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INNOVATIVE SCIENCE EDUCATION ASSESSMENT – LINKING THEORY WITH PRACTICE

Coral Campbell
Deakin University
<cjlc@deakin.edu.au>

Abstract: This paper presents an assessment approach which demonstrates the characteristics of excellent assessment. In a third year Science Education unit in an undergraduate degree in teacher education, assessment is seen as an integral part of the learning process. Learning outcomes are improved for the students and they appreciate the validity of the assessment. Assessment is an important aspect of any unit in higher education but should be seen, not as an end in itself, but rather as a means for educational improvement. Using the assessment task as an illustration, this paper will discuss the theoretical framework of assessment. It will describe how the unit, delivered in a school-based mode, provides opportunity for students to link their theoretical understandings with practical applications, drawing together the academic debates with the first-hand experiences. It will illustrate how the assessment task itself embeds the principles of constructivism and conceptual change models in science education. Finally, the paper will highlight the benefits of this assessment approach with particular reference to the student learning.

An Overview of Assessment

In our market driven society and outcomes-based education, the need to measure our accomplishments has caused a greater focus on assessment at all levels. Byrne and Flood (2003, p135) state “Higher education institutes world-wide are experiencing a wave of quality evaluation, as demand for public accountability escalates”. There are enormous pressures on universities to produce graduates who have a range of abilities – general competencies, enterprise skills and other qualities (Brown and Knight, 1994, p12). In addition to this, universities are facing increasing student numbers whilst resources have been shrinking (Harris and Viney, 2003, p413). The drive to remain viable has led to a more diverse student population and in most cases a student body which will face an ever increasingly complex world (Jackson and Ward, 2004, p425). There are several factors which challenge the previously held views on the role and practice of assessment. These include the changing nature of tertiary students today, the importance of the development of generic skills, the increased class sizes, the development of on-line and new technologies and the increased incidence in plagiarism (James, McInnis and Devlin, 2002, p2). With most full-time students working part-time to support themselves through university, the reality is that many of them see the assessment as being at the crux of their unit. “For most students, assessment requirements literally define the curriculum” (James, McInnis and Devlin, 2002, p7). Other authors support this view. Nieweg (2004, p203) quoting Van der Vleuten and Driessen (2000, p9) states that “for students the curriculum is exactly the same as the assessment programme. They do whatever this programme requires and usually nothing beyond this.” This is in contrast to most university lecturers who see the content of their unit as being the most important aspect. If we accept this belief, then we must change our assessment practices so that they become tools of learning. Nieweg (2004, p204) states that it is “appropriate to make assessment policy an integral part of the redesign of the curriculum…”

Within the higher education system which deals with accreditation of individuals through the completion of set courses, assessment is an important part of the accreditation process. Accomplishment is not seen just as the completion of a unit of work, but the extent to which the student has understood and engaged with the material to be learnt. Therefore, assessment can be seen to fulfil a number of different purposes (Earle, 2003). One is the assessment of learning which occurs at the end of a unit of work, frequently termed summative assessment. “In summative assessment, students are graded at the end of a module, unit or course. Summative judgements are also used to accredit learners at the end of a programme.” (Falchikov, 2005, p3). Another is assessment for learning, or what is commonly known as formative assessment. Falchikov (2005, p3) states that formative assessment is used for feedback and also to identify potential for improvement. Finally, assessment can be seen as learning, where the assessment task itself forms the basis
for student learning. This emphasises the student’s role in learning – the development of reflection and self-evaluation as a part of assessment.

The American Association for Higher Education identified nine principles of good practice for assessing student learning (AAHE, 2005).

- The assessment of student learning begins with educational values
- Assessment is most effective when it reflects an understanding of learning as multidimensional, integrated and revealed in performance over time.
- Assessment works best when the programs it seeks to improve have clear, explicitly stated purposes.
- Assessment requires attention to outcomes but also and equally to the experiences that lead to those outcomes.
- Assessment works best when it is ongoing not episodic.
- Assessment fosters wider improvement when representatives from across the educational community are involved.
- Assessment makes a difference when it begins with the use and illuminates questions that people really care about.
- Assessment is most likely to lead to improvement when it is part of a larger set of conditions that promote change.
- Through assessment, educators meet responsibilities to students and the public.

These assessment principles will be used in evaluating the assessment approach of the school-based science education unit.

Description of the School-based teaching

In a third year Science Education unit, students undertake micro teaching as part of the unit. An essential component of the unit and hence the assessment tasks is the fact that the unit is taken within schools. Deakin staff and the students move out into a school for the duration of the tutorial time – approximately three hours. In that time, students undertake a discussion related to pedagogical issues, modelled teaching, ‘hands-on’ activities which they can use with primary children and their own micro-teaching. The discussion about pedagogy can be anything from the theoretical underpinnings of constructivism through to the use of technology in science teaching. It is taken in tutorial format with discussion and exchange of ideas being a large part of the session. In the week leading up to their school-based tutorial, students are expected to undertake relevant readings from their text so that they are informed for this debate. In the modelled teaching component of the tutorial, the lecturer models some teaching ideas, explaining the science concepts, how to teach for conceptual change and allows time for the students to trial some of the activities themselves. In the third stage of the tutorial, students actually teach. They work in pairs with approximately eight primary aged children. Across the ten weeks of their school-based tutorial, they teach six lessons by copying what has been modelled to them in the tutorial. For the other four weeks, they put into place their own sequence. This teaching sequence requires them to probe children’s prior understandings of science concepts, develop a curriculum plan based on the knowledge they gain and then teach the unit. As they teach the unit, they must apply formative assessment strategies to assess children’s developing knowledge and finally use summative assessment to gauge the overall development of children’s conceptual understanding. They then assess the effectiveness of the unit in relation to its role in challenging children’s concepts and moving the children’s understandings further. Finally, the students report their findings. The assessment task (described below) is broken up into two smaller assignments. The first assignment relates to the probing activities and how the students interpret their findings. The second assignment relates to the rest of the teaching sequence.

The use of schools adds credibility to the science education unit and re-positions the assessment task as a deliberate and strategic tool for teaching and learning. Organising the schools, the micro-teaching groups and the further requirement of taking materials out to schools requires additional workload for lecturers. However, the belief in the benefits of this approach and the value to the students in terms of their readiness to teach science, outweighs these other consideration.

The school-based approach has additional benefits for the school community within which it is held. Teachers comment on how they are revitalised by watching the Deakin students undertaking the teaching
tasks. The science content adds depth to the existing school science program, supplementing both content and providing a different approach to teaching. Many current teachers have not engaged with recent literature on constructivist principles, or if they have, have not had the opportunity to translate this into practice. Observation of the Deakin students gives the staff professional development in an incidental manner.

The Assessment Task

Historically, the assessment started as three to four separate lessons which were taken out at a school. The tertiary students attended their normal university tutorials for most of the semester and then went into schools for several weeks to teach primary aged children. Major shortcomings of this approach were that this did not allow the Deakin students to develop relationships with the school children or to become familiar and comfortable in a school situation. In response to students’ positive comments about their teaching experiences as part of the assessment, the entire unit became school-based. Additional time in schools allows modelling of teaching and for the students to practise their skills before developing curriculum and teaching their units.

The previous assessment tasks associated with this unit were based on text-book reports and assignments. This did not produce the same in-depth understandings and knowledges that the students gain from the current assessment task.

The assignments could be made better. As teachers we are told that reading from a text and answering questions is not an effective method of learning, however, that was the basis for the first assignment. (Science education student, 2000)

After this year (2000), the assignments were changed. The text-based assignment was removed and the second assignment (based on the small-group teaching situation) was broken into two parts to reflect the amount of work required by students to plan, teach and evaluate their own teaching sequence.

The assessment task therefore, has three aspects: the planning and delivery of a four lesson sequence; the reflective process in between and the written report which details the Deakin students’ developing understanding underpinned by the teaching of their cohort of children. The assessment is grounded in an authentic, school-based learning experience. Students, while undertaking the assessments, are actually undertaking a much larger range of teaching and learning processes, all embedded in the assessment task. In the probing phase, they develop “activities that engage children’s attention and interest, and explore with them their ways of looking at and representing phenomena” (Deakin, 2005, p10). These are sometimes called ‘elicitation’ activities. Deakin students probe children’s prior science understandings. In doing so, they put constructivist theory into practice, in particular the most recent research around conceptual change models within the science teaching framework. As they undertake the probe, they use a number of questions and have to evaluate their questioning skills as they gather responses from children. In situ, they have to make judgements about their questioning and have to refine or add to what they are requesting of the children. The students have to analyse the children’s responses and make a determination about their understandings and how they can address these through subsequent teaching. This analysis is closely related to a real teacher’s practice.

The Deakin students then plan a three-four week teaching sequence. This planning process also parallels that of a practising teacher. They need to take into account students’ current knowledge, what concepts they wish them to learn, what teaching strategies are most appropriate for the children involved, and how they will assess their learning. As the Deakin students implement their curriculum unit, they are expected to review each lesson and make adjustments to their teaching plan based on their current findings. Again, they are operating as a practising teacher. The teaching experience itself allows our students to integrate teaching theories with practical skills. The students start to develop pedagogical content knowledge, that intermix of a content knowledge and teaching strategy within a particular context. Husu (2002, p15,) states that teachers’ pedagogical knowing is about being “involved in their action and reflection and made combinations of such features as intellectual skills, virtues, habits of mind, appropriate social behaviour”. The intensity of the micro teaching situation allows the students to concentrate on their teaching skills rather than discipline or management issues.
To understand the full benefits of this school-based teaching and the assessment task itself, it is valuable to revisit some of the accepted views about how students learn and apply these not only to what the tertiary students are undertaking, but how their own teaching of children is influenced.

The Reflective Process: Constructivist theory and ideas around conceptual change

Constructivism as a theory of learning and indeed as a theory of knowing is widely accepted by science educators (Skamp, 2004, p11). Skamp (2004, p11) states that “all knowledge is a human construction”. The general understanding is that what students learn is influenced by their prior understandings and how they link new ideas and experiences to these to build new concepts and information. Vygotsky (McInerney and McInerney, 2001, p41) also expands the current view on constructivism to include the idea that people learn in social situations, that social interactions influence learning. Driver, Asoko, Leach, Mortimer and Scott (1994, p7) discuss the role of social constructivism in science education and state, “If learners are to be given access to the knowledge systems of science, the process of knowledge construction must go beyond personal empirical enquiry. Learners need to be given access not only to personal physical experiences, but also to the concepts and models of conventional science.” If we accept these statements, then we realise that the Deakin students are actually modelling these three premises. By undertaking their teaching sequence they are experiencing things themselves, by working with a partner and with their contact with children, they are involved in a social interaction, and they do so with the tools of both the concepts and models of science teaching.

Part of the constructivist theory relates to the idea of conceptual change or growth as students are exposed to other experiences, other students’ views and the reflective process. The related theory indicates that children and adults holding alternative ideas about complex scientific ideas resist changing those ideas (Beeth, 1995, p1). They need to be challenged in a number of ways and offered conflicting experiences before the conceptual understandings are likely to change. Conceptual change, or more appropriately conceptual growth, has a number of possible outcomes (adapted from Skamp, 2004, p14)

- Students accept the new concept but not necessarily replace the old, leading to the holding of two concepts which are contextually based.
- The formation of an intermediary concept – another alternative concept, more correct than previous but not scientifically accurate.
- The rejection of any contradictory concept

For conceptual growth to occur, students have to be dissatisfied with their current understandings, the new experiences must be able to be linked with prior knowledge and can be applied to new situations and the new learning must make sense to the learner (Skamp, 2004, p14).

The Deakin students must have an understanding of constructivism and conceptual change to be able to reasonably guide their children’s learning. However, these ideas can also be applied to the Deakin students. In order to assist the primary students, the Deakin students need to reflect on their own teaching practices. Through this active, reflective process, the students are undergoing conceptual change as they re-think their understandings of how children learn. This metacognitive process is support by Beeth and Hewson (1997, p5) who state that ‘the ability to reflect on competing ideas’ is part of the conceptual change process.

As the students are continually making judgements about the children’s learning and adjusting their teaching, they are modelling the best practice of teachers.

The Written Component

At the completion of the teaching sequence, students are required to submit two written reports. The first report, based on the probing lesson, includes a description of the probing activities, any questioning, children’s written work and oral comments. Students provide a list of conceptions that were probed and then discuss the variations in understandings within the group of children, giving explicit reference to children’s work (verbal, written, drawings, actions). Aspects addressed here could include responses to the following questions (Deakin, 2005, p12):

- Were their understandings similar?
- Were some students’ understandings ‘closer’ to scientific understanding than others?
- Did some of their ideas match those described in the literature?
- Were there variations in the way they approached the tasks that are significant for their science learning?
- What are the implications of your findings for a teaching sequence that might flow from this probe session?

As questioning plays such a major role in the probing activities, students are required to comment on the effectiveness of their questioning, again by referring to student responses. They are asked to evaluate the efficacy of their probe activities for eliciting children’s ideas in science and discuss what the implications are in terms of teaching science by referring to educational literature. The assessment criteria for this assignment are explicitly stated (Deakin, 2005, p12):

- Appropriateness of the methods by which student’s understandings are probed (this includes the questioning and activities).
- Insight shown into children’s understandings from the probe activities.
- The clarity of evaluation of your questioning including suggestions for improvement.
- The clarity of evaluation of the probe activities for exploring children’s understandings of science
- Depth of discussion of the implications of the findings for teaching, drawing on the literature into children’s science understandings.

The second assignment reports on the remainder of the teaching sequence. This report provides an overview of the nature and purpose of the teaching sequence including a rationale and an account of the decision making that occurred from lesson to lesson (relating to the formative assessment of the children’s learning). It then provides an evaluation of the sequence in terms of children’s learning, supported by examples of children’s responses. It finishes with the Deakin student’s evaluation of the how successful the teaching was in respect to primary school student learning and the effectiveness of any assessment strategies used. The assessment criteria for this second assignment are (Deakin, 2005, p15):

- The quality and coherence of the sequence.
- The justification of the aims and purposes of the sequence.
- Insight with which children’s science understandings and/or skills are assessed (i.e. how effectively are individual children’s understandings probed and reported on?).
- Extent to which assessment is supported by evidence of children’s work (written, verbal, drawings, actions etc.)
- Insights shown in the evaluation of the sequence, based on evidence.
- Extent of familiarity with ideas in the science education research literature.

**Benefits of the Assessment Approach**

There are aspects of the assessment task which enhance other teaching and learning experiences. These include:

- the development of relationships with the children. As their relationships with children develop, the students start to appreciate the role of pastoral care and the inherent responsibility of educating others.
- Assessment is seen by tertiary students as integral to the learning process. Assessment guides the development of subsequent teaching episodes. This is an extremely relevant aspect as it is providing training for the incorporation of assessment into the development of curriculum.
- Students recognise that assessment can have different purposes – from the ongoing formative assessment of learning to the summative or ‘judgement’ aspects.
• The tertiary students start to gain an appreciation of the many aspects of learning which can be assessed – knowledge, skills, behaviours and attitudes.

• Students indicate an understanding of the links between the development of children’s understandings, the teaching strategies employed to enhance their understandings and the manner of assessment of children’s knowledge. This is clearly articulated in the report they write as part of the assessment.

Clearly, these additional benefits provide support for the continuing use of this assessment task. However, positive student feedback relating to the assessment is another compelling factor to consider. Faculty of Education students have always had an involvement in the improvement of a unit and its assessment. At the end of each semester’s work, every student is invited to provide an anonymous evaluation of the unit. One aspect requires students to provide an evaluation against the unit’s assessment tasks.

Example

Please indicate with a tick your reaction to the statements below; from 'Strongly agree' (SA) to 'Strongly disagree' (SD).

<table>
<thead>
<tr>
<th>The unit program</th>
<th>SA</th>
<th>A</th>
<th>N</th>
<th>D</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 The unit was successful in increasing my knowledge of science.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 The unit was successful in increasing my confidence and ability to effectively teach science.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 The text (Skamp) was useful in supporting my learning.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 The assignments have been valuable in supporting my understandings about teaching science.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Working with children in schools was a supportive aspect of the course in increasing my confidence to teach science.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 The work load in this unit has been appropriate.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 The balance between learning about science ideas, and strategies for teaching science, has been appropriate.</td>
<td></td>
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</tr>
</tbody>
</table>

In the majority of evaluations, the comment ‘The assignments have been valuable in supporting my understandings about teaching science’ receives a ‘Strongly agree’ or ‘Agree’ response. These unit evaluations are judiciously read and overall trends noted. Students are provided with many opportunities to discuss the school-based teaching and the assessment tasks. In recent times, these comments have all been positive and reflect the validity of the assessment.

I am a lot more confident now to teach science (Science Ed student, 2001)

I feel better equipped to teach science in schools. (Science Ed student, 2002)

I think this unit has helped me link science ideas to the broader context of the world in which we live. This being the case, it makes teaching science more engaging and meaningful. (Science Ed student, 2002)

Hands-on – allowed me to see what my students will be seeing. Important to teach teachers to always view things from learner’s perspectives. (Science Ed student, 2004)

This assessment approach has greatly benefited students by preparing them for their subsequent role as a teacher. It adds validity to all their education studies by providing opportunities unlike any other unit they study. It is extremely powerful in that by showing how science education fits into current educational practice, it also supports the other units that students study. The students start to realise how other units’ theoretical perspectives may also align with a teacher’s practice.
In the first year of our course we talked about theories such as those of Piaget and never had
the opportunity to see it in practice. During this unit with the probes we were able to put in into
practice and related it to real life. And for me it’s honed my skills in questioning students,
using open questioning, and looking at the different types of questions a teacher could use in a
classroom had really good general application. Science Ed student 2005

Students commented recently on the benefits of the school-based assessment task when asked “In what
ways has the assessment structure been different to other forms of assessment conducted at the University?

Other subjects, like maths, we have interviewed students; but we haven’t spent weeks with
them.

Puts in more from the perspective of the teacher, instead of reading it from books, so it has real
meaning for us.

It has allowed us to team teach, and so bounce ideas off each other.

Three Science Education Students, 2005

A more recent development within this program, related to the assessment task, is the request by school
teachers for our students to provide a short report on the children’s science understandings. This is of
significant benefit to the teachers and the school community as it provides yet further data on children’s
accomplishments. The teachers have provided some feedback to Deakin students over the last few years,
but would like to strengthen the links by formalising the exchange of information. This would be in the
form of a proper feedback session in which our students would be given additional strategies to enhance
their teaching.

An experienced teacher (with a PhD in Science education) involved with the school-based program, was
asked recently to discuss it with particular reference to the assessment approach. Her comments of the
assessment task indicate that she rates it extremely highly in terms of preparing students for their fitness to
practice as new teachers.

I think that the program is excellent because the assessment tasks match very well with best
practice as a classroom teacher. The assessment tasks are asking the Deakin students to
explore a range of ways to assess students so they are not just looking at one form such as
pencil and paper; catering for students with different learning styles and different learning
abilities; some of the students have mentioned in their assignments that when they have looked
at the students comments in written sentences sometimes it has been different when orally
given. The teaching has change from teacher directed to more student centred.

Discussion

From the comments above, it would appear that this assessment approach is successful in bridging the gap
between theory and practice. However, would it be considered good assessment in terms of how it
addresses some of the principles of good assessment practices? The assessment approach, when taken as a
whole, relates strongly to the three core objectives for higher education assessment as identified by the
University of Melbourne’s Centre for the Study of Higher Education (2005). It is assessment “that guides
and encourages effective approaches to learning”. It does this by providing students with experiential
learning situations which are valued for their direct applicability to their chosen profession. It “validly and
reliably measures expected learning outcomes, in particular the higher-order learning that characterises
higher education”. Students’ learning outcomes are directly measured by the ongoing success of the
assessment task in which they are challenged to devise their own solutions to any teaching issues. Finally,
it “defines and protects academic standards” in that the report the students complete as part of the
assignment requires them to relate to the theoretical components of their study and draw together many
different aspects of their learning into a cognate ‘whole picture’. It is an example of exemplary assessment
which ‘enhances learning by enhancing assessment’ (University of Melbourne, 2005).

If we were to consider the nine principles of good assessment indicated by the American Association for
Higher Education (2005), does this approach fulfil any or all of the components?
The assessment of student learning begins with educational values. Assessment is seen as a way to improve student learning rather than just as a measurement of what is learnt. In this school-based assessment approach, students are encouraged to reflect and strive for professional improvement.

Assessment is most effective when it reflects an understanding of learning as multidimensional, integrated and revealed in performance over time. This component relates to students using what they know and how they use it. Clearly in this approach, Deakin students are using a number of teaching strategies, employed over time, to ascertain their own students’ learning. This illustrates the multidimensional complex nature of this assessment approach.

Assessment works best when the programs it seeks to improve have clear, explicitly stated purposes. In the assessment tasks, criteria are clearly articulated before students attempt the school-based teaching. Opportunities arise for practice and trialling of activities before the actual teaching sequence takes place.

Assessment requires attention to outcomes but also to equally to the experiences that lead to those outcomes. The students are expected to reflect on the process, their own learning and the outcomes. The experiences, the development of the teaching sequence, the relationship with children are valued as valid learning opportunities.

Assessment works best when it is ongoing not episodic. According to the American Association for Higher Education (2005), “student improvement is best fostered when assessment entails a series of linked activities undertaken over time”. As the students teach, their reflections are taken across several weeks, their teaching is responsive to children’s learning on a weekly basis and they are progressively making judgements.

Assessment fosters wider improvement when representatives from across the educational community are involved. In this case, the involvement of classroom teachers who advise students, observe the teaching and provide additional resources, is seen as integral to the improvement of student learning as the students are enacting aspects of teaching in an authentic way. Teachers’ knowledge of their students and ways to engage individuals is information which is extremely useful to the student teachers.

Assessment makes a difference when it begins with the use and illuminates questions that people really care about. In this assessment approach, the students are gathering data which will provide them with useful information in future careers as teachers. The skills they gain will be directly applicable to their teaching. In evaluation surveys of the students, comments relate to the usefulness of the school-based and assessment in preparing the students for their role as teachers.

Assessment is most likely to lead to improvement when it is part of a larger set of conditions that promote change. Assessment in of itself does not change anything. Using the information from the assessment tasks as a form of self-evaluation is where the real learning comes into play and students’ exhibit improved learning outcomes.

Through assessment, educators meet responsibilities to students and the public. In undertaking this assessment, the students do exhibit greater understanding of theoretical aspects of learning, but also, are being better prepared for their future role. The responsibility to the broader educational community of primary schools is being met through the readiness of the undergraduate student to teach.
Conclusion

This paper set out to discuss the links between theory and practice using as an illustration an assessment approach undertaken by third year Science Education students in an undergraduate education course. It examined the role of assessment in higher education and the elements of effective assessment. In discussing the theoretical aspects of constructivism and conceptual change, the paper demonstrated how the assessment approach considered these aspects. Following a detailed explanation of the assessment approach, the views of students were highlighted to provide further evidence of the value of this approach. Finally the discussion returned to the purported principles of good assessment and illustrated how these were evident in the assessment approach used by Deakin students. In conclusion, the paper has covered many aspects of assessment demonstrating how the assessment approach in the science education unit at Deakin University links practice to theory. It has provided an example of a successful assessment approach which is additionally supported by reference to the literature on exemplary assessment in higher education.

References


Deakin University. (2005) *Primary Science Education Unit Guide.*


