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Improving student writing in science: a help or hindrance

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Introduction
When six Nobel Prize winners were discussing what makes a good scientist, each commented that proficiency with reading and writing was fundamental (Ebbing, 2001). While writing skills have been acknowledged as important for learning science these skills are also important because of the continuing reliance on student-produced writing for evaluation of academic progress (Ward, Roden, Hewlett and Foreman, 2005; Gregson, 2003; Yore, Hand and Prain, 1999; Woodward, 1998; Hand and Prain, 1996). Researchers found that 87% of student writing in science was directed towards the teacher and solely for the purpose of assessment (Green, 1998; Britton, Burgess, Martin, McLeod and Rosen; 1979). The form that these assessments take may vary, but the process has remains the same; the students write and the teacher grades the work. As such, academic success becomes a matter of learning the subject matter and the necessary skills, and then being able to respond in writing to questions about that material. Those that are unable to write well are immediately disadvantaged.

This paper presents one phase of a five-phase investigation that focused on the capacity of unsuccessful Year 8 students to accurately demonstrate their knowledge and understanding of scientific concepts in writing. A comparison of student writing and their contributions to class discussions led to the belief that the students knew more than they were able to record in their written answers. After ascertaining how these students viewed science, and the role writing played in their study of science, a series of activities was employed to develop their writing skills within the context of a Year 8 science classroom.

The aim of this phase of the study was to improve student writing in science by demonstrating audience (teacher) expectations of answers by providing immediate teacher feedback and to give students practice in shaping and revising answers to meet those expectations.
Models of writing
During 15 years of studying writing processes Flower and Hayes (1980) developed the cognitive model of the writing process that “identifies not only the sub-processes of the composing process, but also the organization of those sub-processes” (Hayes and Flower, 1980, p.10). Subsequent models, developed by Cooper and Matsushashi (1983) and de Beaugrande (1982, 1984) focused on text production. These models describe the composing processes required for expert text production and provide a ‘coherent global argument for what expert writers do’, (Flower and Hayes in Grabe and Kaplan, 1996 p. 93).

Grabe and Kaplan (1996) extend these ideas with their model of communicative competence applied to writing that embraces listening, speaking, reading and writing. This model features the writer’s ability to use writing as a communication activity and describes skills and processes where the writer’s understanding of participants, setting, task, text and topic and performance with textual output are integrated (Grabe and Kaplan, 1996, p. 225).

In contrast Bereiter and Scardamalia (1987) and, subsequently Galbraith (1992) argue that no single model can cover the process of writing and that different cognitive models should be considered at different stages of the writer’s development. These authors argue that the skilled writer is not performing the same process as the novice writer. Their model recognises two different processes; knowledge telling and knowledge transformation. The ‘knowledge telling’ model acknowledges that novice writers simply change their oral ideas into writing where their major difficulty is producing enough written material so that what they write reflects what they know about a particular concept. According to these authors, writers, who are writing for telling, do not find the task of writing to be onerous because of the simplistic approach they take to the task of writing. These authors also believe that knowledge telling writers will continue in the same vein without progressing unless implicit instruction is given to support a change in attitude to and style of writing. In the ‘knowledge transformation’ model the more experienced and capable writer demonstrates a reflective understanding of the nature of the task and produces a more complex style of writing where the writer is aware of the needs of their audience and an understanding of the complexity of the writing required to fully address all components of the task.

To this end student writing and students’ views of writing at this school were investigated in an attempt to identify specific writing difficulties that the students are experiencing. The research question became:

“In what ways can a classroom teacher assist students to convey their science knowledge in writing more clearly?”

Strategies for improving student writing
Teacher modeling of writing, providing models of written material and application of revision practices to text have been identified as some successful strategies used in improving student writing. Scardamalia and Bereiter (1986) propose that one way to improve students writing is to have the teacher model the writing while describing what they are doing and thinking throughout the process. Graham and Harris (1993) proposed that the combination of teacher feedback and modeling of writing supported
the development of students’ writing. Zimmerman and Risenberg (1997) claimed that managing the writing process is centred on three metacognitive actions: planning, translating and revising. Where revising assists expert writers to assess their writing, find errors and formulate changes that will lead to improvement, not only the expression of their understanding, but improvement in that understanding itself (Britteon, 1996; Fitzgerald, 1987; McCutchen, 1988).

For novice writers, however, Butterfield, Hacker and Plumb (1994) and De La Paz, Swanson and Graham (1998) found that revision of written work does not play a major role; any changes tend to be superficial and limited to word changes so these changes have a minimal effect on the quality of the text. This is thought to be due to the students’ lack of underlying understanding of the revision process, which is to respond to mismatches between what was written and what was intended to be written

Teacher-research in an Action Research framework

Stenhouse (1975) pointed out that, because teachers are in charge of classrooms, they are surrounded by rich research opportunities, and are in an ideal position to capture the learning world of students. It is therefore not difficult to see that the teacher–researcher approach is different from traditional ‘researcher outside the experiment’ forms of research, not least because it is largely driven by the teacher’s personal goals (Loughran, 2002; Johnson, 1993). That is, teachers as researchers can offer angles and depths of understanding to a research field normally concealed from ‘outsider’ researchers.

This view was explored further by Fenstermacher (1994) who established a framework for allocating what teachers know into research categories; one that seeks to generate knowledge of teaching that is generated by those who specialize in research on teaching in contrast to the knowledge as a ‘result of their experiences as teachers’ (Fenstermacher, 1994, p.3). These two branches of teacher research have become known as research of the knowledge of episteme (scientific understanding) and the knowledge of phronesis (practical wisdom) (Korthagen, 2001). The latter focuses on knowledge that comes from participatory research that involves reflection on action and experience that is contextually bound within a classroom. Phronesis is concerned with scientific understanding of ‘specific, concrete cases and complex or ambiguous situations’ (Fenstermacher, 1994, p.24) such as a secondary science classroom where the researcher is seeking ‘solutions from concrete details rather than from some theoretical domain’ (p.25).

The study reported here is typical of teacher-research and was concerned with bringing about classroom changes in response to either the needs of the student or the teacher, or both (Cochran-Smith & Lytle, 1999; Belanger, 1992; Copper, 1990; Stenhouse, 1975). An action research framework with the teacher as the researcher was used in this study because the school setting was seen to naturally lend itself more to an informal, interpretive and reflective model of inquiry which allowed the researcher to focus on the complexities of social situations such as those found in classrooms (Holter and Schwartz-Barcott 1993; Zuber-Skerrit, 1992; Allan, 1991; Glesne and Peshkin, 1991). Such research is strengthened, not weakened, by focusing on the participants’ needs as they emerge in the practical situation (Hanrahan, 1998). By following the four steps of the action research cycle (planning, action, observation and reflection),
the researcher is required to focus carefully on the identified problem and to
systematically evaluate the situation, plan and activate an intervention to respond to
the identified problem and then evaluate that intervention.

**Limitations of teachers as researchers**

The work of a teacher who is researching can easily be construed by colleagues as
threatening to them (Mitchell, 2002). This threat can be overcome by having more
than one teacher from the research site as part of the research team, and this is seen as
essential in Kemmis and McTaggart’s model of action research (Kemmis &
McTaggart, 1988). The research process can also be difficult and isolating for a lone
teacher (Mitchell, 2002).

Mitchell (2002) suggested that teacher-research is often messy and logically non-
linear, with the outcomes of the research not always immediately obvious, but taking
some time to unfold (p.252). Finding the time to collect data and to write in journals
while performing normal teaching duties has become recognised as one of the
countered this, however, by suggesting that data are ‘deeper and richer’ (p.252)
because the teacher is always present.

Experience at this research site reflects what has been experienced by others in that
colleagues showed a range of reactions: some did not value the research, others chose
not to find the time to become involved, and a few were openly antagonistic or critical
of the effort being ‘wasted’ on research when science teachers were ‘busy enough just
doing our jobs’ (Osler & Flack, 2002; Cohen & Manion, 1989).

**Context**

This study focuses on students in a coeducational, non-government school in
metropolitan Sydney, New South Wales. The pupils come from a variety of
backgrounds and are not generally economically disadvantaged. Science at this school
is compulsory in year’s 7-10 and optional in years 11 and 12. The author was a
science teacher with fifteen years experience who conducted the teacher research at
the school site as part of the preparation of a doctoral thesis.

All student participants were members of a lower-ability Year 8 science class who
were ranked in the lowest 15% of the grade. The students’ IQ scores ranged from 75
to 119 and the students were experiencing learning, attitudinal or behavioural
difficulties. Three students were from non-English speaking backgrounds.

Prior to this study, students had expressed the view that they did not like science. The
students indicated that one of the reasons for their negative attitude was the writing
that was required of them in the subject. They were not successful writers and
therefore thought themselves to be ‘dummies’, incapable of achieving well in science.

**Method**

This study has two phases. The first included informal interviews with secondary
teachers (n=28) from a range of subject areas to find the extent of the perceived
problems of student writing and to establish each teacher’s view of learning and writing in his/her subject areas. The interview process was semi-structured and informal (Rubin and Rubin, 1995; Burns, 1994). A number of open-ended questions were prepared prior to the interviews and were used to stimulate teacher response, as suggested by Goodwin and Goodwin (1996). While the interview process followed a scheduled list of questions, the teachers were given the opportunity to answer freely and without interruption. The interviews were transcribed and returned to the participating teachers from member checking (Marton, 1994).

The second phase responded to the literature that stressed the importance of revision in student writing. The second source of data was student work samples collected during the modeling activity. The modeling exercise was developed that emphasized how students could improve their written answers by focusing on what they had written and then spending time revising and improving it. Student work samples were collected and analysed.

Data Analysis
The interviews produced complex data that established commonalities exist in many areas of teacher comment. The first analysis of comments sought to identify similarities in responses; that is, while the wordings may have been different, many comments reflected similar meanings. The second analysis focused on findings which reflected differences in responses. The third criterion for grouping of data was one of relevance to student problems and writing. In the fourth analysis the teachers’ statements were grouped into categories such as student behaviour, student expectations, writing requirements in their subject area, and perceived difficulties that the students had with writing. This multi-layered approach reflects that recommended by Marton (1994) and Burns (1994).

The student work samples from the modeling activity given in their science class were analysed during the classroom activity in an attempt to give the students immediate feedback on their work. They were then re-analysed two months later as part of the writing of a doctoral thesis chapter. In this instance the analysis was collaborative with the academic supervisor and a teacher from the research site.

Results
Teacher interviews
The teachers thought that the students were not prepared for the depth and breadth of study needed in their subject areas and all but 2 of the 28 interviewed teachers raised problems of student writing without being prompted by a direct question. Teachers referred to the use of technical language and the difficulties that their students appeared to have with its use. They considered that students were unaware of the expectations of their teachers, especially when it came to writing, particularly in tests and examinations. They either wrote too little or too much, or tended to waffle, and many were said to be unable to write for different audiences and in different genres.

Jody: It is a more academic subject and there is a lot of writing and essays and not so much practical as they think. I think they still come into the course expecting to play around the oval. They don’t expect the rigour of
the course. (Personal Development, Health and Physical Education)

When the teachers were asked the question, ‘What makes a good writer?’

Keith
Creative writers are better writers because they have learned to think laterally. They can take the stuff and really work with it…others who are not necessarily thinking creatively – to them, it is just another task to do (Science).

Rose
[The students] need to be able to put information in sequential order, so that it is logical and will convince another person of their understanding of the information or concept…if students are good (Science).

Too often, students failed to recognise the significance of the specialist terms their teachers introduced in the classroom, and this led to the students not incorporating the terms in their answers in essays, reports and examination questions.

Allison
[The students] think that these are just words that I am using and that they are not required to use them…they talked [wrote in essays in examinations] all the way around it [the term] without saying the word, because if you are using business language you don’t have to use as many words to explain [the concept] (Business Studies).

Rose, however, found that the use of scientific terms was not always an indication of students understanding. She suggested that:

…some students like to use scientific words as a kind of banner that they know the word but they don’t necessarily know what it means.

Paul (Science) expressed the view that students tended to use ‘common language’ during classroom activities or class tests, and then were expected to use more scientific language across the School Certificate and Higher School Certificate grade examinations. Paul thought that many teachers accepted student comments during class discussions that incorporated too much colloquial language about concepts, rather than expecting the students to use more specialised language. He also commented on the change in teacher expectations as students move from junior (Years 7–10) to senior (Years 11–12) syllabuses.

Long-winded answers in junior school are not acceptable in HSC examinations. Students are given limited space in these external exams to express themselves and they often have difficulty coming to the point in a few lines.
Keith observed that students appear to be unaware of the depth and breadth of the responses required in assessment tasks. In his opinion:

...lower level kids tend to give only a few bits of knowledge that everyone would give. A higher level student will give the same three bits of knowledge that everyone else gives and then give a bit extra.

My own observations have been that students are unaware of what teachers are looking for when they mark student work. Many students, and not only those with lower performance levels, take a minimalist view of writing, and provide simple and brief answers in the belief that they have answered all parts of the task. In some cases the students attempt to complete the work as quickly as possible in a effort to move onto something more interesting and, by rushing their answers, fail to address all parts of the task. Either due to the shortness of their answer or the lack of understanding of what is expected, they do not demonstrate their genuine understanding of concepts in response to questions.

**Writing intervention - answer modeling**

During this students were then introduced to answer modeling in the form of a worksheet with a question and a series of possible answers (Figure 1). The answers were presented by showing a hierarchy of answers to a question, ranging from very simple answers that were expressed in common English to answers that contained scientific terms and completely answered the question. We compared the model answers to identify how they differed and why each was better than the previous one. Once all answers had been reviewed, the students were set the task of answering the next question.

The students were instructed to work individually and to bring their completed answers to me for checking. During this checking phase (Zimmerman and Risenberg, 1997; Calkins, 1986), each student received an indication of how his/her written expression could have been improved. This was achieved through questions such as ‘Have you answered the question?’, ‘Have you explained all parts of the concept being tested?’ and ‘Have you used the scientific terms we used in class in your answer?’ The student’s last comment before returning to his/her desk was inevitably a query about the likely mark he/she would get for his/her answer. After the student was given an approximate mark value for the answer, the student was asked to reflect on the answer and to produce another that may be better.
<table>
<thead>
<tr>
<th>Year 8 Modeling of Answers</th>
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<tbody>
<tr>
<td>Question: (a) Name the important process that occurs in the chloroplasts.</td>
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<tr>
<td>(b) Explain why plants need this process to happen.</td>
</tr>
<tr>
<td>Answer: (a) photosynthesis</td>
</tr>
<tr>
<td>(b)</td>
</tr>
<tr>
<td>(i) So that they can grow</td>
</tr>
<tr>
<td>(ii) So that they can produce food that helps them to grow</td>
</tr>
<tr>
<td>(iii) So that they can produce glucose which is needed for growth and oxygen that is required for respiration.</td>
</tr>
<tr>
<td>(iv) So that plants can use the Sun’s energy, carbon dioxide and water to produce glucose and oxygen. The glucose is the energy source that plants need for growth and reproduction. The oxygen is required for respiration.</td>
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<tr>
<th>Practice Questions</th>
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<tr>
<td>1. Explain how seeds germinate.</td>
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<tr>
<td>2. Explain the differences between an element, compound and molecule.</td>
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Figure 1: Answer modeling

Results for the Answer Modelling activity
Initially there was apparent enthusiasm for writing and with the improvement in their answers; the goals of this study were finally being achieved. A diary note dated 19\textsuperscript{th} May recorded

They did it, they’re finally using the words I taught them in class and their answers have really improved. They look great!

The students were writing longer answers, incorporating more scientific terms and, therefore, would now be able to demonstrate the extent of their knowledge more successfully. I still remember the feeling of elation as students proudly displayed their answers to their peers. Not only was their writing showing improvement but their
Attitude to the task was very positive. They were really trying hard and enjoying success.

Norman: I knew I needed to write better answers but I was not sure how.

Kathryn: That was good. I think I will write better answers now.

Later, deeper analysis
Once all the excitement had died down and the opportunity arose for a deeper evaluation of the students’ work to be made, I became increasingly confused and frustrated. This analysis showed that while the students had used more scientific terms, their written expression had become more confused and lacked clarity. As the lesson had progressed and the students had increasingly reviewed and revised what they had written, putting in more scientific terms, their answers were getting less clear. Had the speed of my responding to the rush of students’ written work caused me to focus on the quantity of scientific terms rather than the quality of the total answer? Almost certainly. I had been so swept up in the students’ excitement with the task, that I failed to notice the steady decline in the clarity of what they had written. I had fallen into the subjectivity trap of teacher-research. Having time to gain some objectivity, I realised that my teaching efforts had resulted in an educational contradiction: students had satisfied my requirement for using more scientific terms, but their written expression no longer clearly demonstrated their knowledge and understanding of the concept.

The following examples illustrate the progress the students made as they tried to revise their work to improve the quality of their written expression. These answers were to the question ‘Explain how seeds germinate’.

Tim, 1st answer: The seed opens up and the root comes out and deep into the ground then the stem shoots up and the seed gradually turns into a plant.

Tim’s first attempt to explain how seeds germinate was very good and showed that he knew about the process and understood the concept of germination. His answer was a description of the observable features when seeds germinate but there was little evidence of the terms that had been introduced in the classroom; for example, endosperm, cotyledon, nutrient, heat and water.

Tim, 2nd answer: It uses its endosperm until the roots start feeding it.

Tim’s second answer was very different from his first. He incorporated the scientific term endosperm and moved away from a purely descriptive explanation of observable features to what was happening inside the seed by explaining the role of the endosperm and the roots.
Tim, 3\textsuperscript{rd} answer: It uses up the nutrients in the endosperm and getting water and heat, the seed has enough had enough energy to break out.

Tim, 4\textsuperscript{th} answer: By getting heat from the sun and water the seed can use the nutrients in the endosperm to break through and begin to grow.

In his third answer Tim incorporated more scientific terms when he added \textit{nutrients in the endosperm}, and the requirements of \textit{warmth} and \textit{water}. However, he included a statement that did not make sense nor did it add to value of his answer: \textit{the seed has enough had enough energy to break out}. The seed does not break out, the cotyledon does as the seed breaks open, so Tim supplied misleading information in the latter part of his answer. He repeated this idea in this fourth answer but this time his expression was much clearer.

In the following answers, Jun Cui initially described observations similar to those used by Tim. In his subsequent answers, however, he tried to outline cause and effect but, in doing so, his answers moved towards an explanation of later plant growth – \textit{requiring the sun’s heat to grow up} – rather than the process of germination. His final answer reflected a level of confusion because, although he had used more scientific terms, his answer was almost impossible to understand.

\begin{itemize}
  \item Jun Cui, 1\textsuperscript{st} answer: Seeds germinate is by a seed which is starting to open up and a plant is starting.
  \item Jun Cui, 2\textsuperscript{nd} answer: The seeds germinate with the sun’s help which make seed grow and crack the seed.
  \item Jun Cui, 3\textsuperscript{rd} answer: The seeds germinate with the soil, water and puts under the sun’s heats and to grow up.
  \item Jun Cui, 4\textsuperscript{th} answer: Seeds germinate which need the soil, water and the sun’s heat. Plant it which has nutrient to help the plants grow up.
\end{itemize}

Simon’s answers also follow the same pattern demonstrated by Jun Cui’s answers. He began by simply presenting observable features of a germinating seed in everyday English. As he tried to deepen his explanation, however, the expression of his ideas deteriorated.

\begin{itemize}
  \item Simon, 1\textsuperscript{st} answer: Seeds germinate by a seed which is starting to open up and a plant is starting to come out of the seed.
  \item Simon, 2\textsuperscript{nd} answer: A seed germinates with the sun’s help which it gives warmth makes the seed grow and cracks the seed.
  \item Simon, 3\textsuperscript{rd} answer: The seed germinates when you plant it in the soil and water it and then put it in the sunlight which make it grow. The endosperm which has nutrients in it helps it gets leaves.
\end{itemize}

In consultation with my peers, it was agreed that in all of the above examples the students’ first answers were their best in terms of scientific content and clarity of expression.
Discussion

What happened to their answers?
We know that teaching students to write is not a simple task and that their writing problems require more than a single intervention to produce results that trigger the mechanism to overcome any perceived difficulties for a positive outcome. The only observations that could be made with authority were that the students’ answers became longer. For some students the interventions did not achieve a change in the writing while for others the change was dramatic. At the very least the increased length of their answers allowed the students to record more information than they would otherwise have done so that they had changed from writing minimalists and moved towards writing more about what they knew.

Using scientific terms
When the students tried to add scientific terms into their answers, they lost clarity of meaning. The students were better able to demonstrate the extent of their knowledge using everyday language than when they tried to use scientific terms. The use of these ‘foreign’ words (Hanrahan, 1995) reduces the students’ ability to join meaningful phrases sequentially into clear sentences while a positive consequence of the use of common language is the possibility of the teacher ascertaining whether the student has understood the concept or not. An educational contradiction existed at this school in that the science teachers wanted the students to use more specific terms in their answers and rewarded students for their use, even when the students wrote was considered incorrect.

Did answer modeling work?
To move students towards being expert writers, Graham and Harris (1993) proposed that student writing could be guided by supplying students with models of writing and teacher feedback. However, improvement was not observed with these students. While they enjoyed the activity and seemed to be empowered by it, the data collected demonstrated that most students’ answers deteriorated when using the modeling activities in this study.

In this study, the intention was for the students to use modeling to focus on, identify and appropriate good written answers, specifically in terms of the positive features of completeness, correctness, nature of language (that is, science terms), length, relationships, cause and effect statements, clarity of expression of ideas, all of which could be checked by review and revision. However, only the surface attributes of answers – such as scientific terms and length – were considered by the students and initially by me without deep consideration of the ways the various features of the model combined to provide exemplary clear, correct written expression. Further research might establish whether the discourse and conversations about the meaning of student writing, together with deeper analysis of how model samples of writing convey meaning effectively, contributed to both the development in understanding and writing about science.
The role of revision
Revising was another strategy suggested in the literature as being supportive of writing development and was adopted in this study. Zimmerman and Risenberg (1997) reported that revision allowed for evaluation of prior written material and provided the writer with an opportunity to manipulate his/her text in order to make improvements in content and readability for the audience. De La Paz, Swanson and Graham (1998), on the other hand, found that student revisions tended to be at word or phrase level, and not at the meaning level which requires full sentences. In this study, what the students wrote first was their best answer and clearest in scientific meaning because (or in spite of the fact that) their answers did not contain the scientific terms that their teachers were looking for. For these students, the opportunity to revise invariably led to confusion and misunderstandings in their writing. This would seem to be a de-motivating factor in terms of students practising their writing skills and the checking of their answers during examinations.

Teacher Research and Action Research
There is no doubt that the ‘insider’ view (Allan, 1991) provided by teacher research has been appropriate and beneficial to this study. The process was largely driven by my personal goal to help my students which is typical according to Loughran (2002) and Johnson (1993) and the findings had immediate impact on my practices, as a teacher, which have now been incorporated into my philosophy as a teacher educator. Some of the limitations of this method, suggested in the literature such as ‘messiness of the findings’ and colleague ‘disinterest’ (Mitchell, 2002; Cohen and Manion, 1989) came to fruition in this study. However action research provided the scaffold to systematically trial practices to improve student writing, to reflect and analyse the effects of the practices. The findings to some degree remain interconnected and inconclusive, but can be judged on the ethical procedures used to collect the data, the prolonged engagement, use of multiple methods of data collection and member checks which all provide methodological trustworthiness.

Other issues
The activities of this study led to three students in the class achieving results in the top twenty percent of their cohort which begs the question as to why these students found themselves in a lower ability class? They were capable students who had either failed to achieve their full potential in assessment tasks or their potential had not been recognised by their teachers. It is difficult to believe that all that was holding them back was their inability to express themselves in writing and that the interventions made so much difference. The implication of this finding highlights the inadequacy of assessment strategies on which decisions are made about the placement of students into classes that are appropriate for their needs.

Thus I find myself questioning how students should be tested. What is the value of assessment practices that do not facilitate all students showing their knowledge to the best of their ability and what allowances are made for individual needs of students? While oral testing is suggested as an alternative assessment tool in the new syllabuses it is only used to a minor degree and as an adjunct to written assessments. While not without problems and fraught with inconsistencies and subjectivity, oral testing may be viable alternative for those students who experience difficulties and where writing fails to allow the extent of their knowledge to be demonstrated.
Overall the findings demonstrate how complex yet how powerful teacher-research is in the classroom and highlight the need for teachers to be aware of the potential that researching their own pedagogy has in influencing student learning and motivation, pedagogy and assessment practices. The process of researching students’ scientific literacy has led to the gathering of information about an area of study that was beyond the boundaries of any previous study. During my teacher training, some fifteen years ago, students’ literacy needs were not pursued. The analysis of the data has clarified the value of some strategies I use in the classroom and has led to the questioning of others with the consequence that regular review is made of the outcomes of my teaching through personal reflection and data collection. This process has also led to many questions such as those surrounding the value of scientific terminology and assessment strategies that form the framework for future teacher-research.

The value of teacher-research is questioned because of the personal nature of the issues that are researched within one’s own classroom and because the findings may not be relevant in contexts other than the one in which the research takes place. The complexity of the findings may also not provide future directions other than for the participants. However, what has been highlighted in this study is the difference between initial reflection on practice and data and later deeper interpretations of these practices. Investigation of teachers views on student writing and particularly ‘on the spot’ value judgments that teachers are required to make on a daily basis would be a valuable addition to knowledge about teacher practice.

**Implication for future research.**

The issues relating to student writing are many and so that future research into student writing in science will require collaboration of interdisciplinatory groups including those with expertise in linguistics, language development and tertiary and secondary science teachers.

The dilemma of scientific language remains. The terms used in science classes form part of the body of knowledge of science and are required for communication within the scientific community. Hence to have access to scientific terms and discussion and to communicate scientific ideas, such terms are valued. However, the use of terms for effective communication, that was intended to be promoted in this study of secondary science students, inhibited their written expression. More research is required into the use of scientific terms and removal of the barriers they appear to have on students’ expression of their understanding of scientific concepts.

In conjunction with the use of specific terms, analysis of science teacher attitudes to scientific terms and the influence it has on their assessment of student writing in science is warranted. Consistency of assessment of students’ written responses remains a contentious issue for students and teachers. The continued investigation into the assessment practices of science teachers including the dependency on scientific terms would provide a basis which to improve the assessment of short answer questions.

What has been highlighted in this study is the difference between initial reflection on practice and data and later deeper interpretations of these practices. Investigation of
teachers views on student writing and particularly ‘on the spot’ value judgments that teachers are required to make on a daily basis would be a valuable addition to knowledge about teacher practice.

Concluding Statement
As a teacher–researcher using action research in a single site, this study is not intended to have great implications for curriculum reform at the systemic level. However, it does suggest a teacher is capable of achieving awareness of and improving his/her practice through structured and systematic research of the activities in his/her classroom.

Overall the findings indicate how complex and powerful the writing process is in the classroom and highlight the need for teachers to be aware of its potential in influencing student learning, motivation and assessment. This study has highlighted several critical issues which impact on secondary school science education. Firstly, many students’ perceptions and understanding of science is not always reflected in their written responses to test and exam questions. Secondly, unique technical language and terminology used in science is difficult for students to grasp, and thirdly, assessment practices at this school do not provide a vehicle for all students to demonstrate the extent of their knowledge. Continuing research in this field is needed. Assessment practices need to be implemented that better correlate student understanding with the results they achieve.

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