Teachers' Beliefs about the Nature of Science and Science Education in relation to recently introduced Constructivist Syllabuses in Secondary Schools in Queensland, Australia

B. M. Odgers

School of Education, Australian Catholic University, McAuley Campus, PO Box 247 Everton Park, Qld 4053, Australia.

Topic: Views of Science held by Queensland Secondary Teachers

Key Words: Science, Traditional, Constructivist.

Correspondence

Dr Barbara M. Odgers
School of Education
Australian Catholic University
McAuley Campus
PO Box 247 Everton Park Qld 4053 Australia
Telephone: (07) 3855 7342
Facsimile : (07) 3855 7247
Email: b.odgers@mcauley.acu.edu.au

ABSTRACT

Recently introduced science syllabuses in secondary schools (Years 8-12) in Queensland Australia, have emphasized a constructivist view of science and science teaching and learning. This philosophy of science and science education is in direct contrast to all previous Queensland Science syllabuses which were based on a traditional view of science. It is therefore timely too investigate Queensland teachers views of science and science teaching and learning to see if their views coincide with the intentions of the most recent science syllabuses which firmly stand in the constructivist view of science and science education.

Beliefs about the nature of science within a traditional/constructivist framework were canvassed by questionnaire from 232 secondary science teachers throughout Queensland, Australia. Relationships between teachers' beliefs about the nature of science and the teaching strategies they used in their classrooms were also investigated. Teacher's educational and professional background, gender and age were also noted to determine whether these factors influenced teachers' views about the nature of scientific knowledge.

Correlation analysis revealed that teacher's responses to items of the questionnaire clustered into the two views of science: a traditional view and a constructivist view. Within each of these groups were items relating to teachers' beliefs about the development of scientific knowledge, science education and school science. When analyses were focussed on two specific epistemological items about the nature of scientific knowledge, one relating to a traditional view and the other to a constructivist view, the responses of teachers to the traditional view item indicated that they supported that view. However teachers responses to the item about constructivist view of scientific knowledge were very different with teachers equally divided 'for' and 'against' the constructivist view. Further analyses of these two items revealed that teachers of Years 8-10 Science and Physics (Years 11-12) had similar views to the majority of teachers

which supported the traditional view of scientific knowledge whereas Biology teachers went against the trend and disagreed with the traditional view.

There were no statistically significant differences between teachers' beliefs about the nature of scientific knowledge and the 22 'successful' teaching strategies they described. While 41% of teachers supported a constructivist view of scientific knowledge only 3% of lessons reported by the teachers were based on the constructivist view of learning. There was no link between Queensland secondary school teacher's gender or age and their beliefs about the nature of scientific knowledge.

From this study it is evident that Queensland secondary science teachers have not fully embraced the constructivist view of science or constructivist pedagogy apparent in the most recent Queensland Science syllabuses and in-service programs. If education authorities fully support the change in philosophy to a constructivist view of science and science teaching and learning that is evident in the new science syllabuses, it is recommended that new innovative professional development programs where teachers are working in a constructivist learning community be provided for all secondary teachers from different disciplines, education and professional backgrounds as well as age and gender to enable teachers to make the transition to a constructivist view of science and science education.

INTRODUCTION

There are many views of the nature of science. One view, a traditional view, is that all scientific knowledge is knowable, the truth, a reflection of things as they really are. This view has a 'discover the truth' / 'jig saw' view of science. Within this modern/realist view (Good & Shymansky, 2001), scientists who investigate phenomena using scientific methods will eventually discover all the right answers (Appleton, 1991; Larochelle & Desautels, 1991; Robottom, 1988). Another view, a constructivist view, suggests that scientific knowledge is developed by the construction of knowledge (mental constructions) to explain the world around us (Larochelle & Desautels, 1991). Within this postmodern/relative view (Good & Shymansky, 2001) scientific knowledge is also tentative and subject to change.

In recent years there have been investigations about different views of science held by a variety of groups. Larochelle and Desautels (1991) investigated adolescent's general ideas of scientific knowledge while Songer and Linn (1991) investigated the static and dynamic views of science held by science teachers and students. Laplante (1997) investigated beliefs of two primary teachers who viewed themselves as consumers not enquirers of science. While Pomeroy (1993) investigated the traditional versus nontraditional views of science amongst teachers (elementary and secondary science) and scientists, Zeilder and Lederman (1989) investigated what they called Realist versus Instrumentalist view of science which loosely corresponds to a traditional and constructivist views of science. The latter focussed on the extent of the impact that teachers' language had on students' view of science. It is only recently in education circles in Queensland, Australia that the debate between the traditionalists and constuctivists has become of interest to educators, as there has been a change in the philosophy of science, from traditional to constructivist view, in the most recent Queensland Science Syllabuses.

In Queensland secondary schools, there are two levels of science education. In the compulsory years of secondary schooling (Years 8-10) students work within an integrated science program. In the two post compulsory years of schooling (Years 11-12), science is studied in separate disciplines: Biological Science, Chemistry, Earth Science, Marine Studies, Multi-strand Science and Physics. In recent years there has been a shift in educational thought from a traditional view of science to a constructivist view. This is evident in the Science syllabuses in Queensland secondary schools. Prior to 1999, the Queensland Board of Senior Secondary School Studies Syllabuses for Years 11-12 science (*Senior Chemistry* 1995a, *Senior Physics* 1995b, *Senior Biological Science* 1998a, *Multi-strand Science* 1998b) were based on the traditional view of science.

> "Characteristically (science), it adopts an empirical approach to the search for natural explanations of phenomena observed in the universe" (Queensland Board of Senior Secondary School Studies, 1995a, 1995b, 1998a, 1998b p. 1).

The rationale in the Queensland Board of Senior Secondary School Studies Syllabus for Years 8 -10 Science (*Junior Science* 1987) was similarly worded.

The most recent Years 11 & 12 Queensland Board of Senior Secondary School Studies Syllabus (*Earth Science* 2000) is based on a constructivist view of science.

> Explanations of natural phenomena may be viewed as mental constructions based on personal experiences. They result from a range of activities that may include observation, experimentation, imagination and discussion, and are achieved by considering the complexities of the universe at a level that can be understood. (Queensland Board of Senior Secondary School Studies, 2000, p. 1).

The most recent Queensland Schools Curriculum Council Syllabus for *Science Years 1-10* (1999a) states,

> "Science as a 'way of knowing' is used by people to explore and explain their experiences of phenomena of the universe. It is a process for constructing new knowledge" (Queensland Schools Curriculum Council Syllabus, 1999a, p. 1).
>
> and
>
> "Scientific knowledge is a set of explanations, made by communities of scientists, which attempts to account for phenomena and experiences….they are viable in the light of current evidence and scientific argument" (Queensland Schools Curriculum Council Syllabus, 1999a, p. 1).

With this change to a constructivist view of science in Queensland syllabuses, there has also been a change to a constructivist view of teaching and learning.

> Students construct personal explanations of phenomena they experience in everyday life. One role of the science education is to help students move from their personal constructions, which are often discordant with scientific explanations, towards theories and models accepted by the scientific community. (Queensland Board of Senior Secondary School Studies Syllabus, 2000, p. 1).

The most recent Queensland Schools Curriculum Council Syllabus, *Science Years 1-10* (1999a) states,

> "Science education involves students and teachers working together as each constructs new understandings and compares their current ideas with those of the scientific community" (p. 1).

These views of constructivists learning are similar in intent to the way Fosnot (as cited in Howe and Stubbs (1996) defined constructivism.

1. New knowledge is built on past constructions
2. Construction comes about through assimilation and accommodation (self-regulation)
3. Learning is a process of invention rather than accumulation

4. Meaningful learning occurs through reflection and resolution cognitive conflict. (Fosnot,1999, pp. 19-20).

As new syllabuses which firmly stand in the constructivist view of science and science teaching and learning, are introduced into Queensland schools it is timely to investigate Queensland teachers views of science and science teaching and learning to see if these views coincide with the intentions of the most recent science syllabuses.

This study therefore aims to investigate

- the beliefs held by Queensland senior secondary science teachers about the nature of science within the traditional/constructivist framework
- the types of teaching strategies used by science teachers in Queensland classrooms
- relationships between teachers' beliefs about the nature of science and the teaching strategies they use in their classrooms

Relationships between teachers' beliefs and factors such as educational and professional background, gender and age will also be investigated to determine whether these factors influence teachers' views about the nature of science and the way they teach science.

METHODS

Instrument

A research survey instrument consisting of the three sections (A, B and C) was developed for this study. Section A of the survey consisted of a 20-item questionnaire designed to determine teachers' perceptions about the development of scientific knowledge, the nature of science education and school science within the framework of a traditional view or constructivist view (Appendix 1). Both these views have been expressed through Queensland science syllabuses (Queensland Board of Senior Secondary School Studies, 1987, 1995a, 1995b, 1998a, 1998b, 2000; Queensland Schools Curriculum Council, 1999a) and in-service materials (Queensland Schools Curriculum Council, 1999b).

The 20 item questionnaire was selected for this research because similar instruments have been used successfully in science education research and particularly in research about views/beliefs about science (Aikenhead, Felming, & Ryan, 1987; Bradford, Rubba & Harkness, 1995; Pomeroy, 1993). Twenty statements were used instead of a larger number because those statements adequately covered the two main concepts to be investigated. It was hoped that as the completion of this instrument was voluntary that the smaller number of items may also encourage teachers, who have not developed strong views about the nature of science, to complete the survey and thereby reduce a bias that may be caused from self-selection of respondents who have strong views on the nature of science (Pomeroy, 1993).

The research methodology of this investigation was in the positivist paradigm. Items of the questionnaire were developed by the investigator from a variety of resources including Bradford, Rubba & Harkness (1995), Pomeroy (1993) and Queensland Schools Curriculum Council (1999b). Items were randomly distributed throughout the questionnaire and teachers were asked to rate their responses on a 5 -1 Likert scale format of 5 choices 'strongly agree', 'agree', 'unsure', 'disagree' and 'strongly disagree'. The 20-item questionnaire was pretested by postgraduate science students from universities in Brisbane Queensland, to see if there were any difficulties with interpretation of items.

Section B of the survey required teachers to give an example of a recent teaching session which they thought was successful. Teachers were also asked to give their reasons for believing the lesson was successful and whether the lesson reflected their general teaching style. Because of time and distance constraints and lack of person power the report of 'successful' lesson in this research was based on teacher's descriptions of the lesson instead of observation of science lessons by the researcher.

Section C of the survey contained questions aimed to determine each teacher's educational and professional background, gender and age.

Sample

Six hundred surveys were sent to science teachers in 200 secondary schools (three questionnaires per school) in rural and metropolitan areas throughout Queensland. One hundred of the schools were government sector schools, 50 were Catholic schools and 50 were Independent schools (other than Catholic). The numbers of schools surveyed in each sector reflected the proportion of schools in those sectors of education in Queensland. Six hundred surveys were sent out instead of a smaller number because of an expected low rate of return evident in school environment surveys in Queensland (J. Dorman, personal communication, October, 1999).

Data Analysis

Section A of the Survey: 20 item questionnaire

Item Analyses

To determine the spread of responses across all five categories ('strongly disagree', 'disagree', 'unsure', 'agree' and 'strongly disagree') percentages of responses to each of the five categories and means and standard deviation of responses for each item were calculated.

Correlation Analysis

A 20 x 20-item Pearson correlation was used to determine clusters of questionnaire items relating to teachers views about science and science education.

Internal Consistency

Clusters determined by Pearson correlation were examined for internal consistency by the use of Cronbach's alpha coefficient. A principal component factor analysis with varimax rotation was used to verify the clusters obtained by the correlation analysis.

Teachers' Responses to the 20 Items of the Questionnaire

A 20 x 20-item Pearson correlation was initially used to determine clusters of questionnaire items relating to teacher's views about science. Items 14 and 16 were then selected as representing the constructivist and traditional view of scientific knowledge respectively and Pearson correlation was employed again to examine the correlation between science teachers' responses to teach of these items. Chi-squared Goodness of Fit test was used to further explore differences in teacher's 'active' responses ('strongly agree', 'agree', 'strongly disagree' and 'disagree') (Zoller, Donn, Wild & Beckett, 1991) to Item 14 and Item 16.

Section B of the Survey: Teaching Strategies

Teachers description of the teaching strategies they used in their 'successful' lesson, their reasons for believing the lesson was successful and responses to questions about whether the lesson reflected their general teaching style were all classified by the researcher into subgroups (Appendix 2). Descriptive statistics in the form of percentages were then calculated. Interpretations and classifications of the teacher's descriptions of the 'successful' lessons were those of the researcher and therefore the results must be viewed with caution. (Duit & Trest, as cited in Harrison, 2001).

Section B & C of the Survey: Responses of Subgroups of Teachers to Item 14 and Item 16

Multivariate analysis (MANOVA) was employed to analyse the differences between the responses by subgroups of teachers, who use similar teaching strategies (Section B) and who are of the same age and gender and who have similar educational and professional backgrounds (Section C), to Items 14 and 16. Chi-squared Goodness of Fit test was used to further explore differences in 'active' responses ('strongly agree', 'agree', 'strongly disagree' and 'disagree') (Zoller et al., 1991) by these subgroups to Item 14 and Item 16 of the questionnaire.

RESULTS

Sample

Two hundred and thirty two completed surveys were returned from secondary science teachers in schools throughout Queensland. Teachers in each of the three school sectors (government, Catholic and Independent) returned similar percentages of surveys (32% - 42%). Even though the return of questionnaires was entirely voluntary this rate of return shows that all school sectors were proportionally represented in responses to the survey instrument.

All categories of science teachers were also adequately represented in the sample. Of the 232 science teachers who responded to the survey 55% were male and 44 % were female, 25% were under 30 years of age and 51% were 41 years or older, 41% had been teaching less than 10 years and 25% had been teaching for more than 21 years. Ninety-nine percent of the teachers had tertiary qualifications in science. Within the three years prior to the survey's distribution, ninety-eight percent of the teachers had taught Years 8-10 Science in the compulsory years of schooling, and 53% taught Biological Science, 42% taught Chemistry, 36% taught Multi-strand Science and 22% taught Physics in the post compulsory years of schooling (Years 11&12).

Item Analysis

There was a good spread of responses across the 5 categories of 'strongly agree' to 'strongly disagree' in all items except items 5, 6, 8, 10, 19, 20 as the endorsement proportions demonstrate (Table 1). Thus most items were sensitive to the differing opinions of teachers as illustrated by each item describing a characteristic that was neither too rare nor too common (Dorman, 1999).

Correlation

Pearson correlation analysis revealed that there were the two views of science, traditional and constructivist view within the of teachers' responses to the 20-item questionnaire. Ten items clustered with the traditional view and five items clustered with the constructivist view (Table 2a). Items, which were positively correlated with one view, were negatively correlated with the opposing view. Three items (2, 8, and 9) did not cluster with either the traditional or the constructivist view of science. The items, which clustered with the traditional view, reflected an unchangeable 'jig-saw' view of science (Table 2b). The items clustered around the constructivist view reflected a tentative, changeable view of science.

Internal Consistency

Cronbach coefficient for the two groups determined by Pearsons 20 x 20 item correlation were 0.70 and 0.59 (Table 3) which indicate relatively moderate internal consistencies as these scores are higher than 0.5 but less than the perfect internal consistency of 1.00. A principal component factor analysis verified the two-cluster structure of the instrument (Table 4). Items 2, 8 and 9 were deleted from this factor analysis as these items had not shown any correlation to either of the two groups in the correlation analysis. This resulted in a 15 item instrument with 10 items from the traditional set and 5 items from the constructivist set being used in this analysis (Table 4). The factor structure of 2 sets was consistent with the results of Pearson correlation with only 2 items (Item 10 and Item 11) not included in either group.

Teachers Responses to Item 14 (Constructivist view) and Item 16 (Traditional view)

Not only did Pearson correlation analysis revealed that there were the two polarized groups, traditional and constructivist, within the teachers responses to the 20-item questionnaire as mentioned above, Pearson correlation revealed that there was also a statistically significant negative correlation (p<. 01) between teachers responses to Item 14 and Item 16 of the survey. When percentages of active responses 'strongly agree' and 'agree' as well as 'strongly disagree' and 'disagree' (Table 5) were combined 54% of teachers surveyed supported a traditional view of scientific knowledge and 26% 'strongly disagreed/disagreed' with this view. Chi-square Goodness of Fit test indicated that there was a statistically significant differences (p<.01) between these responses. When 'active' responses for a constructivist's view were combined, there was no statistically significant difference in the responses of teachers to this statement.

Forty one percent of respondents 'strongly agreed/agreed' and 46% 'strongly disagreed/disagreed' with this view.

Teaching Strategies

Of the 207 science teachers who responded to the 'successful' lesson items, 66% of the respondents reported successful lessons in Years 8-10 Science, 13% in Biological Science, 8% Chemistry, 3% Multi-strand Science and 11% Physics (Appendix 2). The successful lessons were distributed equally across the five-Year Levels (Appendix 2).

The teaching strategies for successful lessons were classified by the researcher into 22 subgroups (Appendix 2). While some of these lessons were difficult to categorize the lessons based on a constructivist approach to teaching and learning lessons were easily recognized. Of these 'successful' lessons only 3 % were based on the constructivist view of learning as described by Fosnot (1989). Forty four percent of successful lessons were activities or open-ended investigations initiated by teachers and 18% were experiments in which students followed directions. All other subcategories of 'successful' lessons used had values of 4% or less.

Twenty-seven subgroups were determined by the investigator from the responses of 201 teachers for reasons for the success of their lessons (Appendix 2). Of these responses, constructivist approach to teaching and learning scored 6%, hands-on activities 12%, fun/enjoyment 10%, reinforced concept 9%, thinking 9%, understanding 8% and teacher control 1%. Classification of the reasons given by teachers for the 'successful' lessons into student or teacher centred groups revealed that 91% of reasons given by the teachers for the 'successful' lesson were that they were student centred. Fifty nine percent of the teachers said that they used the style of their 'successful' lesson most of the time (Appendix 2). Reasons given by teachers not using this the style of lessons most of the time were those of time constraints within the school and syllabus requirements.

Responses of Subgroups of Teachers to Item 14 and Item 16

Multivariate analysis (MANOVA) revealed that there were no statistically significant differences between responses to Item 14 and Item 16 by subgroups of any of the categories in Section B or Section C of the survey.

When relationships between the subjects teachers taught and their 'active' responses to Item 14 and Item 16 were analysed by Chi-squared Goodness of Fit test, it was revealed that there were statistically significant differences (p<.01) between groups of Years 8-10 Science teachers supporting a traditional view of scientific knowledge: 54% agreed with the statement and 25% disagreed (Table 6). Years 8-10 Science teachers were equally divided on the constructivist's view with 42% agreeing with the statement and 45% disagreeing with the statement. The majority of Biological Science teachers (53%) disagreed with the traditional view with only 26% supporting it (p<.01). Biological Science teachers equally 'agreed/disagreed' with a contructivist's view. Of Physics teachers who responded to the survey 56% agreed with a traditional view and 24% disagreed (p<.001), whereas there was no statistical significant difference between Physics teachers who agreed with a constructivist view or disagreed with that view.

No statistically significant differences were identified when relationships between teaching strategies used in the 'successful' lessons and the view of scientific knowledge the teachers' supported were examined by Chi-squared Goodness of Fit test. However there was a statistical significant difference (p<.01) between whether the reason for the 'successful' lesson was student or teacher centred and the teachers' view of scientific knowledge (Table 6). Forty five percent of teachers who gave reasons for their 'successful' lessons being student-centred supported a constructivist's view whereas only 22 % of teachers whose reasons for 'successful' lessons were teacher-centred supported this view.

In the subgroups investigated for gender, age and number of years teaching (Table 6), Chi-Squared Goodness of Fit test revealed that there were no statistical significant differences between responses by the subgroups to either a traditional or constructivist view.

DISCUSSION

Instrument

Results of this study revealed that the 15-item instrument used in the analysis of secondary teacher's views of science within the traditional/ constructivist framework was a valid and reliable instrument. This was evidenced by correlation analysis where items positively correlated to a traditional view were negatively correlated to a constructivist view and vica versa. A principal component analysis also confirmed these groupings.

Cronbach alpha coefficient of 0.70 for the traditional cluster and 0.59 for the constructivist's cluster indicated relatively strong internal consistencies where a perfect internal consistency would produce an alpha of 1.0. Pomeroy (1993) found similar alpha values: 0.65 for 8 traditional view items and 0.59 for 9 nontraditional items.

Sample

It may be suggested that 232 respondents from an initial mailing of 600 surveys (three per school) may not be a representative sample, however the number is reasonable in the light of other similar surveys. In the Lumpe, Czerniak & Haney (1998) study of science teachers beliefs and cooperative learning, 107 teachers responded to a survey of a mail out of 200 instruments. In that study, phone-up strategies were used to encourage teachers to reply to the survey. Seventy-one scientists and 109 teachers (both primary and secondary) responded to Pomeroy's (1993) survey, but that report does not mention how many surveys were mailed out to potential participants.

The present study had 232 completed surveys to analyse. This number is similar to other such surveys (Lumpe, Czerniak & Haney 1998; Pomeroy, 1993; Zoller, Donn, Wild & Beckett, 1991) and in a recent Australian wide study commissioned by the Australian Government (Rennie, Goodrum and Hackling (2001) where 296 secondary teachers participated. The respondents in this present study represent a wide range of teachers from different geographic regions of Queensland, school sectors, educational and professional backgrounds, age groups and gender.

Caution must be used when interpreting these results as there is the possibility of sample bias even though steps were taken to reduce the bias of self-selection. Teachers responding to the survey may be the ones who have strong views about the nature of science. If this bias is present, the study is still valuable as it presents an insight into the views of teachers at both ends of the scale - the traditional and constructivist view.

Teachers Views about the Nature of Science

Teachers expressed views about science, whether traditional or constructivist, was the basis of this research. That teachers responses to 15 items of the questionnaire clustered with either a traditional or a constructivist view indicated that there was a clear division between teachers on these views of science. The two opposing views not only encompassed beliefs about the nature of scientific knowledge but also teachers' beliefs about influences on the development of scientific knowledge, views of science education and school science. The clustering supports the assertion of Lederman & O'Malley (1990) that one's view about scientific knowledge parallels one's view about the nature of science.

That Item 8, 'Creativity has no place in science', did not cluster with either view is perplexing. There was an overwhelming rejection (96% of respondents) of this statement; so no matter what their view of science, teachers who responded to this survey agreed that creativity has no place to play in science. Pomeroy (1993) found an equally perplexing response for an item about creativity in science. In that study of the views of scientists, secondary science teachers and primary science teachers, an item about creativity correlated with the traditional view of science.

The division between teachers' responses to the two specific items about the nature of scientific knowledge (Item 14 and Item 16) was consistent with the Pearson correlation results as there was a statistically negative correlation between the 'active' responses to these items of the survey. On closer scrutiny of these 'active' responses, not all teachers had made up their mind about the nature of scientific knowledge within the framework of a traditional and constructivist view. While the majority of teachers agreed with the traditional view of scientific knowledge, teachers were equally divided in agreeing and disagreeing with the constructivist view. It appears that while there has been a shift in educational thought in Queensland amongst syllabus writers to a constructivist view of science, scientific knowledge and science teaching and learning, not all teachers at present support this view. Maybe teachers are convinced that the traditional view of scientific knowledge is the 'right' view or it could be because the idea of constructivism has only recently been brought to their attention. Gallagher (1991) suggests in a study of teachers and philosophies of science, that "secondary science teachers have a distorted understanding of the nature of science because their scientific education has focussed on the body of knowledge of science … and little on the processes by which scientific knowledge is developed" (p. 132). This suggestion which is also supported by Nott & Wellington (1998) could also be the true for secondary science teachers in Queensland schools.

That Years 8-10 Science and Physics (Years 11-12) teachers strongly supported a traditional view of scientific knowledge may indicate that these groups of teachers are not yet willing to embrace a constructivist view. The Years 8-10 data is particularly interesting as it is in this sector that most emphasis on the constructivist view of science has been placed within the Syllabus and in-service programs (Queensland Schools Curriculum Council, 1999a, 1999b). It is also of interest that the majority of Biology teachers went against the trend of the data and disagreed with a traditional view. No reason for this is offered, however it could be linked to an underlying difference between the nature of a physical science and biological science. Further research would be required to establish such a link.

This research also indicated that beliefs about science held by secondary school science teachers transcends gender and age groups and is not related to length of teaching experience. These findings are important as they suggest that professional development programs delivered by education authorities should not be based on differences within these groups but should be provided for all secondary teachers from different disciplines, education and professional backgrounds as well as age and gender.

Teaching Strategies and Views of Science

This study revealed that teachers in Queensland secondary schools use a range of 'successful' teaching strategies in their classrooms, and that most of these strategies are student-centred (Table 2). In contrast, Rennie, Goodrum & Hackling (2001) reported that only in the primary schools in Australia is science generally taught in a student-centred, activity based mode. In this present study teachers reported that they used their 'successful' style of teaching 59% of the time, reporting time constraints and syllabus requirements as the major hindrances for using their successful teaching strategy more often in their classroom. These results support those of Lederman (1992), who suggested factors such as curriculum constraints and administrative policies influence the teaching strategies used in the classroom.

In this present study it was found that there was no link between teachers view of science and their teaching strategies as far a constructivism was concerned. While 41% of responding teachers agreed with the constructivist view of science only 3% of the 'successful' lessons described by teachers were based on the constructivist pedagogy. These results support those of Bell, Lederman & Abd-El-Khalick, 1998, Duschl & Wright (1989) and Lederman (1999) but are in direct contrast to those of Ballone & Czerniak (2001), Brickhouse (1989, 1990), Gallagher (1991), Pajares (1992), Rowell & Gustafson (1993) who reported links between teachers' beliefs about the nature of science and their teaching strategies. The results in Queensland may be because "'people may state (and actually believe) that they believe in one thing but act in a quite different way" (Norman, as cited in Harrison, 2001, p.11). This study did not look at the relationship between teachers and students beliefs and the nature of science and science teaching and learning as did the study of Tobin & Mc Robbie (1997) who reported a direct parallel in teacher and students views of science and science teaching and learning.

From this study it is evident that Queensland secondary science teachers have not fully embraced the constructivist view of science or the constructivist pedagogy apparent in Queensland syllabuses and in-service programs (Queensland Schools Curriculum Council, 1999a, 1999b). These findings are supported by Rennie, Goodrum & Hackling (2001) who noted in Australian schools that there was a large gap "between the ideal or intended curriculum and the actual or implemented curriculum" (p. 494). If the education authorities in Queensland fully support the change in philosophy to a constructivist view of science and science teaching and learning apparent in the new science syllabuses, it is recommended from the findings of this study that new innovative professional development programs based on a construcitivist philosophy be provided for all secondary teachers across different disciplines, education and professional backgrounds, age groups and gender. As Alesandrini & Larson (2002) state "until teachers experience constructivism themselves, they may not be equipped to plan and facilitate constructivist activities by their students" (p 118). Professional development programs would help teachers understand students learning from the constructivist's view and help teachers develop constructivist strategies of teaching and learning for science classrooms. Such programs should take place in learning communities of other teachers and educators similar to the constructivist community that teachers are trying to provide for their students (Prawat, 1992). Professional development programs based on the constructivist approach may also help teachers to understand the constructivist view of science (Pomeroy, 1993) as they reflect on the process of their own learning. Reflection, an important par to constructivist learning should be given prominence in attempts aimed at changing teachers' concepts of the nature of science (Abd-El-Khalick & Lederman, 2000). Professional development programs based on the constructivist are also empowering for science teachers (Howe & Stubbs (1996) as they given them opportunity to construct their own knowledge and meaning.

If education in science is about scientific literacy of students, as noted in the Queensland science syllabuses (Board of Senior Secondary School Studies 1995a, 1995b, 1998a, 1998b, 2000; Queensland Schools Curriculum Council, 1999a) and as scientific literacy involves an understanding the nature of science (Eichinger, Abell, & Dagher, 1997; Griffiths & Barman, 1995) steps need to be taken to address the issue of the nature of science in schools. Hurd (1998) reasons that science literacy characteristics are not taught directly but are imbedded in the enacted curriculum and Lederman (1992) states "the most important variables that influence students' beliefs about the nature of science are specific instructional behaviours, activities and decisions implemented within the context of the lesson" (p.351). Therefore it is essential the secondary teachers implementing a constructivist syllabus use constructivist teaching strategies in their classrooms to demonstrate to students, the nature of science.

Cronin-Jones (1991) reported that if teachers existing belief structures are incongruent with the underlying philosophy of the intended curriculum they will hinder the successful implementation of the curriculum. So if the education authorities in Queensland fully support the change in philosophy to a constructivist view of science and teaching and learning that is apparent in the new science syllabuses, it is recommended from the findings of this study that new innovative professional development programs based on a constructivist philosophy be provided for all secondary teachers from different disciplines, education and professional backgrounds as well as age and gender to enable teachers to make the transition to a constructivist view of science and science education.

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Table 1.
Response percentages, means and standard deviations for each of the 20 items of the questionnaire

Item	StD	D	U	A	StA	N	Mean	SD
1	21.6	31.0	5.2	37.9	3.4	230	2.7	1.27
2	7.8	40.5	8.3	31.5	10.3	228	2.96	1.21
3	4.3	25.0	27.2	39.2	3.0	229	3.12	0.97
4	9.1	34.5	15.1	27.2	12.5	228	3.00	1.23
*5	2.2	3.4	3.9	58.6	30.6	229	4.14	0.82
*6	12.9	56.5	12.5	15.1	2.2	230	2.37	0.97
7	2.2	20.3	14.2	50.9	11.6	230	3.50	1.01
*8	69.8	25.9	0.4	0.00	3.0	230	1.39	0.78
9	6.9	44.0	19.4	25.9	2.2	228	2.72	1.00
*10	0.9	9.5	7.8	57.3	23.3	229	3.94	0.88
11	25.4	49.1	7.3	16.8	0.0	229	2.16	1.00
12	6.9	25.4	12.9	47.8	6.0	230	3.21	1.11
13	12.1	47.0	18.1	19.4	1.7	228	2.51	1.00
14	7.8	37.1	12.5	31.0	9.5	227	2.97	1.19
15	6.0	44.4	21.6	24.1	3.0	230	2.73	1.00
16	1.7	23.7	19.8	47.4	5.6	228	3.32	0.96
17	7.8	46.1	9.1	32.8	3.4	230	2.78	1.10
18	1.7	19.0	31.5	43.5	3.0	229	3.28	0.87
*19	21.1	47.0	18.5	10.8	1.7	230	2.24	0.97
*20	36.6	56.0	3.4	2.6	0.4	230	1.73	0.69

StD = Strongly Disagree; D = Disagree; U = Undecided; A = Agree; StA = Strongly Agree; N = Number of responses
* items where responses were skewed

Table 2a.

Correlation values of items with the Traditional view (Item 16) and the Constructivist view (Item 14) of scientific knowledge (Pearson correlation)

Items	Traditional view (Item 16)	Constructivist view (Item 14)
1	.201**	-.134*
3	.288*	-.220**
4	.285**	-.070
5	.170*	-.006
6	.213**	-.213**
11	.176**	-.162*
13	.232**	-.098
16	1.000	-.220**
17	.182**	-.164*
19	.265**	-.025
20	.187**	-.107
7	-.128	.246**
10	-.156*	.210**
12	-.095	196**
14	-.220**	1.000
15	-.136	.279**
18	-.084	.157*
2#	.121	-.068
8#	.054	.035
9#	.098	.044

* Correlation is significant at 0.01 level (2-tailed)
** Correlation is significant at 0.05 level (2-tailed)
# items showing no significant correlation with either group

Table 2b.

Clusters of items around Item 16 (traditional view of scientific knowledge) and Item 14 (constructivist view of scientific knowledge) (Pearson correlation)

A. *Traditional view*

Items clustered around Item 16. Scientific knowledge is a reflection of things as they really are

1. The scientific method conclusively proves or disproves hypotheses
3. Many scientific models used in research laboratories are copies of reality
4. Students in science should be encouraged to think carefully and logically and be discouraged from developing 'wild' explanations.
5. Valid scientific knowledge is backed up by objective experimentation
6. The only way to increase scientific literacy in students is to encourage them to read science texts and articles.
11. Science can be effectively taught from textbooks and worksheets.
13. Science as portrayed in school textbooks is the same as real science.
17. The main purpose of laboratory work in schools is to validate concepts already studied in class.
19. If scientists keep on working, all the rules of nature will be discovered.
20. Scientific knowledge and explanations in textbooks are always true.

B. *Constructivist view*

Items clustered around Item 14. Scientific knowledge is not discovered but is constructed by scientists

7. Different cultures may develop different scientific explanations for the same event.
10. The values held by scientists influence their observations and explanations of events.
12. Scientific knowledge may be based on hunches.
15. Science would be better taught in schools if students investigated their own ideas rather than do set tasks.
18. There is a significant amount of scientific knowledge in folklore and myth.

C. *Items which did not cluster with either of the two key statements.*

2. Students in science should be encouraged to repeat the experiment if they do not obtain the correct answer.
8. Creativity has no place in science
9. Science in schools is best taught as a set of process skills.

Table 3.
Internal consistency as determined by Cronbach Coefficient Alpha

Cluster	Alpha	No of items	N	Mean	SD
A. Traditional view of science (Items 1,3,4,5,6,11,13, 16, 17,19,20)	0.70	11	222	30.10	5.50
B. Constructivists view of science (Items 7,10,12,14,15,18)	0.59	6	225	19.62	3.50

Table 4.
Principal component analysis of items

Item	Traditional view	Constructivist view
1	0.59	
3	0.51	
4	0.51	
5	0.45	
6	0.47	
13	0.46	
16	0.52	
17	0.35	
19	0.58	
20	0.61	
7		0.60
12		0.31
14		0.56
15		0.70
18		0.61

Table 5.
Teacher's responses to a traditional view (Item 16) and a constructivists view (Item 14).

View of science	Strongly Disagree (%)	Disagree (%)	Unsure (%)	Agree (%)	Strongly Agree (%)	Total no. of responses
Traditional view (Item 16)	1.8	24.1	20.2	48.2	5.7	228
Constructivist view (Item 14)	7.9	37.9	12.8	31.7	9.5	227

Table 6.

'Active' responses ('stongly agree', 'agree', 'strongly disagree' and 'disagree') to Item 16 (Traditional View) and Item 14 (Constructivist View) by Subgroups in Section B & C of the Survey (Chi-squared Goodness of Fit test)

Category	Item No.	Sample (n)#	Sub groups	Sub group sample size (n)#	Agree/ strongly agree (%)	Disagree/ strongly disagree (%)
Section B of Survey						
Student/ teacher centred lesson	16 (T)	195	student : teacher centred	177 : 18	51 : 72	27 : 17
	14 (C)	196	student : teacher centred	178 : 18	45 : 22**	76 : 56
Section C of Survey						
Teachers of:						
Years 8-10 Science	16 (T)	220			54	25**
	14 (C)	219			42	45
Biology	16 (T)	122			26	53**
	14 (C)	122			36	48
Physics	16 (T)	50			56	24***
	14 (C)	49			39	49
No of years teaching	16 (T)	226	<10 : 11-20 : over 21yrs	94 : 74 : 58	52 : 52: 57	25 : 31 : 28
	14 (C)	225	<10 : 11-20 : over 21yrs	93 : 75 : 57	36 : 46: 42	49 : 37 : 46
Gender	16 (T)	225	male : female	125 : 101	50 : 61	28 : 23
	14 (C)	225	male : female	127 : 98	43 : 40	44 : 48
Age	16 (T)	228	21-30yrs : >30 yrs	57 : 171	54 : 54	18 : 29
	14 (C)	227	21-30yrs: >30 yrs	56 : 171	34 : 43	60 : 41

= numbers of teachers responding to the item and the category

* $p < .05$, ** $p < .01$, *** $p < .001$ (Chi-squared Goodness of Fit test)

Appendix 1

Categories of the 20 items of the Questionnaire

A. *Traditional view of scientific knowledge*

16. Scientific knowledge is a reflection of things as they really are. *(Key statement)*
3. Many scientific models used in research laboratories are copies of reality
19. If scientists keep on working, all the rules of nature will be discovered.

B. *Constructivist view of scientific knowledge*

14. Scientific knowledge is not discovered but is constructed by scientists. *(Key statement)*

C. *Teachers beliefs about influences on the development of scientific knowledge*

1. The scientific method conclusively proves or disproves hypotheses.
5. Valid scientific knowledge is backed up by objective experimentation.
7. Different cultures may develop different scientific explanations for the same event.
8. Creativity has no place in science
10. The values held by scientists influence their observations and explanations of events.
12. Scientific knowledge may be based on hunches.
18. There is a significant amount of scientific knowledge in folklore and myth.

D. *Teachers views of science education*

2. Students in science should be encouraged to repeat the experiment if they do not obtain the correct answer.
4. Students in science should be encouraged to think carefully and logically and be discouraged from developing 'wild' explanations.
6. The only way to increase scientific literacy in students is to encourage them to read science texts and articles.
9. Science in schools is best taught as a set of process skills.
11. Science can be effectively taught from textbooks and worksheets.
15. Science would be better taught in schools if students investigated their own ideas rather than do set tasks.
17. The main purpose of laboratory work in schools is to validate concepts already studied in class.

E. *Teachers views of school science*

13. Science as portrayed in school textbooks is the same as real science.
20. Scientific knowledge and explanations in textbooks are always true.

Appendix 2

Science discipline, year level, teaching strategies and reasons for the 'successful' lessons as reported by teachers

Category	Sample size (n) (responses)	Successful lessons (%)
Science Discipline (Subject)	207	
Years 8-10 Science		
Science & Society		13
Earth & Beyond		3
Energy & Change		15
Life & Living		20
Natural & Processed Materials		15
Biological Science		13
Chemistry		8
Multi-strand Science		3
Physics		11
Year level of lesson	207	
8		23
9		20
10		21
11		15
12		20
Teaching strategy	185	
Activity/activities		28
Chalk & Talk		1
Class discussion		4
Concept map		1
Constructivist		3
Demonstration		4
Discovery		2
Dissection		3
Excursion		2
Experiment following directions		18
Explaining		1
Independent students own		1
Investigation (open ended)		16
Library search		1
Model concept		1
Observation		4
Problem solving		1
Question/Answer		3
Several/combination		4
Structured essay writing		1
Workstations		2
Other		1
Traditional/non-traditional lesson	185	
Traditional		54
Non-traditional		46

Appendix 2 (cont.)

Recent successful lessons reported by secondary school science teachers

Category	Sample (n) (responses)	Successful lessons (%)
Reason for successful lesson	201	
Achievable/success		4
Challenging		1
Combination		2
Constructivist		6
Different from usual lesson		1
Difficulties with experimental procedure		1
Discovery		5
Fun/Enjoyment		10
Group work		2
Hands on		12
Interest		7
Investigation/inquiry		1
Modeled concept		1
Novel approach		2
Owned results		2
Prior preparation by students		3
Problem solving		1
Real life		4
Reinforced concept		9
Student centred		5
Teacher control		1
Thinking		9
Understanding		8
Variety of activities		3
Visual		5
Worksheets		1
Other		3
Student/Teacher centred lesson	199	
Student centred		91
Teacher centred		9
Lesson reflects general teaching style	192	
Yes/Generally/Mostly		59
Often		2
Sometimes		10
No		12
Where possible/where appropriate		14
Variety used		3