. M.C. Box, C.L. Dunnagan, L.A.S. Hirsh, C.R. Cherry, K.A. Christianson, R.J. Gibson, M.T. Gallardo-Williams et al., J. Chem. Educ. **94(2)**, 164–170 (2017).
27. L.S. Nadelson, J. Scaggs, C. Sheffield and O.M. McDougal, J. Sci. Educ. Techn. **24(4)**, 476–483 (2015).
28. D.L.A. Scarborougha, S.R. George-Williams and C.D. Thompson, Int. J. Innov. Sci. Math. Educ. **30(2)**, 46–64 (2022).
29. J.L. Chaytor, M. Al Mughalaq and H. Butler, J. Chem. Educ. **94(7)**, 859–866 (2017).
30. S.C. Barrie, R.B. Bucat, M.A. Buntine, K. Burke da Silva, G.T. Crisp, A.V. George, S.M. Pyke et al., Int. J. Sci. Educ. **37(11)**, 1795–1814 (2015).
31. S.J. Rayment, J. Evans, K. Moss, M. Coffey, S. H. Kirk and S. D. Sivasubramaniam, J. Biol. Educ. https://doi.org/10.1080/00219266.2021.2011771 (2022).
32. M.E. Haagsman, M. C. Koster, J. Boonstra and K. Scager, J. Sci. Educ. Tech. **30**, 461–470 (2021).
33. J.W. Wackerly, J. Chem. Educ. **95(1)**, 76–83 (2017)
34. A.G.V. Duzor, J. Chem. Educ. **93(10)**, 1725–1730 (2016)
35. A. Hofstein, M. Kipnis and P. Kind, P, "Learning in and from science laboratories: enhancing students meta-cognition and argumentation skills" in *Science education issues and developments* edited by C.L. Petroselli (Nova Science, London, 2008), pp. 59–94.
36. L.C. Rosenthal, J. Chem. Educ. **64(12),** 996–998 (1987).
37. S. Campbell, J. Case Stud. Educ. **7**, 1–13 (2015).
38. J.A. JeanBurnham, NDIR **9(1)**, 42–48 (2013).
39. J.M. Carr, J. Chem. Educ. **90(6)**, 751–754 (2013).