Science Education International
Vol. 24, Issue 2, 2013, 212-226

Quality assessment by science teachers: Five focus areas

Frances Edwards[*†]

ABSTRACT: In order to teach science well, science teachers need to know what to focus on in order to ensure their assessment of student learning is meaningful and useful for the students' on going learning and development. The diversity and range of content and skills within the subject of science mean that the assessment capabilities required by science teachers are wide ranging and complex, requiring specialist knowledge and skills in the assessment of science learning as part of the teachers' pedagogical content knowledge (PCK). Based on a review of the literature this paper proposes a framework for quality assessment in science which focuses on five areas: teaching, students, evidence of learning, future decision-making and impact. This paper advocates a concurrent consideration of all five areas of the framework to provide a substantial, rich, broad, rigorous quality assessment approach on which teachers and students can base teaching and learning.

KEY WORDS: assessment capability, assessment literacy, science education, pedagogical content knowledge, evidence of learning.

INTRODUCTION

Quality assessment is central to good teaching and is inevitably a key component in learning environments that facilitate students' learning with understanding (Donovan & Bransford, 2005). The primary purpose of this paper is to contribute to quality assessment in the classroom by presenting five focus areas for science teachers. Through meaningful consideration of all five of these focus areas concurrently, teachers can plan, teach, assess and make day-to-day decisions in ways that will support student learning. The framework proposed in this paper has been developed for teachers of science across primary and secondary educational contexts, and should be of interest to an international audience. Based on the view that learning is socially and culturally constructed, these focus areas help teachers consider learning processes as well as outcomes within dynamic social contexts, and encourage teachers to think carefully about their individual students as well as whole classes as they learn science within these contexts.

[*] University of Waikato, New Zealand
† Corresponding Author: francese@waikato.ac.nz

THE NEED FOR QUALITY ASSESSMENT

Assessment is an integral part of learning and is seen as a key component in quality teaching; essential for raising student achievement by supporting learning (Absolum et al., 2009; Black & Wiliam, 1998a, 1998b; Crooks, 1998; Ministry of Education, 2007, 2011; Stiggins, Arter, Chappuis, & Chappuis, 2004). Because of the key role assessment plays in teaching and learning science, it is important that science teachers understand and use high quality assessment processes. Assessment can be thought of as the process by which knowledge or performance of an individual or group is appraised and resulting judgements are made, based on the consideration of evidence (Ministry of Education, 2011). Educational assessment involves teachers applying their understandings of how students develop skills and knowledge, attitudes and values in a subject domain. Then, through the collection of evidence of student performance and reasoning from this evidence, teachers work to understand what students are learning or have learned (Magnusson, Krajcik, & Borko, 1999; Mislevy, 1993; Pellegrino, Chudowsky, & Glaser, 2001). Appropriate interpretations of this data by teachers enable informed educational decisions to be made, related to outcomes such as students' achievement (or lack of achievement) of specific learning goals, and often lead to action (Bell & Cowie, 2001; Black & Wiliam, 1998b; Brown, 2008; Harlen, 2007).

The key constituents of quality assessment practice have been the focus of much research over the last 20 years, and many lists of definitions, principles and practices have been published as a result (Abell & Siegel, 2011; Absolum, 2006; Brookhart, 2011; Brown, Irving, & Keegan, 2008; Gardner, 2006; Harlen & James, 1996; Torrance & Pryor, 1998; Wiliam, 2006). Validity, including reliability, and manageability are key principles underpinning quality assessment, and from these principles specific descriptors of practice have been formulated.

More recently, assessment has been theorised from the perspective of socio-cultural theory or situated cognition (Gipps, 1999; Hay & Penney, 2012; Leach & Scott, 2003; Moss, Pullin, Gee, Haertel, & Young, 2008; Shepard, 2000). Such views highlight social interaction and participation, and characterise learning in terms of distributed cognition and embodied cognition, rather than simply as individual cognitive change (Hickey & Anderson, 2007). A socio-culturally informed learning theory also promotes a formative purpose for all assessment in teachers' and learners' work, and recognises the situated nature of learning, plus the fact that assessment, its routines and protocols, "shape peoples' understandings about what is important to learn, what learning is and who learners are" (Moss, Pullin, Gee, Haertel, & Young, 2008, p.9). Assessment seen in this light places the focus not on a particular instrument or activity, but on the

problem or questions to be addressed e.g. what to do next, or how to refine curricula (Moss, Girard, & Greeno, 2008). In answering these questions, multiple sources of evidence which involve the learners and their environment are used, and interpretations of the evidence need to take cognisance of the particular nature of the local context. From a sociocultural stance, a discursive approach to classroom assessment can be argued, in which classroom assessment begins with assessing collective knowledge represented by classroom discourse, rather than individual conceptualisations. Individual assessment only occurs later in the teaching cycle, and it is suggested that this leads to an improvement in the value of assessments for teaching and learning, and a minimisation of the negative consequences of assessment (Hickey & Anderson, 2007).

Assessment practice impacts students and teachers at many levels, including the way curriculum is presented and the ways teachers operate in classrooms, as has been well documented by a number of researchers (Donovan & Bransford, 2005; Gipps, Brown, McCallum, & McAlister, 1995; Levin & He, 2008; Popham, 2008; Thrupp & Easter, 2012). Assessment practice gives messages both to those assessing and those being assessed. For example, assessment practice may communicate what knowledge is valued and equated with achievement in a particular context. By choosing what to assess (and what not to assess) teachers are communicating messages of the relative values of particular aspects of curriculum to their students.

Quality assessment practices need to include a consideration of the 'fitness for purpose' of an assessment task/activity as well as consideration of the characteristics of the learners themselves, so that best choices are made regarding the nature and timing of assessment (Gardner, 2006). Doing this well allows for the confident use of assessment data by teachers in their decision making. This in turn leads to the improvement of current and future teaching and learning (Harlen & James, 1996).

ASSESSMENT CAPABILITY

Assessment capability can be defined as being "able and motivated to access, interpret and use information from quality assessment in ways that affirm or further learning" (Absolum et al., 2009, p. 19). This capability is developed by teachers, students and other stakeholders over time, and has been alternatively described by some as assessment literacy (Abell & Siegel, 2011; DeLuca & Klinger, 2010; Siegel & Wissehr, 2011; Smith, Worsfold, Davies, Fisher, & McPhail, 2011; Taylor, 2009; Volante & Fazio, 2007).

Teachers' knowledge about assessment (including what to assess and how to assess students) has been theorised as being part of the pedagogical content knowledge (PCK) that teachers develop (Grossman, 1990;

Magnusson et al., 1999; Shulman, 1986). A working definition of PCK, developed by Park and Oliver (2007), is put forward as:

> PCK is teachers' understanding and enactment of how to help a group of students understand specific subject matter using multiple instructional strategies, representations, and assessments while working within the contextual, cultural, and social limitations in the learning environment. (p.264)

Knowledge of assessment of science learning has been identified as an important component of PCK, not developed mutually exclusively from other components, but at the same time and in conjunction with other components (Park & Oliver, 2007). This component includes knowledge of the important dimensions of science learning to assess, assessment methods, and specific assessment approaches and activities (Park & Oliver, 2007; Tamir, 1988), and its development can be affected by a wide range of factors. Because of the nature of PCK and the integral role of assessment in teaching and learning, the development of PCK is a useful way of viewing the development of assessment capability for teachers.

Assessment in science education has been the subject of considerable research and review (Abell & Siegel, 2011; Bell, 2007; Bell & Cowie, 1997; Britton & Schneider, 2007). The way teachers teach in science has a degree of uniqueness from the way teachers teach in other subject areas and it is not fixed. For example, the expanded goals of the revised New Zealand science curriculum (Ministry of Education, 2007) move beyond traditional science content to include objectives on the nature of science, so this now needs to be reflected in the way science is taught and assessed. Because the PCK developed by science teachers includes knowledge about assessment in science (Magnusson et al., 1999), assessment capability cannot be separated from the science teaching context. General principles of assessment can be learned through a generic teacher education programme, but when it comes to specific assessment knowledge, the content and context are both important (Abell & Siegel, 2011). Assessment capability by science teachers includes their understanding and application of generic assessment concepts, as well as science-specific assessment knowledge; for example, the identification of the key science concepts that are important to assess, and how best to asses these. Therefore, the concept of assessment capability for science teachers intersects with their science PCK, and it is useful to consider such capability within this paradigm.

QUALITY ASSESSMENT FOR SCIENCE TEACHERS

Assessment capability, assessment literacy, assessment knowledge and skills, or assessment competencies have been defined and categorised by many educational researchers over the years. Standards, teacher competency lists, conceptual frameworks and lists of principles for assessment have been formulated by researchers and educationalists in a number of countries (Abell & Siegel, 2011; Brookhart, 2011; Moss et al., 2008). The New Zealand Teachers' Council (NZTC) has developed Registered Teacher Criteria (www.teacherscouncil.org.nz/rtc) in which aspects of assessment capability for teachers are embedded.

In recent work by Susan Brookhart, conceptions of formative assessment knowledge and skills are considered, alongside the knowledge and skills teachers need when working in the current climate of accountability and standards-based reform in the USA (Brookhart, 2011). She redeveloped a list of eleven competencies (I-IX) in educational assessment knowledge and skills for teachers that were seen as reflecting current teacher assessment needs and responsibilities. These were:

I. Teachers should understand learning in the content area they teach.
II. Teachers should be able to articulate clear learning intentions that are congruent with both the content and depth of thinking implied by standards and curriculum goals, in such a way that they are attainable and assessable.
III. Teachers should have a repertoire of strategies for communicating to students what achievement of a learning intention looks like.
IV. Teachers should understand the purposes and uses of the range of available assessment options and be skilled in using them.
V. Teachers should have the skills to analyse classroom questions, test items and performance assessment tasks to ascertain the specific knowledge and thinking skills required for students to do them.
VI. Teachers should have the skills to provide effective, useful feedback on student work.
VII. Teachers should be able to construct scoring schemes that quantify student performance on classroom assessments into useful information for decisions about students, classrooms, schools, and districts. These decisions should lead to improved student learning, growth, or development.
VIII. Teachers should be able to administer external assessments and interpret their results for decisions about students, classrooms, schools, and districts.
IX. Teachers should be able to articulate their interpretations of assessment results and their reasoning about the educational decisions based on assessment results to the educational populations they serve (student and his/her family, class, school, community) .
X. Teachers should be able to help students use assessment information to make sound educational decisions.

> XI. Teachers should understand and carry out their legal and ethical responsibilities in assessment as they conduct their work. (Brookhart, 2011, p.7)

This framework is useful and could be further developed by placing a focus on the context of the assessment. Other researchers (eg Hay & Penney, 2012; Moss et al., 2008) thus take a broad view of assessment to look beyond the practicalities and technical issues surrounding assessment, and take cognisance of the particular environment within which assessment is situated. The fundamental perspective of assessment being a social activity and occurring within social, economic, cultural and political contexts, means that the focus needs to be broad enough so as to consider these factors as well. The impact that assessment has on individuals and wider communities is a further factor to consider. With this in mind, a socio-cultural perspective adds layers of complexity on to what is already seen as a challenging task: assessing learning in a meaningful and useful way.

FIVE POINTS OF FOCUS

This framework condenses Brookhart's list of competencies and adds a socio-cultural perspective to produce five key focus areas for teachers to engage with quality assessment in science. This rationalisation makes the list more manageable for teachers, and reflects the logical connection between the eleven points in Brookhart's extended list. Through the concurrent use of the five focus areas, described in this framework, teachers are guided to plan for, and use, assessment in an informed way.

Focus 1: Focus on teaching

Good teacher planning feeds good assessment

Teachers are better placed to assess well, if they consider the assessment components of their teaching during the planning stages. All science teachers would agree that understanding the content they are going to teach, and the ways students typically learn this content, is crucial for effective teaching and assessment (Henze, Van Driel, & Verloop, 2008; Macugay & Bernardo, 2013). However, early in the planning-for-teaching stages, science teachers need to articulate their range of intentions and goals for the lessons so they can communicate these to their students. The use, and communication, of clear learning intentions and achievement criteria for each topic is put forward as an important, initial aspect of good planning for teaching and assessment (Kennedy, 2008). These learning intentions then linked directly with the focus of what is taught and assessed (and, of course, how it is assessed). Understanding the pathways

students are likely to follow towards mastery of core concepts, also known as learning progressions, is an integral part of the process.

The effectiveness of "plotting a course between the domain of learning and the assessments, selected to embody it" (Brookhart, 2011, p. 6) depends on teachers'

(i) deep understanding of the content area, and
(ii) their knowledge of the way students learn and their particular learning context.

With such attributes, the science teacher can take care to match the teaching tasks and assessment tasks. For example, if a teacher is wishing a group of students to learn how to plan an investigation, they can be guided to learn this skill through a series of carefully planned tasks that scaffold this learning. The best method of assessment will by giving students the opportunity to provide evidence of their skill through actually planning investigations that are meaningful to them in the science laboratory or in the field. With a focus on good teaching, it is important to plan for assessment that is "learning oriented, authentic, valid and socially just" (Hay & Penney, 2012, p.64).

Brookhart (2011) refers to this focus as **assessment literacy** and identifies the following as a key teacher feature: promote learning in the content area they are teaching by their ability to articulate clear and useful learning intentions, and their ability to communicate what achievement within such learning intentions looks like. These directly align with the focus on teaching in this framework.

Focus 2: Focus on students

Good assessment addresses the intended student learning and is responsive to group/class and individual feedback needs

Quality assessment in science needs to acknowledge and meet the requirements of the specific students whose learning is being assessed. Therefore teachers must focus on their students' needs. Teachers are required to develop the skills to be able to design assessment tasks (which gather achievement evidence related to progress and/or mastery), bearing in mind their students' aptitudes, prior learning and the context in which they are working. With this in mind, it is important that students understand the purposes of any assessment undertaken by the teacher (or undertaken as self-assessment), as well as the ways they can approach and engage in such assessment tasks. By empowering students with this information, teachers are increasing learner **assessment capability.**

To promote learning, science teachers need to go beyond assessing their students and need to develop skills to provide meaningful and help-

ful feedback to their students in response to the work they produce (Brookhart, 2011; Hattie, 2009; Hattie, Timperley, & Clarke, 2003). It thus stands to reason that by getting to know their students, teachers will be able to provide this feedback in a form most effective to each individual. This includes any grading or scoring of students' efforts. Brookhart (2011) points out that this needs to be done in ways that lead to improvements in student learning, growth or development. As the students are central to the learning and assessment process, the design of assessment tasks, methods, marking schemes etc. needs to be carried out in ways that enable feedback that best supports students' on-going learning. This means the specific assessment tasks should be designed with the students in mind, their strengths and interests, culture and language.

From a socio-cultural perspective, assessment of students need to be considered at both an individuals and a group/class level. Adopting a culturally responsive practice is essential in all aspects of teaching and assessment, and as part of this, recognising the wider learning context (which includes the communities in which students exist) is required. Follow any assessment task, teachers can be expected to debrief the class or individuals, and hence assist students in the productive use of assessment information and feedback, and reduce inappropriate interpretations (and the consequential effects of these). Hay and Penney (2012) emphasise the importance of traversing and negotiating social relations in assessment. These social relations, which the teacher needs to consider, include aspects of power relations, rules of engagement i.e. how individuals interact with each other and treat each other. In practical terms then, teachers who get to know their students, and their students' communities, will possess knowledge that can help them assess their students more meaningfully, both through the tasks they design and use, and their interpretations of students' work.

Focus 3: Focus on evidence of learning

Quality assessment gathers evidence of student progress as a purposeful pursuit

Quality assessment requires a careful focus on the evidence of learning that is gathered from students, in order to enable judgements to be made about their learning. This focus on **evidence of learning** is a consolidation of the Brookhart dimensions IV, V and VII (listed earlier).

Certainly it is important for teachers to be knowledgeable and skilled in the use of assessment tools (technical aspects of assessment), as well as being able to decide on those which provide 'best fit' for the purposes for which they are being used. Nevertheless, it is the building on the technical aspects that is important so as to develop efficacy in the gathering of evidence of learning. **Assessment efficacy** refers to the "purposeful pursuit

of a desired result or effect" through assessment (Hay & Penney, 2012, p. 86), and depends on the teacher's understanding of the conditions under which evidence is best gathered and interpreted.

Evidence of science learning can be gathered via a wide range of methods, as indicated in Table 1.

Table 1. Methods for collecting evidence of science learning

Method	Description
Observation	Teacher observes the students during an individual or group activity
Report	Students produce an individual or group report
Practical investigation	Students carry out a practical investigation in groups
Test	Students participate in a class written text
Quiz	Students participate in an oral quiz
Matching exercise	Students participate in an oral or written match of text, pictures, shapes, designs, etc
Diagram	Students draw an illustrative diagram
Explanation	Students produce an oral or written explanation
Seminar	Students interact in a open discussion forum
Website	Students look up, evaluate and extract information from a website or websites

The choices teachers make when deciding what evidence to gather, and how to gather it, not only influence the classroom environment, but may have a great influence on assessment validity and reliability. For example, the use of ecologically valid assessment is important, allowing students the best opportunities to produce evidence of learning. Recently, there has been a move away from systems wholly dedicated to externally prescribed examinations (e.g. in countries such as New Zealand and Australia), and towards an integrated assessment system within the schools. This gives teachers the freedom and the responsibility to choose the best ways to elicit evidence of learning from their students. Good assessment can then be designed to be authentic and valid, best suited to the students by taking into consideration their strengths and interests. For example, some students may be able to provide better evidence of their learning orally, or by designing a web page, rather than by writing responses to examination questions or writing an essay.

Focus 4: Focus on future decision-making

A focus on future decision making requires assessment that is authentic for this purpose

Assessment data can and is used by teachers to make interpretations and decisions about what an individual or group know, or are able to do. Interpretations of this data are communicated to students, perhaps other teachers within their school, and to groups outside of schools such as parents, school communities, and government agencies. It is thus important that quality assessment is seen as being carried out and reported in ways that facilitate sound decision-making. The interpretation of assessment data and consequent decision making resulting in action is obviously linked directly to validity, as validity refers to the soundness of interpretations, decisions and actions (Moss, Girard, & Haniford, 2006).

Brookhart (2011) refers to two elements with respect to the interpretation and use of assessment data. Firstly, she explains that teachers should be able to articulate their interpretations of results and associated reasoning about decisions leading from this (to a range of stakeholders), and secondly, she focuses on the teachers' abilities to help students use assessment information to make sound decisions.

As teachers prepare tasks and use assessment to inform their next steps in teaching, or to determine levels of attainment that are reported to others, there is a need for teachers to focus on future decision making . For example, in science, a common use of assessment data is as a 'gatekeeping mechanism' to permit students to embark on specialty subjects in the senior school . If this is the purpose of the assessment data, then care must be taken to ensure that the right data is collected, in an appropriate manner, to allow the right decision to be made.

Focus 5: Focus on impact

Quality assessment allows the impact of the assessment to be ascertained

Research has shown that assessing students' learning is not a benign practice, as it does have direct impacts on students, including shaping their identity (Cowie, Jones, & Otrel-Cass, 2011). Assessment of students' learning can also have an impact on the curriculum, classroom culture, teachers and school leaders in the context of the assessment (Carr et al., 2005; Thrupp & Easter, 2012). This means a deep understanding of these impacts is needed so that a more accurate appraisal can be made of the use, value, and effect, of any student assessment.

Assessment practices are not neutral, but are value-laden in their construction and their consequences (Hay & Penney, 2012). Throughout the process of assessment, issues of power exist, and the disproportionate power that teachers have needs to be recognised and considered by those science teachers who want to assess well. This is because teachers (or higher authorities) most often choose what is to be assessed and how it is to be assessed and graded. These teachers have a particular view of knowledge and a cultural lens through which they view success. Teachers

and students, as well as other stakeholders, need to be very aware of the limits this places on the interpretations of particular results and the partial view any assessment activity gives related to students and their learning. Making meaning is a contextually and culturally situated activity. It is influenced by beliefs and values brought by the interpreter. Science teachers need to be aware of the range of impacts an assessment task they use may have on those around them, especially where the impacts are negative. The impacts might range from private feelings, only known by the person assessed, to widely publicised results which open (or close) doors to an individual's future pathways.

By focusing on an awareness of the impact or consequences of assessment, teachers may be more likely to

(a) design ways to assess science learning that are natural and perceived as an integral part of the teaching
(b) ensure valid assessment having meaning both in the eyes of the teacher and the students. and
(c) be careful in the way they interpret and make decisions based on their interpretations.

CONCLUSION

Quality assessment is an integral part of good teaching practice. Teachers need to know on what to focus in order to ensure their assessment of student learning is meaningful and useful for the student's on-going learning and development.

Five focus areas are put forward for teachers to use when considering their assessment practice. These are teaching, students, evidence of learning, future decision making and impact.

The five focus areas enable

(i) science teachers to consider their assessment practice within the wider context of the learning environment
(ii) both technical and sociocultural aspects of assessment to be acknowledged and valued.
(iii) the needs and care of individual students to be a focus,
(iv) science teachers to meet the requirements of their employing authority.
(v) science teachers to use these five focus areas as reference points as they continue to develop their assessment capability as part of PCK,.
(vi) broaden the factors that science teachers take into account when they assess the learning of their students.

REFERENCES

Abell, S. K., & Siegel, M. A. (2011). Assessment literacy: What science teachers need to know and be able to do. In D. Corrigan, J. Dillon, & R. Gunstone (Eds.), *The professional knowledge base of science teaching* (pp. 205–221). Dordrecht: Springer.

Absolum, M. (2006). *Clarity in the classroom*. Auckland, N.Z.: Hachette Livre N.Z. Ltd.

Absolum, M., Flockton, L., Hattie, J., Hipkins, R., & Reid, I. (2009). Directions for assessment in New Zealand: Developing students' assessment capabilities. Retrieved from http://assessment.tki.org.nz/Assessment-in-the-classroom/Directions-for-assessment-in-New-Zealand-DANZ-report

Bell, B. (2007). Classroom assessment of science learning. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education*. London: Lawrence Erlbaum Associates.

Bell, B., & Cowie, B. (1997). *Formative assessment and science education: Research report of the learning in science project (assessment)*. Hamilton, N.Z.: Centre for Science Mathematics Technology Education Research, University of Waikato.

Bell, B., & Cowie, B. (2001). *Formative assessment and science education*. Dordrecht and Boston: Kluwer Academic.

Black, P., & Wiliam, D. (1998a). Inside the black box: Raising standards through classroom assessment. *Phi Delta Kappan*, *80*(2), 139–148.

Black, P., & Wiliam, D. (1998b). Assessment and classroom learning. *Assessment in Education: Principles, Policy & Practice*, *5*(1), 7–74. doi:10.1080/0969595980050102

Britton, E. D., & Schneider, S. A. (2007). Large-scale assessments in science education. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education*. London: Lawrence Erlbaum Associates.

Brookhart, S. (2011). Educational assessment knowledge and skills for teachers. *Educational Measurement: Issues and Practice*, *30*(1), 3–12.

Brown, G., Irving, E., & Keegan, P. (2008). *An introduction to educational assessment, measurement and evaluation* (2nd ed.). Auckland, N.Z.: Pearson Education NZ.

Brown, G. T. L. (2008). *Conceptions of assessment: Understanding what assessment means to teachers and students*. New York: Nova Science Publishers.

Carr, M., McGee, C., Jones, A., McKinley, E., Bell, B., Barr, H., & Simpson, T. (2005). *The effects of curricula and assessment on pedagogical approaches and on educational outcomes*. Wellington, N.Z.: Ministry of Education.

Cowie, B., Jones, A., & Otrel-Cass, K. (2011). Re-engaging students in science: Issues of assessment, funds of knowledge and site for learn-

ing. *International Journal of Science & Mathematics Education, 9*(2), 347-366.

Crooks, T. (1998). The impact of classroom evaluation practices on students. *Review of Educational Research*, *58*(4), 438–481.

DeLuca, C., & Klinger, D. A. (2010). Assessment literacy development: Identifying gaps in teacher candidates' learning. *Assessment in Education*, *17*(4), 419–438.

Donovan, M. S., & Bransford, J. D. (Eds.). (2005). *How students learn: History, mathematics and science in the classroom.* Washington: National Academies Press.

Gardner, J. (Ed.). (2006). *Assessment and learning*. London: Sage Publications.

Gipps, C. (1999). Socio-cultural aspects of assessment. *Review of research in education*, *24*, 355–392.

Gipps, C., Brown, M., McCallum, B., & McAlister, S. (1995). *Intuition or evidence?* Buckingham: Open University Press.

Grossman, P. L. (1990). *The making of a teacher: Teacher knowledge and teacher education*. New York: Teachers College Press.

Harlen, W. (2007). *Assessment of learning*. London: Sage Publications.

Harlen, W., & James, M. (1996). Creating a positive impact of assessment on learning. Presented at the AERA annual conference, New York, NY.

Hattie, J. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. London; New York: Routledge.

Hattie, J., Timperley, H., & Clarke, S. (2003). *Unlocking formative assessment*. Auckland, N.Z.: Hodder Moa Beckett.

Hay, P., & Penney, D. (2012). *Assessment in physical education: a sociocultural perspective*. Florence, KY: Taylor and Francis.

Henze, I., Van Driel, J. H., & Verloop, N. (2008). Development of Experienced Science Teachers' Pedagogical Content Knowledge of Models of the Solar System and the Universe. *International Journal of Science Education*, *30*(10), 1321–1342. doi:10.1080/09500690802187017

Hickey, D. T., & Anderson, K. T. (2007). Situative approaches to student assessment: Contextualizing evidence to transform practice. In *Yearbook of the National Society for the Study of Education* (Vol. 106, pp. 264–287). Retrieved from: http://onlinelibrary.wiley.com.ezproxy.waikato.ac.nz/doi/10.1111/j.1744-7984.2007.00105.x/pdf

Kennedy, D. (2008). Linking Learning Outcomes and Assessment of Learning of Student Science Teachers. *Science Education International*, *19*(4), 387–397.

Leach, J., & Scott, P. (2003). Individual and sociocultural views of learning in science education. *Science and Science Education*, *12*, 91–113.

Levin, B., & He, Y. (2008). Investigating the content and sources of teacher candidates' personal practical theories (PPTS). *Journal of Teacher Education*, *59*(1), 55–68. doi:10.1177/0022487107310749

Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining pedagogical content knowledge* (pp. 95–132). Dordrecht: Kluwer.

Macugay, E. B., & Bernardo, A. B. (2013). Science coursework and pedagogical beliefs of science teachers: The case of science teachers in the Philippines. *Science Education International*, *24*(1), 63–77.

Ministry of Education. (2007). *The New Zealand curriculum for English-medium teaching and learning in years 1-13.* Wellington, N.Z.: Learning Media.

Ministry of Education. (2011). Assessment: Schooling sector. Ministry of Education.

Mislevy, R. J. (1993). Foundations of a new test theory. In N. Frederiksen, R. J. Mislevy, & I. I. Bejar (Eds.), *Test theory for a new generation of tests*. Hillsdale, NJ: Erlbaum.

Moss, P. A., Girard, B. J., & Greeno, J. G. (2008). Sociocultural implications for assessment II: Professional learning, evaluation, and accountability. In P. A. Moss, D. C. Pullin, J. P. Gee, E. H. Haertel, & L. J. Young (Eds.), *Assessment, equity, and opportunity to learn*. New York: Cambridge University Press.

Moss, P. A., Girard, B. J., & Haniford, L. C. (2006). Validity in educational assessment. *Review of research in education*, *30*, 109–162.

Moss, P. A., Pullin, D. C., Gee, J. P., Haertel, E. H., & Young, L. J. (Eds.). (2008). *Assessment, equity and opportunity to learn*. Cambridge, UK: Cambridge University Press.

Park, S., & Oliver, J. S. (2007). Revisiting the Conceptualisation of Pedagogical Content Knowledge (PCK): PCK as a Conceptual Tool to Understand Teachers as Professionals. *Research in Science Education*, *38*(3), 261–284. doi:10.1007/s11165-007-9049-6

Pellegrino, J. W., Chudowsky, N., & Glaser, R. (Eds.). (2001). *Knowing what students know: The science and design of educational assessment*. Washington DC: National Academies Press.

Popham, W. J. (2008). Assessment literacy for teachers: Faddish or fundamental? *Theory into Practice*, *48*(1), 4–11.

Shepard, L. A. (2000). The role of assessment in a learning culture. *Educational Researcher*, *29*(7), 4–14. doi:10.2307/1176145

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4–14. doi:10.2307/1175860

Siegel, M. A., & Wissehr, C. (2011). Preparing for the plunge: Preservice teachers' assessment literacy. *Journal of Science Teacher Education*, *22*(4), 371–391. doi:10.1007/s10972-011-9231-6

Smith, C. D., Worsfold, K., Davies, L., Fisher, R., & McPhail, R. (2011). Assessment literacy and student learning: the case for explicitly developing students "assessment literacy". *Assessment & Evaluation in Higher Education*, 1–17. doi:10.1080/02602938.2011.598636

Stiggins, R. J., Arter, J. A., Chappuis, J., & Chappuis, S. (2004). *Classroom assessment for student learning: Doing it right, using it well*. Portland, OR: Assessment Training Institute.

Tamir, P. (1988). Subject matter and related pedagogical knowledge in teacher education. *Teaching and Teacher Education*, *4*(2), 99–110. doi:10.1016/0742-051X(88)90011-X

Taylor, L. (2009). Developing Assessment Literacy. *Annual Review of Applied Linguistics*, *29*, 21–36. doi:10.1017/S0267190509090035

Thrupp, M., & Easter, A. (2012). *Research, analysis and insight into national standards (RAINS) project* (No. 1). Wellington, N.Z.: The New Zealand Educational Institute Te Riu Roa.

Torrance, H., & Pryor, J. (1998). *Investigating formative assessment: Teaching, learning and assessment in the classroom.* Florence, KY: Taylor & Francis. Retrieved from: http://www.eric.ed.gov/ERICWebPortal/detail?accno=ED439149

Wiliam, D. (2006). Assessment: Learning communities can use IT to engineer a bridge connecting teaching and learning. *Journal of Staff Development*, *27*(1), 16–20.