

DOCUMENT RESUME

ED 458 093

SE 064 759

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TITLE Reflective Science: An Exploration of the Uses of Reflective Dialogue Journal Writing in Secondary Science Classrooms.
PUB DATE 2000-12-00
NOTE 8p.; Paper presented at the Annual Meeting of the Australian Association for Research in Education (Sydney, Australia, December 4-7, 2000).
AVAILABLE FROM For full text: <http://www.aare.edu.au/00pop/rya00201.htm>.
PUB TYPE Reports - Research (143) -- Speeches/Meeting Papers (150)
EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Action Research; Foreign Countries; *Journal Writing; *Metacognition; Scientific Literacy; *Scientific Principles; Secondary Education; Student Development
IDENTIFIERS *Conceptual Change; Marginal Students; *Reflective Writing

ABSTRACT

This paper reports on critical Action Research into the scientific literacy of secondary school students, as evidenced in student Reflective Dialogue Journals. Focussed on one secondary school classroom located in Brisbane, Australia, the research draws on literature concerned with writing and its use across the curriculum, particularly as this relates to scientific literacy and the nature of science. Specifically the interest of the research is with philosophies of science rather than the transmission of scientific constructs. The paper suggests that individual student reflections and teacher-student dialogue, made possible through such journal-writing, provide significant opportunities to support students' development of complex understandings on the nature of science. Informed by a concern for matters of social justice, the paper also contemplates what such an approach to learning science might mean for marginalized students, particularly those differentiated on the basis of their gendered identities. The paper concludes that while initial results appear promising, longitudinal research into the value of reflective writing in science classrooms is now required. (Contains 31 references.) (Author/SAH)

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ED 458 093

Reflective Science:

An exploration of the uses of Reflective Dialogue Journal writing in secondary science classrooms.

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A paper present at the Australian Association for Research in Education annual conference, University of Sydney, 4-7 December 2000.

ABSTRACT: This paper reports on critical Action Research into the scientific literacy of secondary school students, as evidenced in student Reflective Dialogue Journals. Focussed on one secondary school classroom located in Brisbane, Australia, the research draws on literature concerned with writing and its use across the curriculum, particularly as this relates to scientific literacy and the nature of science. Specifically the interest of the research is with philosophies of science rather than the transmission of scientific constructs. The paper suggests that individual student reflections and teacher-student dialogue, made possible through such journal writing, provide significant opportunities to support students' development of complex understandings on the nature of science. Informed by a concern for matters of social justice, the paper also contemplates what such an approach to learning science might mean for marginalised students, particularly those differentiated on the basis of their gendered identities. The paper concludes that while initial results appear promising, longitudinal research into the value of reflective writing in science classrooms is now required.

Overview:

In this paper, I offer a brief report on a critical action research study. The study focussed on students' understandings of the NOS as revealed by Reflective Dialogue Journal writing. This writing was embedded in everyday science lessons in a mixed ability, Yr10 Science class that I taught during my nine-week final pre-service teaching practicum at a coeducational, private school in Brisbane.

Specifically, I shall:

1. Explain how RDJs can support the development of complex understandings about the NOS.
2. Answer the question as to what that might mean for marginalised students and
3. Suggest areas for further research.

First however, some conceptual and pedagogical background is needed.

Conceptual Background:

Two aspects of conceptual background are essential to note. The first has to do with the NOS in science

education itself, while the second relates to factors that affect the development of student's understandings of the NOS.

Shamos (1995) placed great importance on NOS education when he indicated that science content may not be necessary for attaining scientific literacy, [but] understanding the NOS is requisite. The NOS is the "fertile hybrid arena" that blends the history, sociology, philosophy and psychology of science, including

"what science is, how it works and how scientists operate as a social group and how society itself both directs and reacts to scientific endeavour" (McComas *et al.*, 1998, p. 4).

Much research (Duschl, 1997; McComas *et al.*, 1998; Griffiths & Barman, 1993; Solomon, Scott & Deveen, 1996) suggests that students conceptualise the NOS in scientific ways, including claims to the absolute truth, fact, infallibility, logic and objectivity of science. Such perceptions of the NOS have been linked to equity issues in science education (see McComas *et al.*, 1998; Wooldridge, 1997; Johnston & Dunne, 1996; Harding, 1991; Gilbert, 1997; Kenway & Gough, 1998) and have serious ramifications for scientific literacy (Coburn & Loving, 1998; Lucas & Roth, 1996; McComas *et al.*, 1998; Shamos, 1995; Solomon, 1995).

While out-of-school factors contribute to such impressions, school science is also culpable. McComas *et al.* (1998) report, many teachers feel inadequately equipped to engage their students in considering the NOS, especially given the content emphasis and assessment regimes of many classroom contexts. Additionally, science courses tend to instruct students in *the* scientific method, rather than recognising the multiplicity of approaches that scientists use (Fleener, 1996). Moreover, despite evidence that scientific reports misrepresent the nature of scientific endeavour (Clough 1997; Medawar, 1990; Soltis, 1984), many science courses mandate that students compose these and do not provide opportunities to critically review the implications of this kind of writing. Finally, many science textbooks either consider tokenistically, omit, or misrepresent the nature of science (McComas, *et al.*, 1998). Nonetheless some researchers (Lucas & Roth, 1996; Matthews, 1998; Solomon, 1995) claim that higher levels of understanding are accessible to many students.

Pedagogical Background

With these ideas in mind, my study set out to investigate one teaching-learning tool to help students examine and reconstruct their understandings of the NOS. That strategy involved the use of Reflective Dialogue Journals. The three words in the title of the tool, Reflective Dialogue Journals, spell out its nature:

- *Reflection* refers to the metacognitive act of "intentional[ly] casting back on experience";
- *Dialogue* refers to the exchange of meaning that occurs as teachers respond in writing to students' entries, and
- *Journal* refers to the regular, sustained pattern of written entries.

Such journals are not usually considered a scientific genre - indeed that is part of their value. RDJs help to confront some of the stereotypes that are perpetuated by traditional, third personal, past tense impersonal scientific prose (Medawar, 1990). Moreover, journal writing is a means for students to use language to think and learn about science and replicate aspects of the journal writing engaged by professional scientists (Grumbacher, 1987). Finally, the metacognitive skills developed in keeping an RDJ are essential aspects of conceptual change strategies (Hewson, 1996; Baird, Fensham, Gunstone, & White, 1991) and are congruent with constructivist approaches to science education (Osborne & Freyburg, 1985; Treagust, Duit & Fraser, 1996).

Students' RDJ writing during the study was scaffolded by the use of teacher-prepared proformas known as response frames that used prompt questions to stimulate and guide their reflections. Probe questions were formulated linguistically to focus Mental Processes and the associated conscious cognition, active reflection and analysis (Eggins, 1994). In terms of subject matter, I sought to construct reflective writing tasks that would help the students to make conscious their tacit understandings of the NOS; highlight the implications for the student of the issue being considered, and problematise scientific assumptions.

The goals of this study centred on investigating if, through reflective dialogue journal writing, students might engage with, and reconstruct their understandings of the nature of science (NOS). Notably however, these goals were not an attempt to define *the* 'correct' understanding of the NOS, but to encourage students to engage with the limitations of scientism. I sought to highlight the dynamic, fallible and context-bound nature of the discipline and value a diverse range of skills including creativity and logic, intuition and rationality. Such values were also integral to the study's naturalistic, critical Action Research design and methodology (Carr & Kemmis, 1986).

How RDJs can support the development of complex understandings about the NOS.

As an outcome of my research, I constructed two case studies to help me explain how RDJs can support the development of complex understandings of the NOS. These case studies derived from two-fold analyses of students' RDJs.

The first analytic strategy draws on contemporary research (Edwards & Potter, 1992; Gilbert & Mulkay, 1984) indicating that it is problematic to suggest that participants responses provide an untinted window on their beliefs or essential personality. Rather, respondents' statements are analysed in terms of their use of discursive repertoires - that is, the statements in a particular discourse context which allow people to support their claims (cf. Lucas and Roth, 1996). After Lucas and Roth (1996), I constructed nine discursive repertoire categories suggested by, and inferred from students' responses to RDJ prompts about the NOS.

1. **Pragmatic** : In contrast to the Separatist repertoires described below, Pragmatic repertoires cite the usefulness and relevance of science, including the satisfaction of curiosity, interest and capacity to help people and society. For example: "It [science] lets us apply this knowledge to make life easier and more interesting for us" (Student 25, Journal Entry (JE) 1.0).
2. **Active** : Active repertoires invoke the social, collaborative and personal nature of science, highlighting multiplicity and diversity and including empathy, imagination, critique, consensus building and interpretation. For example: "Science is about everything. Everything is scientific" (Student 6, JE1.2) or "I am a critic and I ask myself if I believe what other scientists have said" (Mandy, JE2.1).
3. **Elitist** : An Elitist repertoire highlights the importance and power (social and explanatory) of science and endows it with a special capacity for certainty, objectivity, neutrality and logic. It frequently includes a sense of awe and suggests the difficulty, complexity and justice of science where past errors or failures have been rectified. For example: "I don't believe that Mendel 'fudged' his results... he was only observing what happened" (Mandy, JE1.1) or "Albert Einstein will always be more important than writers or poets"(Student 20, JE1.0).
4. **Separatist** : Statements from a Separatist repertoire construct science as irrelevant, removed and separate from oneself and everyday life. They frequently include a sense of alienation. For example: "I don't know about scientific knowledge so therefore I don't really relate to me [sic]" (Student 10, JE1.5).
5. **Human** : Claims supported by a Human repertoire invoke the fallible, tentative, incomplete and problematic nature of science, including recognition of its non-neutrality, constructedness and potential for revision and unethical conduct. For example: "Nothing is proven... Scientists could be wrong" (Mandy, JE1.5).
6. **Experimentalist**: Experimentalist repertoires call on classical scientific method as the path to knowledge, highlighting objective observation, hypothesis testing, control and repetitive verification of results. For example: "For me, doing science means doing experiments" (Student 7, JE1.0) or "Scientists are meant to use only the data available to them, and predict most probable outcomes" (Student 25, JE1.4).
7. **Factual** : Factual repertoires invoke a version of science limited to a collection of disembodied facts. For example: "For me, doing science means [I] know a lot more about life ... and how things work and what certain stuff does" (Student 17, JE1.0) or "I'm not good at remembering laws" (Student 17, JE2.1)
8. **School Science** : Use of the School Science repertoire supports a school-bound version of the nature of science, emphasising content recall, tests, textbooks, teachers and classes. For example: "Science is a subject that I do at school" (Student 2, JE1.1).
9. **Non-scientific** : Statements from Non-scientific repertoires invoke the common, rather than scientific meaning of terms, particularly of laws and theories and in so doing, construct a version of the NOS based on these misconceptions. For example: "Laws ... are theories that have been proven 100% true" (Student 8, JE1.5) or "only the successful people produce laws and many produce theories that they hope are correct" (Student 28, JE1.5).

In addition to these nine interpretive repertoires, I also constructed a category that included "Alternative uses of RDJs". These alternative uses were divided into sub-categories including interpersonal remarks; feedback on lessons; expressions of uncertainty, and both positive and negative comments about the experience of keeping an RDJ.

The second analytic strategy required the examination of students' texts to verify linguistically my identification of interpretive repertoires and confirm student outcomes from RDJ writing by exploring and explaining how texts mean. After Eggins (1994) I employed Transitivity analysis and identified the types of processes (verbs) employed by the two students in selected RDJ entries. That linguistic focus enabled me to understand how students made sense of the NOS through their selection and deployment of Processes. A predominance of mental processes indicates the text's concern is with conscious cognition (Eggins, 1994, p.317) and verifies the writer's constructivist efforts as what Treagust *et al.* (1996, p. 4) call "cognising subjects".

Over the course of the study, I identified changes in the students' use of interpretive repertoires and process types. The nature and extent of these changes formed the basis for selecting two students for the case studies, Mandy and Jenny. Both students are representative in the sense that representation "does not mean 'typical,' 'most common' or even 'insightful'" (Willison, 1999, p. 115), but refers to the power to demonstrate the experience of writing reflectively about the NOS. Mandy was selected because her use of interpretive repertoires progressively moved towards a "High" level engagement with NOS issues as she reflected on relevant issues on occasions other than when prompted. Jenny was chosen to represent a "low" level of engagement since very little, if any, engagement with NOS issues was evident in her use of interpretive repertoires.

From very early in the study, there were clear differences between Mandy and Jenny's journals. Jenny was apparently unwilling to risk attempting a response to an RDJ about the origins of genetics, asking only for additional guidance before she would write back. In contrast, Mandy explored some complex and challenging possibilities. The students' approaches to the tasks also seemed different. Whereas Jenny apparently sought to answer each question I posed in the response frame, Mandy tended to use the probes as guides to her reflection. Differences in approach and word length raised concerns about Jenny's perception of the purpose of RDJs, and even at this early stage, were accompanied by different developments in the students' usage of interpretive repertoires. Mandy employed Human and Active repertoires that I was unable to identify in any of Jenny's early journal writing.

Table 1: Summary of outcomes from Transitivity analysis of students' writing in "Origin of Genetics" Journal Entry		
	Mandy	Jenny
Process Type	Incidence	Incidence
Mental		
Cognitive	11	1
Perceptive	1	
Affective	3	
Relational	8	
Material	3	2
Verbal	2	

Transitivity analysis revealed other significant differences (see Table 1). Mental Processes, particularly Cognitive Mental Processes, dominated Mandy's writing. According to Williams (1994), Mental Processes project metarepresentations of experience and show conscious cognition, active reflection and analysis. This is an example, with Mental Processes underlined:

I don't believe that Mendel fudged his results. The reason I think this is because if it (his theory) is true in theory, it should [be] true in practice. I mean he was only observing what happened. On second thoughts though perhaps he hypothesised his theory and couldn't prove it exactly. Therefore, maybe he did tamper with his results...

The dominance of Mental Processes in this selection of Mandy's journal writing is evidence of this text's status as an example of reflective writing. Further, the circumstance of her conscious cognition is made explicit by her use of the noun phrase "[O]n second thoughts".

Jenny's journal entry did not show either these hallmarks of successful reflective writing or attempts to construct understandings of the NOS. Her response was very brief and I identified only three Processes in total, of which two were Material Processes. Material Processes have to do with 'doings' and 'happenings' (Williams, 1994) and their use here is evidence that Jenny was concerned mainly with the 'doing' of her journal, rather than reflecting on the nature of science. Indeed, not having understood what was required of her, Jenny requested clarification, promising reciprocal action to follow when she asserts that if I "write" an explanation, then she "will write back".

As the study progressed, the differences between the two students' journal entries became even greater. Notably, Jenny's journal writing became more sporadic than Mandy's as she did not attempt to respond to three reflective writing tasks, while Mandy missed only one. Mandy consistently also moved away from supporting her claims with Elitist repertoires, towards greater use of Human and Active resources, whereas Jenny's writing continued to rely on School Science,

Separatist, Non-scientific, Elitist and Factual repertoires.

By the end of the study, both students had kept an RDJ for nine weeks. Developments in the closing stages of the study highlighted the possibility that Jenny may have been beginning to engage productively with the NOS. Although Mandy had routinely used Human and Active repertoires to support her claims about the NOS,

only Jenny's penultimate journal entry, reflecting on the probe "What is Science?", offered preliminary indications that she too may have been reconstructing her ideas about the NOS. Jenny's use of Active repertoires stands in stark contrast to her earlier use of Separatist repertoires. Likewise, my observations of Jenny during science classes also indicated changes. She had become more participative and willing to attempt questions and had developed more effective strategies for seeking assistance when needed.

Table 2: Summary of outcomes from Transitivity analysis of students' writing in "What is Science?" Journal Entry

		Mandy	Jenny
Process Type		Incidence	Incidence
Mental			
	Cognitive	8	2
	Perceptive	1	
Relational		4	2
Material		8	2
Verbal			1
Existential		2	

Transitivity analysis verified the progress that both students seemed to have made (see Table 2). Mandy's writing continued the pattern of Mental and Material Processes dominating, providing further evidence of her success in reflective writing and engagement with the NOS. Significantly, Jenny's response to "What is Science?" also featured a greater deployment of Mental Processes, although no Process type was clearly dominant. Of the seven Processes identified, two were typed as Mental/Cognitive, namely "I didn't choose" and "I believe". This was the first evidence that Jenny was beginning to consciously cognise, actively reflect on, and analyse NOS issues and this pattern offers additional support for the developments I identified in terms of her use of interpretive repertoires in this journal entry.

A survey of the two case study students' journals (and journeys) as a whole is revealing. In just nine weeks I contend that both students began to engage with NOS issues. While it seems apparent that Mandy was able to do this more successfully, resulting in greater reconstruction of her ideas about the NOS, Jenny also made important steps, particularly in the study's closing stages.

For almost all of the study, Jenny's writing relied on School Science, Separatist, Non-scientific, Elitist and Factual repertoires. It seems significant that she began, in the final stages of the study, to support her claims about the NOS using Active repertoires. As well, it seems valuable that this was accompanied by both observed changes in her classroom interactions and an increase in her use of Mental Processes in her journal writing.

In comparison, Mandy's journal writing increasingly constructed the NOS in ways that drew on Active and Human, rather than Elitist or Factual repertoires. She engaged with some of the most problematic aspects of scientism including certainty and objectivity and grappled with the resultant confusion, ambiguity and frustration. Mandy's engagement with NOS issues was also evidenced by the prominence of Mental Processes throughout the journal entries selected for Transitivity analysis. Although Jenny's progress may seem slight in comparison to Mandy's, the brevity of the study makes both students' outcomes worthy of note.

Certainly, many stones are left unturned. At the study's cessation, Mandy's writing still drew on Experimentalist and Elitist resources, she continued to seek external validation, and I am unable to make any inferences about her perceptions of science outside the classroom. Likewise, Jenny continued to construct her responses in a question and answer format and did not engage with issues such as proof, objectivity and justice. In the end, Jenny's experience of journal writing and her growing self-efficacy were soured by her disappointing result on a physics test. From this, I can note several features that seem to have been present in Mandy's journal writing, but absent from Jenny's and which may be related in some way to Mandy's success.

Comparatively lengthy, regular and highly reflective responses.

Mandy's journals were almost universally longer than Jenny's and she completed a greater proportion of the response frames offered. Moreover, Transitivity analysis confirmed that Mandy's writing included more frequent use of Mental Processes than Jenny's did, and can therefore be deemed more centrally concerned with conscious cognition, reflecting Mandy's constructivist efforts as "cognising subjects" (refer Treagust *et al.*, 1996, p. 4). Since the nature of reflective writing requires a writer to speculate, explore and question and given that this is unlikely to be achieved in one or two sentences, perhaps it is not surprising that successful reflection has been linked with lengthy response. Jenny's more sporadic journal writing may have been tied to her apparent misunderstanding of the value and purpose of keeping a Reflective Dialogue Journal.

Understanding of the purpose and value of RDJs.

Both the nature of the students' responses throughout the study and their explicit reflections on keeping an RDJ revealed substantial differences in their perceptions of RDJs. Whereas Mandy had been willing to change her mind, and speculate when she was unsure, Jenny either did not attempt responses, or tried to state answers to questions. While both the students stated that keeping an RDJ was about making them think, only Jenny perceived dialogue as correction. Finally, Jenny stated explicitly that she felt that keeping an RDJ had not helped her, while Mandy conveyed a sense of having benefited from the process. It is possible however, that Jenny's reflections on the experience of keeping an RDJ may have been quite different had I asked her about them before returning her physics test results.

Sense of ownership of journals.

Finally, Mandy's writing more commonly featured personal pronouns, including possessive ones when she referred to her journal. These are virtually absent from Jenny's journal indicating that perhaps Mandy felt a greater sense of ownership.

A qualification.

The relationship between these features remains unresolved. It is not possible, based on the evidence available, to conclude which of these features of successful reflective writing were prerequisite to others. Moreover, it is not possible to conclude whether they were causes or effects of successful RDJ writing. By this I mean it is not possible for me to determine whether Mandy succeeded because her response were lengthy or if her responses were lengthy because of the success she experienced. Similarly, did Mandy value her RDJ because of her success or did she succeed because she valued the experience. I merely contend that comparatively lengthy entries, regular and reflective responses; understanding of the purpose and value of RDJs, as well as a sense of ownership of the journal seem to accompany successful reflective writing about the NOS.

What does this mean for marginalised students?

Social justice strategies in science education have in the past bought into a range of androcentric and essentialist stereotypes (Kenway & Gough, 1998; Gilbert, 1997). That history, together with the nature and goals of this research, calls for specific qualification to the interpretation of my findings. Despite the success that two female case study students experienced in keeping an RDJ, this should not be interpreted as a recuperative equity strategy. Although I have mentioned that NOS education is important for achieving social justice in science, I was not seeking to develop a strategy either to give girls skills to succeed in science or to 'feminise' science. My intention was to help all students to develop "inclusive and *expansive*" understandings of the NOS that valued ways of knowing that are traditionally marginalised from this discipline (Kenway & Gough, 1998, p. 24, authors' emphasis). That the two case study students were girls is coincidental. This is not a "girl-friendly" pedagogy (Kenway & Gough, 1998), any more or less than it is a 'boy-friendly' one and should not be interpreted as such.

Recommendations for Further Research.

In light of the outcomes of the project, I perceive several areas deserving of further research. The preliminary positive outcomes indicate the need for a more

longitudinal study of the value of Reflective Dialogue Journal writing to NOS education. Furthermore, a longitudinal study where the researcher has access to students' background information could facilitate an evaluation of this tool in terms of students' multiply constituted identities.

Also, while much rhetoric has been contributed to debate, little research has been conducted into the value of various forms of writing in science education contexts. Although this study offers preliminary weight to arguments for composition in non-scientific genres, more research is required. This includes further study of both writing in science and the nature of reflective writing.

Finally, in introducing this paper, I mentioned the problems associated with the overwhelming content emphasis in secondary science courses and indeed I had great difficulty finding class time for reflective writing. Questions need to be asked about what the goals of junior secondary science education should be and how these can be best realised. I would argue that junior secondary science should be about preparing students for effective and responsible citizenship in an increasingly scientific world. This certainly includes some knowledge of scientific content. However, it must also include a critical awareness of "what science is, how it works and how scientists operate as a social group and how society itself both directs and reacts to scientific endeavour", as McComas *et al.* (1998, p. 4) define the nature of science. Clearly, a greater understanding of the balance between scientific content and the nature of science is needed.

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