Formative assessment in science education: Is it being practiced?

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Abstract. This study investigated the formative assessment practices in Science education in relation to the enhancement of student learning. The sample comprised of three teachers and 114 students at the Year 9 to 11 levels at one of the private secondary schools in Brunei Darussalam. The study was carried out in three phases: classroom observations, dissemination of the teacher/student self-reflection surveys and individual interviews with the teachers. The findings revealed that the weaknesses, such as the partial use of formative assessment and few student-led discussions that outweigh the strengths of the current formative assessment practices at this particular secondary school. Despite the teachers’ attempts to improve the process of teaching and learning, there is a need to change their mindsets and upgrade their skills so that the formative assessment in Science education can be implemented successfully.

1. Introduction

A number of researchers have asserted that articulating formative assessment methods can support student development of inquiry competences in the classroom [1-7]. Teachers may use portfolios, journals, rubrics, checklists, graphic organisers, written reports, the Socratic questioning or other evidence-eliciting techniques to best stimulate and assess the students’ cognitive processes [8-15]. Thus, formative assessment practices are slowly emerging to bridge the gap between classroom teaching and learning. When formative assessment is integrated into classroom instruction, it is a planned process to and it does not happen by coincidence [16]. Formative assessment occurs when ongoing and collaborative feedback is provided to the students to improve learning and teaching [17-19]. Moreover, formative assessment underpins student involvement both as evaluators of their own learning and as resources to other classmates [20]. Through providing descriptive feedback, the students gain an understanding of their strengths and weaknesses in connection with classroom learning. However, limited feedback to the students may not lead to improved student learning as suggested by a significant body of research.

This study aims to investigate and report the strengths and weaknesses of formative assessment practices in Science education in one of the private secondary schools in Brunei Darussalam. The student learning was not measured in this study since it only focused on the participants’ perceptions of how formative assessment is being practiced in Science education. The formative assessment practices to be examined are limited to the ten dimensions or criteria as identified by the ‘Formative
Assessment of Students and Teachers State Collaborative on Assessment and Student Standards’ also known as the FAST SCASS [21, 22], namely: (1) learning goals, (2) criteria for success, (3) tasks and activities that elicit evidence of student learning, (4) questioning strategies that elicit evidence of student learning, (5) feedback loops during questioning, (6) individualised descriptive feedback, (7) peer assessment, (8) self-assessment, (9) collaboration, and (10) use of evidence to inform instruction.

2. Method
This study investigated the formative assessment practices in Science education in relation to the enhancement of student learning. The sample comprised of three teachers and 114 students at the Year 9 to 11 levels at one of the private secondary schools in Brunei Darussalam. The teachers were selected purposefully so that they can contribute specific knowledge about the topic of the study. On the other hand, the students were randomly chosen with the use of cluster sampling based on their subject teachers. All participants were made aware of the study and they were willing to participate.

The study was carried out in three phases, namely: classroom observations, dissemination of the teacher/student self-reflection surveys and individual interviews. Mixed quantitative and qualitative methods were employed to investigate the topic presented in this paper. In the first two phases, a quantitative method was applied to develop an assessment tool for classroom observation and subsequently in developing the survey. For the classroom observations of the first phase, the lessons were observed in order to determine if the teachers were indeed consistently practicing the formative assessment. In the second phase, two surveys were performed to validate the classroom observations with the participants’ perceptions. In the final phase, applications of the qualitative method from the recorded structured interviews were done with the teachers to explicate the survey results. Descriptive statistics was used to describe the quantitative data gathered from the classroom observations and surveys. And finally, thematic analysis was employed to present the qualitative data that emerged from the individual interviews.

3. Results and discussions

3.1. Demographic profile of the teachers
Table 1 shows the demographic profile of the three female teachers who participated in the study. The teachers came from two different nationalities and the subjects taught are Physics and Combined Science. Note that the subject Combined Science generally covers a basic combination of the three pure science subjects of Biology, Chemistry and Physics. From Table 1, the mean scores of the teachers’ age and the years of teaching are 31 and 9 respectively.

| Nationality | Age | Years of Teaching Experience | Subjects                      |
|-------------|-----|------------------------------|-------------------------------|
| Indian      | 34  | 12                           | Combined Science              |
| Indian      | 29  | 11                           | Physics                       |
| Chinese     | 30  | 4                            | Combined Science and Physics  |

3.2. Demographic profile of the students
Table 2 displays the student gender distribution for each year level in the first phase. The male students for each year level mainly dominate the sample population with 59%. Meanwhile, Year 10 had the most number of participants (47%) and Year 11 with 25% of the sample.
Table 2. Student gender and year level distribution for the classroom observation (N = 114).

| Year Levels | Male     | Female   | Total |
|-------------|----------|----------|-------|
| 9           | 18 (56%) | 14 (44%) | 32 (28%) |
| 10          | 30 (56%) | 24 (44%) | 54 (47%) |
| 11          | 19 (68%) | 9 (32%)  | 28 (25%) |
| Total       | 67 (59%) | 47 (41%) | 114   |

Table 3 illustrates the student gender distribution for each subject taught by the teachers in the second phase of the study. The females are more than 20% than males who answered the survey on student self-reflection. Almost three-quarters of the respondents were enrolled in Physics.

Table 3. Student gender and subject distribution for the survey (N = 15).

| Subjects          | Male     | Female   | Total |
|-------------------|----------|----------|-------|
| Combined Science  | 2 (40%)  | 3 (60%)  | 5 (33%) |
| Physics           | 4 (40%)  | 6 (60%)  | 10 (67%) |
| Total             | 6 (60%)  | 9 (40%)  | 15     |

3.3 First phase of data collection

The results of the classroom observation based on the ten criteria identified by the FAST SCASS [14, 15] are shown in Table 4. The highest mean score is for item 3. Meanwhile, the lowest mean score is for item 7.

Table 4. Frequency distribution of respondents based on the levels of implementation for the classroom observation (N = 3).

| Dimensions       | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   |
|------------------|------|------|------|------|------|------|------|------|------|------|
| Beginning (1)    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| Developing (2)   | 1    | 0    | 0    | 1    | 0    | 2    | 0    | 2    | 1    | 1    |
| Progressing (3)  | 2    | 2    | 1    | 1    | 1    | 2    | 0    | 2    | 1    | 2    |
| Extending (4)    | 0    | 0    | 2    | 1    | 1    | 1    | 0    | 1    | 0    | 0    |
| Mean Score       | 2.7  | 2.7  | 3.7  | 3    | 3    | 3    | 2    | 3.3  | 2.3  | 2.7  |

Note: 1 – Learning goals, 2 – Criteria for success, 3 – Tasks and activities that elicit evidence of student learning, 4 – Questioning strategies that elicit evidence of student learning, 5 – Feedback loops during questioning, 6 – Individualised descriptive feedback, 7 – Peer assessment, 8 – Self-assessment, 9 – Collaboration, and 10 – Use of evidence to inform instruction.

3.4 Second phase of data collection

Table 5 presents the survey results of the teachers’ responses for every criterion of formative assessment. The highest mean score is for item 10. By contrast, the lowest mean score is for item 9.

Table 5. Survey results of teacher self-reflection (N = 3).

| Items            | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   |
|------------------|------|------|------|------|------|------|------|------|------|------|
| Extensively (4)  | 1    | 2    | 1    | 0    | 0    | 1    | 1    | 0    | 0    | 2    |
| Reasonably (3)   | 2    | 0    | 1    | 2    | 3    | 2    | 1    | 3    | 1    | 1    |
| Partial (2)      | 0    | 1    | 1    | 0    | 0    | 1    | 0    | 2    | 0    |      |
| Limited (1)      | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |      |
| Mean Score       | 3.3  | 3.3  | 3    | 2.7  | 3    | 3.3  | 3    | 3    | 2.3  | 3.7  |

Note: 1 – Learning goals, 2 – Criteria for success, 3 – Tasks and activities that elicit evidence of student learning, 4 – Questioning strategies that elicit evidence of student learning, 5 – Feedback loops during questioning, 6 – Individualised descriptive feedback, 7 – Peer assessment, 8 – Self-assessment, 9 – Collaboration, and 10 – Use of evidence to inform instruction.
Table 6 exhibits the frequency distribution of the students’ responses in the second phase of the study. The highest mean score is for item 3. On the contrary, the lowest mean score is 2.9 for both items 7 and 10.

Table 6. Survey results of student selfreflection (N = 15).

| Items         | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  |
|---------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Extensively (4) | 8   | 5   | 10  | 7   | 8   | 9   | 4   | 7   | 9   | 8   |
| Reasonably (3) | 4   | 7   | 4   | 3   | 5   | 2   | 6   | 7   | 2   | 1   |
| Partial (2)    | 2   | 1   | 1   | 3   | 2   | 3   | 4   | 1   | 3   | 2   |
| Limited (1)    | 1   | 2   | 0   | 2   | 0   | 1   | 1   | 0   | 1   | 4   |
| Mean Score     | 3.3 | 3.6 | 3.4 | 3.3 | 2.9 | 3.4 | 3.3 | 2.9 |

Note: 1 – Learning goals, 2 – Criteria for success, 3 – Tasks and activities that elicit evidence of student learning, 4 – Questioning strategies that elicit evidence of student learning, 5 – Feedback loops during questioning, 6 – Individualised descriptive feedback, 7 – Peer assessment, 8 – Self-assessment, 9 – Collaboration, and 10 – Use of evidence to inform instruction.

3.5 Third phase of data collection

Table 7 presents the thematic analysis results of the structured interviews with the teachers to elicit how they understood and applied formative assessment in Science education. The interviewees had varied viewpoints about formative assessment. The brief responses expressed in concordance are, providing feedback to advance learners, the purpose of formative assessment is checking understanding of the topic, and there are challenges in planning the assessment.

Table 7. Thematic analysis results from the teacher interviews (N = 3).

| Themes                      | Summarised responses (% responded)                                                                 |
|-----------------------------|--------------------------------------------------------------------------------------------------|
| 1. Purpose of formative assessment | Checking understanding of topic (67%); Testing knowledge (33%)                                      |
| 2. Tools used in formative assessment | Giving short quizzes (33%); Giving questionnaire (33%); Analysis of knowledge (33%); Providing written examinations (33%) |
| 3. Benefits of formative assessment | Differentiate level of understanding (33%); As a self-reflection (33%); To assess quickly the strengths and weaknesses (33%) |
| 4. Evidence of learning     | Students asked questions (33%); Students’ satisfaction (33%); From the students’ language and facial expressions (33%); By asking the students directly (33%); By getting clarifications from the students (33%); Admitting to limitations (33%) |
| 5. Strategies for advance learning | Giving extended topics (33%); Providing feedback to the students (100%)                          |
| 6. Challenges in planning the assessment | Assessment Planning (67%); Lacking motivation (33%); Students not responding to some assessment questions (33%) |

The findings obtained from this study provided an overview of the strengths and weaknesses of the formative assessment practices in Science education at a private school in Brunei. Based on the classroom observations, surveys and interviews, the weaknesses, such as the partial use of formative assessment and few student-led discussions that outweigh the strengths of the current formative assessment practices at this particular secondary school. In analysing the reported qualitative and quantitative data, there are six points that needs to be highlighted.
1. Formative assessment was only practiced partially by the teachers in the classroom setting. One probable reason is that the teachers’ understanding of formative assessment was parallel to summative assessment.

2. The students were able to understand the learning goals at the start of the lesson with the added presentation using visual aids. For example, in one of the Physics lessons, a thermal expansion was brought to the class to stimulate the students’ interest in the topic.

3. The students perceived that their tasks and activities were connected to the learning goals and these goals will be able to elicit evidence of learning. They had opportunities to ask questions but only a few students were involved in the discussions. Furthermore, it was observed that the students preferred to copy and write the notes rather than being involved in the student-led activities. This observation implied that the students relate copying and writing notes as one of the task activities thereby enabling them to learn the topic.

4. In reporting the participants’ self-reflection of formative assessment, item 4 on the use of evidence to inform instruction had the highest mean score for the teachers (3.7 or 93%) but it is the lowest mean score for the students (2.9 or 73%). There were opposing views on collecting evidences of student learning connected to the learning goals. Thus, the teachers’ efforts to modify their teaching styles in accommodating learning had not been executed extensively to impress upon the minds of the students.

5. Although the teachers assessed the students’ mastery of the topic, peer assessment, as discerned by the students, had not been explored thoroughly. The absence of peer assessment restricted the students’ exposure to a variety of work that may help them incite their cognitive processes. This insight validated the teachers’ self-reflection on having less collaboration to deepen the learning experience in the classroom.

6. The teachers gauge learning experience based on the students’ reactions to the words and body language. Using portfolios, journals, rubrics, checklists or graphic organiser had been overlooked in the lessons. Importantly, based on the findings from previous studies [8-15], the use of such tools may assist in making learning experience more meaningful by allowing and supplementing teachers to impart evidence-based descriptive feedback to their students before, during, and after the lesson.

Generally, despite the teachers’ attempts to improve the process of teaching and learning, there is a need to change their mindsets and upgrade their skills to implement the formative assessment successfully in Science education. Exploring the differences in the understanding and implementation of formative assessment practices by secondary teachers in Science education has revealed important facets for further research undertakings. Based on the findings of the study, there are several suggestions and recommendations that may be taken into consideration, such as the need to conduct school-wide investigation of the current formative assessment practices in the secondary school section to identify gaps between teaching and learning; to review existing curriculum to determine how to embed formative assessment aligned with the learning goals, content, and outcomes; to establish mentoring and coaching programme to assist the teachers in making significant transitions in mindset and skills for effective implementation of the formative assessment; to develop an evaluation tool to be used for to ensure that criteria for success in the implementation of formative assessment practices are achieved; and to organise student-led conferences to allow the students to have reflection and take responsibility for their learning as they collect, compile, and present them using a portfolio or graphic organiser.

4. Conclusions
Formative assessment has its advantages and disadvantages when it comes to validating student success. Therefore, teachers must determine how to blend formative assessment with other approaches in order to have a meaningful evaluation of student learning. As a consequence, teachers need to keep abreast with emerging trends that shape the future of teaching and learning.
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