The Impact Of Quality Assessment Information On Teaching And Learning In Science Classrooms

Ann Northover and Sue Leslie
Educational Operations Division
Multi Serve Education Trust,
Auckland, New Zealand
(anorthover@multiserve.co.nz and sleslie@multiserve.co.nz)

Abstract

This paper reports on a New Zealand project aimed at raising the achievement of students in science. A key to the effectiveness of the programme is the collection of quality information about student achievement and the use of this information to identify and plan to meet student learning needs. By basing pedagogical decision-making on evidence rather than intuition, teachers in the project are initiating changes to teaching and learning programmes in a purposeful and productive manner. The focus of this paper is on this aspect – the testing, collation, aggregation and use of valid, reliable information on student achievement and attitudes in science using national and internationally recognised assessment tools. Analysis of assessment data and teacher and student attitude surveys has resulted in the development and implementation of school-based initiatives in participating schools. Subsequent evaluation of the impact of these initiatives has led to changes in approaches to teaching and close scrutiny of student learning and learning needs. Thus the use of data makes the invisible visible, allowing decisions to be made on the basis of evidence rather than assumption or intuition.

The Impact Of Quality Assessment Information
On Teaching And Learning In Science Classrooms

Introduction

Both the literature and direct experience suggest that the interrogation of present teaching practice is an essential precursor to the initiation and successful implementation of change strategies. The common practice of implementing programmes without first testing and evaluating their effectiveness denies us the opportunity to critically evaluate and improve our teaching, and hence student learning.

> *"Schools don't pilot anything. They just send ideas and innovations off and wave at them from the pier, never to be seen again."* (Wiggins, pers.com. as cited in Schmoker, 1999:31)

In 2001 the New Zealand Ministry of Education invited tenders for professional development programmes that would impact not only on teacher performance, but also and primarily on student achievement in science. Multi Serve Education Trust successfully bid for one such programme, based in three Waikato / Bay of Plenty communities.

The ***School Science Pilot Project*** (S^2P^2) programme is aimed at raising student motivation and achievement through a three-pronged approach:

1. The identification of students' current understandings of science concepts across the four contextual strands of the science curriculum (Ministry of Education, 1993) in order to build on strengths and to close gaps in knowledge.
2. The acknowledgement of motivational factors and their impact on learning in science – and to identify what contexts are appropriate and meaningful for students in the pilot schools. From this identification to design learning experiences of interest and relevance to students.
3. The identification by teachers of their pedagogical content knowledge (Shulman, 1986) in order to target professional development towards effecting improvement in teaching practices and hence student learning outcomes.

The project is underpinned by current New Zealand and international research in science education and teacher professional development, with the original impetus coming from the Deakin University Science in Schools research project in Victoria, Australia. It is situated within a theoretical framework that may broadly be considered to be constructivist in nature.

How we view the nature of science and how we view knowledge has a profound impact on how we learn science. *"Learning science involves developing an understanding of science and about science"* (Baker, 1997:157). If knowledge is viewed as being constructed through experience (personally or socially mediated), this will inevitably impact on teaching and learning formats and strategies. In the same way adoption of the development of scientific literacy as the aim of science teaching and learning, as in Science in the New Zealand Curriculum, implies certain conditions for science programmes. Such programmes will be those in which:

- ***Strategies are employed to expose students' prior knowledge and to develop learning programmes that build on existing understandings whilst challenging misconceptions.*** The conceptual change model of learning in science suggests that learners will not abandon their existing preconceptions unless the new ideas are more plausible, intelligible and fruitful than those they currently hold (Hewson and Thorley, 1989). Conversation is a necessary teaching method in the identification and challenging of these conceptions (Carr, Barker, Bell, Biddulph, Jones, Kirkwood, Pearson and Symington, 1994).

- ***Programmes are set in and address contexts relevant and meaningful to students.*** If one accepts that science knowledge is socially constructed then it follows that learning in science must be contextually situated (Hennessy, 1993). By engaging with scientific concepts in familiar and less familiar contexts, students are able to develop problem-centred knowledge, which is more transferable to new situations (Carr et al. 1994).

- ***The focus is on learning through investigation, as an active collaborative process.*** An investigative approach to science learning is important for student motivational reasons, but also for the development of problem-centred knowledge, the promotion of collaboration in science learning and for encouraging students to develop metacognitive reasoning strategies (Haigh and Hubbard, 1997).

- ***The teacher's role is that of facilitator of student learning, whilst acknowledging the vital importance of teacher pedagogical content knowledge.*** Teachers need to be knowledgeable in order to identify and set learning outcomes that are achievable for students, whilst meeting the requirements of the school and national curriculum. This knowledge integrates understanding of curriculum, of the 'content' of science and of appropriate teaching approaches (Shulman, 1987).

- ***Strategies are adopted that encourage students to become metacognitive and more actively involved in their own learning.*** Students need opportunities to think about how they have solved problems, so that they can learn both about and from their learning (Haigh and Hubbard, 1997). Teaching strategies that encourage reflection and which promote forward planning, support student self-management and metacognition are of prime importance.

- ***The use of formative assessment strategies is promoted*** in order to communicate to learners what is valued; to provide students and teachers with opportunities to maximise 'deep' rather than 'surface' learning (Harlen, 1998) and to generate opportunities for further learning.

Teachers need sound pedagogical knowledge and content knowledge to be effective practitioners. Two long term projects have profoundly influenced science teaching and learning in New Zealand schools over the past two decades. In New Zealand, the Waikato University Learning in Science Project (LISP) findings are used extensively in science classrooms to improve student learning. Similarly, the Project for Enhancing Effective Learning (PEEL) at Monash University in Victoria Australia has identified a range of effective strategies to promote learning and student self-efficacy across all learning areas.

S²P² Programme Development

In order to facilitate these objectives, the project team adopted an approach based on the action research cycle, as shown in the following diagram (Figure 1). The key elements of action research, namely those of planning, acting, observing and evaluating, are embedded in the 'cycle of improvement'. Central to this model is the ownership by the participants of the process; the goals or objectives are set by the individual, acted on by them (in collaboration with a facilitator) and evaluated and modified by them.

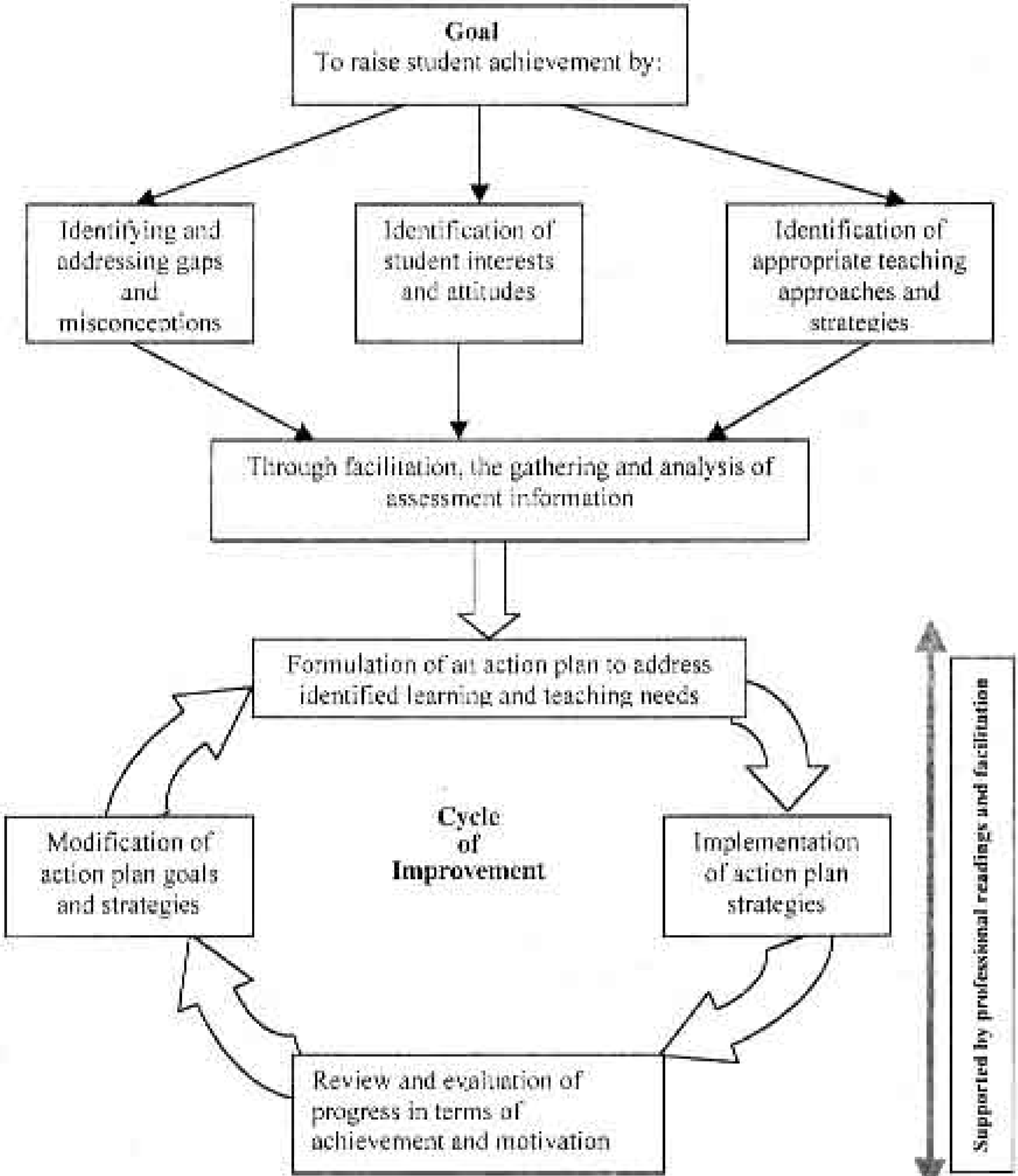

Figure 1: The S²P² Process

Key components of the process included:

A. Identification of the current position with respect to student attitudes and achievement and teacher competencies – the data making the invisible visible (Schmoker, 2001)
B. Formulation of an action plan, based on the evidence from (A) with goals, actions and agreed outcomes
C. A focus on ongoing review and reflection at all levels – students, teachers and facilitators
D. The facilitation and support of teachers whilst trialing new strategies, including the provision of timely and relevant professional readings.

The initial part of the programme involved identifying the current position for student achievement. The need for a reliable assessment led to the investigation of three studies: two international and one designed to assess student achievement for the New Zealand curriculum. The use of TIMSS, PISA and NEMP to inform practice in science and mathematics education has been occurring for several years, so it seemed timely to utilise both the findings and the assessment tasks provided by these studies.

The International Mathematics and Science Study (TIMSS) looks at Year Five and Nine students (nine and thirteen year olds) and measures progress with intended, implemented and attained curriculum. The results are designed to be linked with current school curricula.

The Programme for International Student Assessment (PISA) focuses on what fifteen year old students may require for the future i.e. knowledge and skills for real life challenges, rather than whether they have mastered a specific school curriculum.

The National Education Monitoring Project (NEMP), used for New Zealand students only, is intended to find out and report on achievements of a representative sample of year four and eight students (eight and twelve year olds). The reports give a detailed profile of students' knowledge and skills.

These studies provide extensive data on student achievement in science and mathematics and factors that impact on this achievement. The findings provide researchers, policy makers and practitioners with rich, comparative data and are a potentially valuable resource for educators interested in seeking ways to improve learning in science. For the project we chose to use NEMP material for assessment of student achievement. One of the benefits of using NEMP is in its inclusion of comparisons for Maori students' achievement as all of the schools in the pilot programme have a high percentage of Maori students.

Identification of student interests and attitudes gave the next essential piece of information for the programme planning. A survey asked about how students felt they learnt best and what they thought it was important to learn about. Results were collated and analysed in such a way that the most frequent responses were ranked at the top of a list of number of all responses. This allowed teachers to easily observe the most common interests and attitudes of students.

The final data collection for this part of the programme came from the teachers themselves. A Reflective Practice Profile was designed to investigate their current classroom practice. By indicating how often various practices were covered, a profile for each teacher could then be drawn. Features such as encouraging students to think critically, demonstrating a broad view of science, linking science with students' lives and interests, taking into account individual learning needs and embedding assessment within learning were the key components of the survey. Teachers kept their profiles and reflected on their practice at points throughout the programme identifying changes and progress being made.

Key outcomes
The three schools involved in the pilot project have been very positive, actively involved and keen to continue developments beyond the term of the programme. Interest has also spread to contributing schools, resulting in a science achievement focus for a community of schools. However, in terms of the key aims and objectives of the project, a number of significant shifts have been observed, which have implications for science teaching and learning nationally and possibly internationally.

Teachers are making pedagogical decisions in teaching science based on evidence rather than inference. To provide relevant assessment information for the project we devised an assessment based on NEMP material that was easy to administer, was not reliant on content already covered by teachers and was able to be compared nationally. Reports from NEMP material provide in-depth analysis of every question and/or assessment task. The questions used were aimed at mainly year eight students (twelve year olds) and gave the percentage of students' answers, nationally, for each question. It also provided relevant percentages for Maori students. Analysis of the pilot schools' assessments included comparisons with national findings.

This gave the teachers several pieces of relevant information. Firstly, they could see where their students 'were at'. Whilst teachers have an idea or feeling about the abilities and knowledge of their students that are generally accurate, they were surprised at how well and how badly, in some cases, their students compared with others who were at least a year younger than those tested by us. It also showed them the gaps in students' content knowledge. For example, teachers from one school were amazed that their students did not seem to know that insects had six legs. The collation and analysis of the results of this national test allowed the teachers to begin making decisions about what to teach.

Basing their programmes on good assessment material meant that the students began to work from an appropriate level of understanding rather than tackling work that was either too difficult or too easy. The identification of gaps in student learning also allowed teachers to discuss what the students knew and understood and in doing so allowed students to clarify and modify their own ideas. The teachers quickly saw that they were beginning to meet the learning needs of their students instead of teaching a programme based on content and often at an inappropriate level.

One teacher decided to approach teaching practical investigation using compost bins as a context relevant to the students. All of the schools are rural schools and many students lived in homes with vegetable gardens. The teacher allowed each student to design and build their own mini compost bin. The students discussed what materials would be needed for their bins and how they would go about measuring the success of their compost. The teacher helped the students to understand and use concepts such as variables, accurate and repeated measurement and to research what was commonly found in good compost. In the end, the compost bins themselves were a total failure but the student enthusiasm and learning that took place during the project was extraordinary.

The students entered the science room each lesson with enthusiasm, measuring the temperature of their bin. They recorded their own results and began to discuss changes in their compost with other students without prompting from the teacher. The expected rise in temperature of the bins gradually tailed off and the students worked out that their bins were too small to sustain the development of good compost. *"Although the compost bins didn't work"*, said the teacher, *"the students had clearly learnt how to control the variables, take repeated measurements and draw accurate conclusions from their investigation. They also researched what was needed for good compost and worked out why their own bins had not succeeded. I could have told them all this, but it would never have had the impact nor generated the enthusiasm that doing it for themselves did."*

Teachers are developing teaching and learning strategies appropriate to students' needs and interests. If teachers are aware of how students best learn in science they are able to design learning experiences that promote learning. Furthermore, they can ensure that learning is based in relevant contexts of interest to students, allowing for the integration of scientific knowledge and skills in a meaningful, authentic manner. This approach should not be confused with the activity-based focus often observed in science teaching at primary level, where the context obscures the learning to the point where students perceive the task to be 'making hotcakes' rather than 'investigating physical and chemical change'. The focus of the project teachers remains firmly on the conceptual and procedural knowledge required for learning in science, but situates this in a 'real world' context or problem.

The aforementioned example of compost bin design was an outcome of the student attitude surveys. Many students indicated that they were motivated by having opportunities to carry out their own investigations and were interested in finding out how things work. By basing the learning in a real life situation where students already had some experience and knowledge, and allowing them to work in a way that felt they learnt best, students were more able to develop problem-centred knowledge which is more transferable to new situations.

Through the sharing and negotiation of learning outcomes in science students become partners in learning, rather than seeing it as being done to them by teachers. They also become more self-critical and better able to evaluate their own learning against given standards or expectations. When learning outcomes and criteria for achievement are shared with students, rather than being held by teachers, the quality of the feedback given to students is enhanced (Clarke: 2001) with the focus clearly being on the learning rather than the social and managerial aspects of the task.

In one of the S^3P^2 schools teachers decided to adopt different teaching approaches with each class. Students were working on science fair projects, a popular event in New Zealand primary and secondary schools. One teacher decided to let the students work at their own pace and in their own way, offering support, information and guidance when needed. The other teacher took a more structured approach. She made the learning outcomes clear and set up checkpoints for feedback and feed forward in order to construct a way forward. The student was expected to discuss their progress with the teacher at each checkpoint.

The outcome of the two approaches, as demonstrated through summative assessment, was interesting. The first teacher found that the range of grades achieved by students was very broad. The more able students achieved very high grades but the less able ones achieved very low grades or did not complete the project. The middle students achieved at an expected level based on previous results. The second teacher's class achieved results that were more tightly bunched. The more able students did not achieve such high grades but the less able students achieved better grades than expected. Middle students achieved slightly better than expected. From these results the teachers are now looking at how they can combine the best practice of their teaching approaches to allow all students to improve their learning.

Students are becoming more adept at managing their own learning and are beginning to adopt metacognitive strategies. An initial concern in surveying and testing students at the commencement of the programme was that this testing would be perceived by students as an imposition or threat, which would have severely compromised the success of the project. Teachers were careful when administering the tasks to emphasise the formative nature of the data being collected. Furthermore, after teachers had analysed the findings, identifying the key messages for them and their students, these key messages were shared with students in classroom discussion, rather than the tests and surveys being returned to students.

In one school, teachers have developed a science portfolio to guide student progress and achievement. The portfolio not only contains key pieces of student work, but also provides opportunities for pupils to reflect on their learning and attitudes to science in an on-going and constructive manner.

The pieces of work chosen for the portfolio cover key curriculum areas. For example, students have gathered work on planning, carrying out and reporting on investigations. As they have improved on these pieces of work, they can see the progress they have made, have readily available feedback from the teacher and are able to use it for self-assessment. The pieces of work are also useful in revising for summative assessments in that they have a complete annotated record of their formative work. The portfolios have become exemplars of the student's own work and provide building blocks for reflection and improvement. A noticeable shift in students' ability to self assess was in their movement from saying *I like doing...* to *I have learnt that...*

Shifts

Throughout the programme teachers and students have made several significant shifts in teaching and learning. These include:

- Teachers are now basing their teaching programmes on good assessment data
- They are taking account of students' interests and attitudes toward science
- Units of work include clear learning outcomes, identified formative assessments and opportunities for self assessment by the students
- Students are taking more responsibility for their own learning and are developing metacognitive strategies
- Teachers recognise the value of research and literature on both science

knowledge and teaching strategies.

Implications for future development

The S^3P^2 professional development programme has by all accounts been a great success. Key success factors identified by participants and the project team include:

- The provision of professional time in the busy teachers' schedule – time to reflect on current practice, to prepare resources for classroom initiatives, to read and participate in professional discourse.
- Professional support in making changes to practice.
- Assistance in collating and analysing assessment information.
- Access to relevant up-to-date literature and high quality assessment tools.
- Preparedness on the part of participants to take risks and to try new strategies.

It is relatively easy to identify these success indicators, but the greatest challenge now facing the project team is that of effecting change to science teaching practice outside the confines of the project schools. The current results have been obtained in ideal conditions with strong support. Any feasible expansion of the programme across the New Zealand school system cannot reasonably expect this degree of support, so the next task is to develop a strategy making the best use of the lessons learnt thus far.

Acknowledgements

We would like to acknowledge the support of Chris Arcus and the Ministry of Education who funded the project and who made the initial identification and contacts with the schools. We also wish to thank the schools and in particular the participating teachers for their time commitment, enthusiasm and willingness to take risks in trialling new ideas.

References

Baker, R. (1997). What is science 'about'? In Beverley Bell and Robyn Baker (Eds) *Developing the Science Curriculum in Aotearoa New Zealand* Auckland: Addison Wesley Longman.

Baker, R. & Jones, A. (2002). How can international studies such as TIMSS and PISA be used to inform practice, policy and future research in science education? Paper presented at *Third New Zealand Science Education Symposium,* Wellington, 22-23 November 2002.

Burns, J. (1997). Achieving understanding in science. In Beverley Bell and Robyn Baker (Eds) *Developing the Science Curriculum in Aotearoa New Zealand* Auckland: Addison Wesley Longman.

Carr, M., Barker, M., Bell, B., Biddulph, F., Jones, A., Kirkwood, V., Pearson, J. & Symington, D. (1994). The constructivist paradigm and some implications for science content and pedagogy. In Fensham, P.J., Gunstone, R.F. & White, R.T. *The Content of Science: a constructivist approach to its teaching and learning.* London, Falmer, pp 147 – 160.

Clarke, S. (2001). *Unlocking Formative Asssessment. Practical strategies for enhancing pupils' learning in the primary classroom.* London: Hodder & Stoughton.

Cowie, B. (1997). Formative assessment and science classrooms. In Beverley Bell and Robyn Baker (Eds) *Developing the Science Curriculum in Aotearoa New Zealand* Auckland: Addison Wesley Longman.

Haigh, M. & Hubbard, D. (1997). 'I really know I have learned something': investigative work in science education. In Beverley Bell and Robyn Baker (Eds) *Developing the Science Curriculum in Aotearoa New Zealand* Auckland: Addison Wesley Longman.

Hennessy, S. (1993). Situated Cognition and Cognitive Apprenticeship: Implications for classroom learning. *Studies in Science Education*, 22, pp.1-41.

Hewson, P. & Thorley, R. (1989). The conditions of conceptual change in the classroom. *International Journal of Science Education*, 11 (5), pp. 541-53.

Harlen, W. (1998). Classroom assessment: a dimension of purposes and procedures. *SAMEpapers 1998*, Hamilton: Centre for Science and Mathematics Education Research, University of Waikato, pp.75-87.

Ministry of Education (1993). *Science in the New Zealand Curriculum* Wellington: Learning Media.

Schmoker, M. (1999). *Results: The Key to Continuous School Improvement* (2nd Ed) Alexandria: Association for Supervision and Curriculum Development.

Shulman, L. S. (1987). Knowledge and Teaching: Foundations of the New Reform. *Harvard Educational Review* Vol 57, 1, 1-22.

Title	:	**The Impact of Quality Assessment Information on Teaching and Learning in Science Classroom**
Presenter	:	Ms. Ann Northover Ms. Sue Leslie
Date & Time	:	13 August 2003 (Wednesday), 10.30 – 11.30 a.m.

1. Content of the Paper

1.1 Background of National Education Monitoring Project (NEMP)
- NEMP commenced in 1993 to monitor the achievement of the New Zealand primary school children in all areas of curriculum.
- Children are assessed at two levels – Year 4 and Year 8 of primary school.

1.2 The main goal of NEMP is to provide detailed information about what children can do so that:
- Pattern of performance can be recognized
- Successes celebrated
- Desirable changes implemented.

NEMP aimed at raising achievement in science by effecting changes to:
- Teacher knowledge, skills attitudes and beliefs
- Teacher practice
- School wide practice.

1.3 Measuring Student Achievement

The assessment task was based on NEMP material to:
- Investigate a variety of science concepts, process skills and applications
- Provide baseline achievement data for each student, class and school.

1.4 Student Attitude Survey

The survey investigated how students felt about science, what they learned best and what they thought was important to learn about science.

1.5 Teacher Reflective Practice Survey
- Stimulating students to think about science
- Demonstrating a broad view of the nature of science
- Linking science with students' lives and interest
- Encouraging critical thinking
- Taking account of individual learning needs
- Embedding assessment within science learning strategy.
-

1.6 Impact on Teacher Knowledge, Skills, Attitudes and Beliefs
- Change in focus – thinking about what students learn rather than what they do.
- Greater awareness of the range of assessment tools available to support teaching and learning (eg. ARBs, PISA, NEMP).

1.7 Impact of Teaching Practice

- Setting science units in contexts of relevance and interest to students
- Setting science learning goals appropriate to each class
- Giving feedback to students on progress towards learning goals
- Using a range of teaching strategies to address student learning needs.

1.8 Impact on Student Achievement

- Good baseline data provides reliable measurement of student achievement
- Improve teaching strategies allows students to take more responsibility for their own learning
- Formative assessment allows students to monitor their own progress.

2. Discussion

2.1 *Mr. Chua Hock Kam (Chairperson)* enquired how much time was required to train teachers to do quality assessment and the time frame involved?

Answer
The speakers mentioned about the materials needed such as the documents which outlined the tasks and practical investigations that students were required to do.

2.2 *Madam Harison Yusoff from Petrosains* asked where do the teachers obtain the teaching and learning materials.

Answer
The teachers developed the materials themselves.