Self-assessment of chemistry laboratory basic skills using performance scoring rubrics at the chemistry teacher training

I B N Sudria*, I W Redhana, I W Suja and I N Suardana
Universitas Pendidikan Ganesha, Jalan Udayana 11 Singaraja Bali 81116 Indonesia

* E-mail: ibnsudria.undiksha@gmail.com

Abstract. This student self-assessment of chemistry laboratory basic skill performances is intended to overcome the heavy time-consuming and very intensive involvement of lecturer as the only performance assessor, promote and accelerate the skill improvement based on learner self-performance assessment. The study involved 26 students undertaking Basic Chemistry subject at Chemistry Education Department of Universitas Pendidikan Ganesha in Bali. The self-assessment applied the scoring rubric developed by Sudria and Sy’a’ban. Each item of the 22 assessment items applies five-scaled grading performance indicators as very good, good, sufficient, poor, and very poor. Every skill item was assessed at least three time along the semester and analyzed twice namely at the middle of the semester as data S1 and near the end of the semester as data S2. The same performance assessment was also conducted by a lecturer team as the laboratory work examination at the end of the course as reference data of S3. This study showed significant correlation of S1 and S2 toward S3 with score correlation amounts of 0.520 for r1-3 and 0.588 for r2-3 which were above the critical value of 0.374 at 95% confidence. Guidance and monitoring during laboratory work supported to the success of the self-assessment study.

1. Introduction

Stiggins [1,2] recommends the use of performance scoring rubrics to assess skills and products. Sudria [3,4] developed an analytic performance scoring rubric to assess basic Chemistry laboratory skills in teacher training education and also can be used for secondary school. The availability of the instrument to conduct skill performance assessment facilitates to figure progress along an exercise program of which the assessment results for certain time periods such at the middle and end of the training project can be compiled. But the use of the assessing rubrics of laboratory work skills only by lecturer/teacher in the assessment caused intensive activities and heavy time-consuming for the educator [3]. Meanwhile, prospective teachers must have sufficient performance in basic Chemistry laboratory skills and require the best skills training as needed for professional teaching. A reasonable strategy is needed to increase the feasibility of the use of scoring rubric in delivering performance assessment. Concerning the effectiveness of performance improvement based on self-performance assessment of students and reduction of lecturer workload in using performance assessing rubrics, self-assessment of performance is a prospective alternative solution in the assessment of basic chemistry laboratory skills for effective progress. Self-assessment with rubric assessment for basic laboratory works skills is needed either as group works or independent activities on chemistry in limited social situations such as the Covid-19 pandemic. Careless of chemical handling and apparatus setting was often observed for teacher training students in several laboratory work courses, even when they conduct field practice of chemistry teaching at secondary school, such as horizontal position of chemical filled dropping pipette, use of a same pipette
for taking different liquids or solutions even without cleaning first of the pipette, untightened clamp/s on a stand such on filtering apparatus fitting, and placement of glass wares in a risky position. The careless of hazardous chemical handling and apparatus fitting due the poor laboratory work skills could raise endanger in laboratory works.

Chemistry laboratory work optimally apply basic skills which strongly supports science inquiry learning as one recommended for the scientific learning approach. Scientific method is the reference for creative and critical learning through investigation in the scientific learning approach. Well understanding of basic chemistry requires data supports collected with the use of laboratory basic skills in preparing quality of prerequisite conceptions for further chemical lessons. Mastering the basic skills will empower and accelerates further construction of science conceptions. Chemistry laboratory basic skills are also life skills in processing daily goods for daily demands and also a tool to develop thinking skills and creativity.

Performance assessment rubric facilitates authentic assessment, the appropriateness of the goal, target, method and instrument of skill and product assessment [1]. Learners who are assessed through performance scoring rubric are assigned a task, and then they perform the desired skills which are observed and recorded by assessors or via self-assessment [5] using the performance scoring rubric. “A rubric is a rating scale that consists of ordered categories, together with descriptions of criteria that may include exemplars, which are used to sort student-produced responses into levels of achievement” [6]. They stated further that “rubrics as vehicles that can provide a useful mechanism to translate achievements into assessment terms”. Rubric has four aspects: criteria, examples, scale, and standards [7]. Analytical rubric is used to assess specific learning aspects. Effective performance assessment requires same perception of scoring criteria of grading of performance quality indicators. The scoring criteria should be clearly socialized at the beginning of the assessment program.

Self-assessment is “the involvement of students in identifying standards and/or criteria to apply to their work and making judgments about the extent to which they met these criteria and standards” [8]. Student self-assessment involved the students in monitoring and making judgments about aspects of their own learning. Students should have opportunities to make adjustment in learning based on their self-performance assessment [9]. Self-assessment contributed to preferred feedback, more open and supportive learning environment, responsibility assignments expectations, proactive actions, and to develop a more interactive role [10]. Self-assessment is a key strategy to involve students in taking more responsibility for their own learning.

The same perception and clear understanding of quality gradation scoring criteria of performance quality indicators among learners and assessors before the administration of self-assessment program will lead to effective assessment conduct. This will effectively focus the learners and assessors on practicing the performance quality of the desired skills, makes it is easier to assign the related assessment tasks and feed back to the learners during practices, so administration of the performance assessment would be feasible. This paper showed the feasibility administration supported by significant score correlation between Chemistry laboratory basic skill performance assessment results recorded via student self-assessment and that assessed by the lecturer team through final examination of the basic skill performances at the end of the course.

2. Method

This correlation research on learning aims at supporting the validity of self-assessment of chemistry laboratory basic skill performance. The research involved one class of 26 students undertaking Basic Chemistry II at Chemistry Education Department of Universitas Pendidikan Ganesha. Situation of self-assessment were created due to it had not normally observed. Guidance of conducting self-assessments were given for every laboratory session. Assignment to conduct administrated individual student self-assessment for the whole laboratory skills were conducted in two sessions. First session was conducted at the middle semester involving topics of chemical kinetics (P1) and chemical equilibrium (P2) which resulted average score data of S1. Second session was conducted near the end of semester involving topics of solution (P3) and redox (P4) which resulted average score data S2. As a reference of correlation
method, the same performances of the whole specific skills were assessed by a lecturer team at the end of the course as final exam of the accommodated laboratory basic skills.

Table 1. The organization of specific skills accommodated in the units

| No. | Basic skills                                                                 | Events | 1st Half smt. | 2nd Half smt. |
|-----|-------------------------------------------------------------------------------|--------|---------------|---------------|
|     |                                                                               |        | P1            | P2            | P3            | P4            |
| 1   | Taking pure solid substances from a storing container                         | ✓      | ✓             | ✓             | ✓             |
| 2   | Taking pure liquid solution from its container                                | ✓      | ✓             | ✓             | ✓             |
| 3   | Taking a liquid or a solution from a container provided for whole learners in a class | ✓      | ✓             | ✓             | ✓             |
| 4   | Demonstrating laboratory equipment and use of chemical safely                  | ✓      | ✓             | ✓             | ✓             |
| 5   | Using fume hood                                                                | ✓      | ✓             | ✓             | ✓             |
| 6   | Lighting Bunsen burner                                                         | ✓      |               | ✓             |
| 7   | Handling and disposing chemical waste safely                                  | ✓      | ✓             | ✓             | ✓             |
| 8   | Weigh chemicals                                                                | ✓      | ✓             | ✓             | ✓             |
| 9   | Using volumetric equipment                                                     | ✓      | ✓             |               |
| 10  | Decanting a liquid/solution from a mixture                                     | ✓      | ✓             | ✓             | ✓             |
| 11  | Using a dropping pipette to transfer a liquid/solution                          | ✓      | ✓             | ✓             | ✓             |
| 12  | Preparing a certain concentration of a solution from a pure substance          | ✓      | ✓             | ✓             | ✓             |
| 13  | Preparing a certain concentration of a solution by dilution                    | ✓      | ✓             | ✓             |               |
| 14  | Using a stand to support the equipment / glassware                             | ✓      | ✓             | ✓             |               |
| 15  | Setting filtering tools                                                        | ✓      | ✓             | ✓             |               |
| 16  | Filtering liquid/solution phase from its containing mixture                    | ✓      |               |
| 17  | Flowing gas which is assisted by heating to a liquid solvent to make its solution | ✓      | ✓             | ✓             |
| 18  | Cleaning glassware                                                             | ✓      | ✓             | ✓             | ✓             |
| 19  | Observing a cloud/colloidal dispersion as a chemical reaction product in a solution | ✓      | ✓             |               |
| 20  | Observing color change especially for color intensity due to chemical reaction | ✓      | ✓             | ✓             |               |
| 21  | Identifying the chemical reaction on heating which characterized by gas formation | ✓      | ✓             | ✓             |               |
| 22  | Identifying a chemical product by smelling (wafting) safely                    | ✓      | ✓             | ✓             |               |

2.1. Materials
The laboratory basic skills performance instrument includes 22 items. Each item assesses a basic skill. The whole sessions of self-assessments of the basic skills involved two sessions. Each session contained the whole items. The first session involved two topics revealing the whole basic skills for self-assessment session I at the middle of the semester and the other two topics revealing the whole basic
skills for self-assessment session II at about the end of the semester as presented in table 1. Several items did not reveal for each topic with respect to the topic characteristics.

2.2. Instruments
This research used instrument of the analytical performance scoring rubric developed by Sudria [3]. The laboratory basic skills performance instrument originally included 19 items with the Cronbach’s alpha reliability coefficient of 0.880 [4], then it extended up to consisted of 22 items in this study. The reliability of the used instrument in this study is also as a result to support the feasibility of this conducted self-assessment. The reliability is assigned by Pearson correlation coefficients between the scores on the laboratory basic skills achieved by students via respectively self-assessment collected at the middle and end of the semester toward the scores achieved at final exam of the laboratory basic skill performances scored by the lecturers.

Each item measured a specific aspect of chemistry laboratory basic skill. The item involved 5 (five) grading quality categories of the skill performance to be chosen which matched to the observed performance indicator. The quality grading scores were 5 for very good, 4 for good, 3 for satisfactory, 2 for poor, and 1 for very poor observed performance. The learners who do-self-assessment or assessors just put check in the cell of the observed performance indicator category for the observed student. One example of the self-assessment rubric item for filtering skill is shown as table 2.

Table 2. Format of performance scoring rubrics with an example item for filtering skill

| Score | Quality grading indicators of skill/product performances | Observed performance |
|-------|----------------------------------------------------------|-----------------------|
| Practice | | 1st | 2nd | 3rd | ... |
| Filtering | | | | |
| 5 | Use stand/support safely, fold filter paper in right way without leaking, avoid the increase of pressure inside the filtrate container (there is a way air to come out). | |
| 4 | Use a stand and fold/fix filter paper not so properly but without leaking, avoid the increase of pressure the filtrate container | |
| 3 | Without stand/support, no leaking on the filter paper, avoid increase of pressure inside the filtrate container | |
| 2 | Do not avoid the increase of pressure inside the filtrate container (there is no way air to come out). | |
| 1 | Use leaking filter paper or loosely sets the stand | |

Each specific skill was observed several times through self-assessment along the course revealing it. Mapping the assessed skills along the semester is showed at table 1. All specific aspects were also observed once as final exam at the end of the course.

2.3. Procedure
The procedure used in this study involved several steps. At the beginning of the performance assessment program, the lecturer team socialized and discussed the scoring rubric criteria to subjects of this study, students undertook the Foundation Chemistry II subject and also explained the assessment tasks included in the worksheet for the whole of the course in which self-assessment units were organized following the topics/sub-topics stated in the table 1. Then, student self-assessments were assigned to the students by applying rubric items of the scoring rubric units for topics/sub-topics of chemical kinetics (unit P1), chemical equilibrium (unit P2), solutions (unit P3), and redox (unit P4). Lecturer team also
assessed each specific skill accommodated in each unit for several samples of the students throughout program conduct with special focus on well and bad skill performances observed. The data were used by lecturer for giving reflection of the session and for improvement of the skills in further exercises. At the end of the course, the lecturer team conducted assessment for the whole specific skills once as final exam of the practices of the basic laboratory skills as scores S3 (as a reference). Average self-assessment of the basic skill performance scores of each student for first half semester (P1 and P2) as S2 scores and for second half semester (P3 and P4) as S2 scores were calculated. Finally, the correlation coefficient among student self-assessment performance scores (S1 and S2) and S3 scores which were assigned by lecture team were determined using product moment method as \( r_{1,3} \) and \( r_{2,3} \) to conclude the validity of the student self-assessment. At the end of the assessment program, the responses of subjects to this performance self-assessment study also recorded using a questioner. Feasibility of the student performance self-assessment administration confirmed by the magnitude of correlation coefficient found (empirical validity), recorded student responses to the self-assessment program, and improvement of situation of the self-assessment administration along the course.

3. Results

3.1. Correlation of performance scores assessed by student himself and by lecturers

Average scores recorded through student self-assessment in the first half of semester (S1), second half of semester (S2) and the performance final exam scores assigned by lecturer (S3) shown in table 3. Correlation coefficients were 0.520 for \( r_{1,3} \) and 0.588 for \( r_{2,3} \) which were above the critical value (>0.374) at 95% confidence.

3.2. Learner comments on performance self-assessment

The subjects of this student chemistry laboratory basic skill performance self-assessment program gave responses as shown in the Table 3. The subject responses in five categories namely strongly agreed (SA), agreed (A), moderate (M), disagreed (D), and strongly disagreed (SD) were shown in Table 4.

Majority learners (about 90%) gave positive responses to involve in self performance assessment of the basic skills. This positive response showed that the benefits of self-assessment on student learning mentioned by many authors were recognized by students.

4. Discussion

The self-assessment was difficult and slow implementation at the beginning. In the region of this conducted research, the students are rarely involved in laboratory work in secondary schools. It takes time to understand and remember the adequate five options of descriptive qualitative grading indicators of skill performance such as for filtering skill showed in table 2. After that, the steady improvement on the laboratory basic skills took place along the semester. The significant correlations of student performance scores by self-assessment either collected at the middle and near the end of the semester toward student performance scores on final performance exam assessed by the lecture team. The average performance scores were steadily in good category since the middle of the semester. The students appreciated the self-assessment program. Those indicated the feasibility of this conduction of laboratory basic skill self-assessment.

The performance scoring rubric item states quality levels of performance indicator descriptions for one dimension of the laboratory basic skill. The options of the graded quality indicator descriptions range from the best to the worst to be selected according to the observed/recognized skill of the assessed learner. Using this scoring rubric with qualitative description options is more objective than giving quantitative score. The results of the assessment in the form of a quality description of the performance provide direct input if there is an inappropriate performance of the skill, then for improvement. The selected option automatically and consistently gave a quantitative score of the observed skill as long as it is chosen objectively as the skill quality performed. On the other hand, skills assessment without the support of an assessment rubric tends to be inconsistent, especially by learners, so it is less objective.
and does not provide direct information about inappropriate skills that need to be improved. Each skill dimension was assessed at least three times throughout the scheduled semester according to the topic/sub-topic of the laboratory work that accommodates it. Involvement of students in co-scheduling self-assessment basic skills practices makes self-assessment more feasible.

Table 3. Average scores of chemistry laboratory basic skill performance.

| Subjects (No.) | Average scores |
|----------------|----------------|
|                | Student self-assessment | Lecturer conducted assessment at end semester |
|                | 1st half Smt. | 2nd half Smt. | |
| 1              | 4.2          | 4.3          | 4.7          |
| 2              | 4.0          | 4.3          | 4.7          |
| 3              | 3.8          | 4.3          | 4.5          |
| 4              | 4.4          | 4.4          | 4.7          |
| 5              | 4.5          | 4.9          | 4.6          |
| 6              | 4.2          | 4.8          | 4.6          |
| 7              | 4.4          | 4.3          | 4.1          |
| 8              | 4.2          | 4.3          | 4.4          |
| 9              | 4.6          | 4.6          | 4.4          |
| 10             | 4.0          | 4.5          | 4.3          |
| 11             | 4.0          | 4.2          | 4.0          |
| 12             | 3.6          | 4.0          | 4.0          |
| 13             | 3.9          | 4.4          | 4.3          |
| 14             | 4.6          | 4.5          | 4.5          |
| 15             | 3.7          | 4.3          | 4.5          |
| 16             | 3.5          | 4.3          | 4.2          |
| 17             | 3.9          | 4.6          | 4.3          |
| 18             | 4.1          | 4.6          | 4.3          |
| 19             | 4.5          | 4.6          | 4.6          |
| 20             | 4.2          | 4.6          | 4.4          |
| 21             | 3.9          | 4.0          | 4.0          |
| 22             | 3.7          | 4.0          | 3.9          |
| 23             | 4.1          | 4.0          | 4.5          |
| 24             | 3.7          | 4.2          | 3.8          |
| 25             | 4.4          | 4.8          | 4.5          |
| 26             | 4.2          | 4.7          | 4.4          |

Table 4. Several learner responses to self-performance assessment administration of Chemistry laboratory basic skills.
The 15th Joint Conference on Chemistry (JCC 2020)

IOP Conf. Series: Materials Science and Engineering 959 (2020) 012005
doi:10.1088/1757-899X/959/1/012005

| No | Response descriptions                                                                                                                                                                                                 | Number of responses |
|----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|
| 1  | The rubric stated clear quality performance indicator grading for learners and assessors                                                                                                                       | SA 18 A 8 M 0 D 0 SD 0 |
| 2  | Assigning descriptive observation of performance quality grading indicators were more objective then giving a quantitative score                                                                                  | SA 12 A 10 M 4 D 0 SD 0 |
| 3  | Confuse and very slow to apply scoring rubric items at the beginning self-performance assessment program. It was not a problems for the second session and further                                           | SA 5 A 20 M 1 D 0 SD 0 |
| 4  | Criteria of scoring rubric must be properly socialized at the beginning of the performance assessment program                                                                                              | SA 15 A 9 M 2 D 0 SD 0 |
| 5  | Practiced tasks must be socialized properly at the beginning of the performance assessment program                                                                                                             | SA 20 A 6 M 0 D 0 SD 0 |
| 6  | Student self-performance assessment stimulated optimal improvement on student learning                                                                                                                          | SA 13 A 11 M 2 D 0 SD 0 |
| 7  | Performance scoring rubric helped learners to recognize benchmark of the competence                                                                                                                           | SA 11 A 12 M 3 D 0 SD 0 |
| 8  | Students agreed to assess Chemistry laboratory skills through self-assessment of performance                                                                                                                   | SA 6 A 12 M 7 D 1 SD 0 |
| 9  | Mastering Chemistry laboratory basic skills improved self-confident of the students to properly conduct laboratory works                                                                                      | SA 8 A 16 M 2 D 0 SD 0 |

Average responses for the whole aspects | 12.0 A 11.6 M 2.3 D 0.1 SD 0.0 |


The socialization of the scoring rubric at the beginning of the semester and the clear self-assessment procedure had many impacts contributing to the success. The rubric provides a reference for the dimensions of the expected skill aspects and could challenge the best performances. The involvement of students in scheduling of assessed skills training throughout the semester contribute to practice with their own initiative which tends to promote commitment to improving skills independently. Guidance at the beginning and accompaniment facilities especially with demonstration of basic laboratory skills by lecturer team when students ask for help along exercising periods accelerated the development of the basic skills as well as the capability to conduct self-assessment. The understanding of the rubric assessment criteria improved along with self-assessment of their performance. Those potentials synergistically empower self-performance assessments to accelerate the skill improvement. Significant positive correlation between the average score of self-assessment and the score given by the lecturer team in accordance with student appreciation.

This study agreed to many reported studies [11,12]. Benefits of self-assessment [5] were reemphasized such as contribution to improve the students' understanding of assessment, feelings of control over one's own learning, self-worth, self-motivated to independent learners, honest with themselves when setting targeted skills, a greater sense of ownership of their work, demanding enthusiastic to learning, the potential to help students to develop important professional skills using higher-order thinking, improve ability to focus on key elements of an assignment, increase effectiveness in identifying strengths and weaknesses in their work, provide students with an opportunity to participate in the assessment process which increases their motivation, force student assessors to have a more conscious understanding of the processes involved in the learning activity, and to be used as a means of producing formative learning oriented feedback to complete the learning cycle and encourage the...
ongoing development of skills. Self-assessment of chemistry basic skills would be useful in limited social distancing such on the covid-19 pandemic situation.

5. Conclusion
Learners self-assessment on their performance of the Chemistry laboratory basic skills were feasible to be conducted for Basic Chemistry subject at teacher training education. The learners recognized the benefits of self-performance assessment of Chemistry laboratory basic skills in chemistry learning.

Acknowledgments
Our thanks go to research institute of Ganesha University of Education for funding support, and also to teaching staffs, laboratory technicians, as well learners at Chemistry Teacher Training Education at Ganesha University of Education for their involvement and supports.

References
[1] Stiggins R J 1994 Student-Centered Clasroom assessment (New York: Maxwell Macmillan International)
[2] van Helvoot A A 2010 J. Inf. Lit. 4 22
[3] Sudria I B N and Sya’ban S 2008 J. Penelitian Pengembangan Pendidikan 2 30
[4] Sudria I B N and Siregar M 2009 J. Pendidikan Pengajaran 42 222
[5] Andrade H 2007 Educ. Leadersh. 65 60
[6] Shafer W D, Swanson G, Bene N and Newberry G Appl. Meas. Educ. 14 151
[7] Kuo S A 2007 Educ. Research. J. 22 179
[8] McDonald B and Boud D 2003 Assess. Educ. 10
[9] Ndoye A 2017 Int. J. Teach. Learn. High. Educ. 29 255
[10] McMillan J H and Jessica H 2008 Educ. Horiz. 87 40
[11] Papanthymou A and Darra D 2019 J. Educ. Learn. 8 48