Writing Differently about a Socioscientific Issue: Developing Students' Scientific Literacy through the Writing of Hybridised Scientific Narratives

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Abstract

The development of scientifically literate citizens remains an important priority of science education; however, growing evidence of students' disenchantment with school science continues to challenge the realisation of this aim. This triangulation mixed methods study investigated the development of 152 9th grade students' scientific literacy through their participation in an online science-writing project on the socioscientific issue of biosecurity. Children from eight intact science classes wrote a series of short stories that integrate scientific information with narrative storylines. We call these hybridized scientific narratives, *BioStories*. The students' BioStories were quantitatively analysed using a series of specifically-designed scoring matrices that produce numerical scores that reflect students' developing fundamental and derived senses of scientific literacy. In addition, the students also completed an on-line Likert-style questionnaire, the *BioQuiz,* which examined selected aspects of their affect toward science and science learning. The results suggest that the students' participation in the project enhanced their awareness and conceptual understanding of issues relating to biosecurity, while writing differently about a socioscientific issue developed a more positive affect toward science and science learning, particularly in terms of the students' interest and enjoyment. Implications for research and teaching are also discussed.

Introduction

International assessments of scientific literacy undertaken by TIMSS (Trends in International Mathematics and Science Study) and PISA (Programme for International Student Assessment) have sought to determine the degree to which students are prepared with the skills and knowledge they need to participate fully in society, upon completion of compulsory education. In recent years, the goal of science education in schools has broadened to encompass more than simply *doing* science (i.e., creating or recalling scientific knowledge). Millar and Osborne (1998) reported that students should demonstrate the ability to assess the significance of scientific and technical information; to evaluate evidence, distinguish theories from observations, and critically evaluate the validity of scientific claims. It can be said, therefore, that a (if not *the*) key goal of science education should be the development of scientific literacy (Sadler, 2004b).

Although the development of scientific literacy has come to represent a key priority of science education, it is well-known that disengagement is a common and widespread problem in secondary science classrooms, which is reflected in students' disenchantment with the science curriculum, and declining enrolments in science classes beyond compulsory schooling (Dekkers & De Laeter, 2001; Hackling, Goodrum, & Rennie, 2001; Lyons, 2006; Tytler, 2007). Middle school students (i.e., Grades 6-9) demonstrate lower levels of interest in science as they become less engaged in school science activities (Goodrum, Hackling, & Rennie, 2001; Logan & Skamp, 2008; Osborne & Collins, 2001; Woolnough, 1994). For example, an analysis of attitudinal data from the TIMSS 2007 survey found that the proportion of Australian students who had a positive affect toward science dropped from 78% in 4^{th} grade to only 47% in 9^{th} grade (Martin, Mullis, & Foy, 2008). This deterioration in students' attitudes toward science is a concerning issue for science educators, as it threatens the development of a scientifically literate future citizenship who uses natural, scientific and technological resources responsibly for a sustainable future (Linder, Ostman, & Wickman, 2007; Tytler, 2007). Subsequently, educators continue to call for teaching and learning strategies that promote the development of scientific literacy, and engage students in the learning of science, particularly in the middle years of schooling (e.g., Fensham, 2007; Prain, 2006).

A number of studies have shown that diverse writing tasks that include imaginative or creative writing can have strong motivational effects on students (Hildebrand, 2004; Negrette, 2004; Yore, Bisanz, & Hand, 2003). Furthermore, contextualizing learning within contemporary socioscientific issues can engage students while developing their understanding of scientific phenomena, the skills necessary to make informed decisions about topical issues and information, and an appreciation of the role that science and technology plays in both the local, wider and global communities (Sadler, 2004a; Sadler & Zeidler, 2005a, 2005b; Sadler, Barab, & Scott, 2007). This study investigates the learning experiences of eight intact 9^{th} grade science classes as they engage in the writing of short stories that merge scientific and narrative genres (i.e., hybridized scientific narratives) about the socioscientific issue of biosecurity, as a way of developing their scientific literacy.

View of Scientific Literacy Adopted in Current Study

In his extensive review of scientific literacy and its role in science education, Roberts (2007) highlighted two "potentially conflicting" (p. 729) visions of scientific literacy that have very different implications for curriculum planning and assessment: Vision I is focused on the importance of science subject matter (i.e., scientific literacy as viewed from a scientists' perspective); and Vision II, which emphasizes the contexts in which citizens will encounter science, and acknowledges the ways in which science plays a role in human affairs (i.e., the socioscientific role of scientific literacy).

Roberts argued that there are dangers in over-emphasizing either Vision I or II in any science curriculum. Vision I would have students view the world through the eyes of a scientist, which is problematic, as it would narrow “the student’s experience with the breadth of science as a human endeavour” (p. 767). Furthermore, it is concerning that Vision II material may only be included as a means of motivating students in lessons. Eisenhart, Finkel and Marion (1996) argued that there is also an implicit assumption that teaching students scientific knowledge and methods of inquiry will result in the socially responsible use of science, or a citizenry that will involve themselves in scientific discussions and debates. Conversely, Vision II programs may not focus sufficiently on scientific content (Roberts, 2007).

For the purposes of this study, a view of scientific literacy as citizen preparation that draws upon both Visions I and II has been adopted (Roberts, 2007). Although science is traditionally perceived as a “coherent, objective, and unproblematic body of knowledge and practices … [i]n everyday situations, citizen thinking may offer a more comprehensive and effective basis for action than scientific thinking” (Roth & Barton, 2004, p. 7). While students engaged with a socioscientific issue as a means of developing positive affect toward science and science learning (Vision II), an emphasis also was placed on the development of conceptual science understandings (Vision I).

Research Problem

The current study extends previous national and international research that has established a link between writing and learning science, with particular emphasis on scientific literacy, the examination of students’ written artefacts to ascertain conceptual understanding, and students’ affect toward science and science learning. It investigated the development of 9th grade students’ scientific literacy through their participation in an online science-writing project. The participants in the study authored a series of hybridized scientific narratives, or short stories that integrate scientific information about the socioscientific issue, biosecurity (i.e., BioStories). More specifically, the following research questions were investigated:

1. To what extent is the scientific literacy of 9th grade students enhanced through the construction of hybridized scientific narratives about biosecurity?
2. To what extent do students who author hybridized scientific narratives about biosecurity demonstrate conceptual understanding of related scientific concepts through their written artefacts and in interviews about the artefacts?
3. To what extent does students’ participation in the BioStories’ project influence their attitudes toward science and science learning?

It has been suggested that no single writing task can be used to engage *all* the dimensions of scientific literacy (Hand, Prain, Lawrence, & Yore, 1999); therefore, three important aspects have been explored in the current study: conceptual science understandings, the students’ ability to transform scientific information and write stories about biosecurity, and affect toward science and science learning. Norris and Phillips’s (2003) notions of scientific literacy, and the definition adopted by PISA (OECD, 2006) guided the selection of these aspects for investigation.

Research Design & Procedures

In exploring notions of scientific literacy, Norris and Phillips (2003) argued that coming to know science requires competency in two notions of scientific literacy. They made a distinction between the *fundamental* sense of scientific literacy (reading and writing science content), and the *derived* sense (being knowledgeable, learned and educated in science). They argue that "conceptions of scientific literacy typically attend to the derived sense of literacy and not to the fundamental sense" (p. 224). A distinction has also been made between a simple and expanded sense of fundamental scientific literacy (i.e., decoding texts, and inferring meaning from text, respectively) (Norris & Phillips, 1994, 2003). The investigation of students' conceptual science understandings in the current study represent a derived sense of scientific literacy, while their ability to write stories about biosecurity through the transformation of scientific information is indicative of their simple and expanded fundamental senses of scientific literacy, respectively. In-keeping with the view of scientific literacy as citizen preparation adopted by this study, students engaged with conceptual science understandings at a level that was appropriate in the context of everyday conversations about science (and thus in the context of their hybridized narratives about biosecurity). In other words, their depth of understanding was not intended to eclipse that of practicing scientists (an unreasonable expectation, argued by some) (Sadler, 2004b).

In addition to these aspects of scientific literacy, affect toward science and science learning was also selected for investigation, as this study sought to determine whether middle school students' participation in an alternative writing-to-learn science strategy would improve their disposition toward science. This aspect of scientific literacy has been acknowledged by PISA, in that a scientifically literate person should demonstrate an "awareness of how science and technology shape our material, intellectual, and cultural environments; and willingness to engage in science-related issues and with the ideas of science, as a reflective citizen" (OECD, 2006, p. 23).

Through their participation in the project, students wrote a series of three BioStories (i.e., Parts A, B and C). The first two tasks required students to complete unfinished narratives about biosecurity through the provision of writing templates (Appendix A), while the third and culminating task asked the students to compose their own unique BioStory. The tasks examined the socioscientific issue of biosecurity, and through their participation in the writing tasks, students learnt about a number of different biological incursions that threaten natural and/or agricultural ecosystems in Australia (e.g., fire ants, tilapia, citrus canker, avian influenza). The ability to negotiate socioscientific issues in making informed decisions may be considered an important component of scientific literacy (Kolstø, 2001; Sadler et al., 2007; Zeidler, Sadler, Applebaum, & Callahan, 2009). According to Prain (2006), if socioscientific issues form the subject of students' diversified writing tasks, their scientific literacy can be enhanced by "developing their interest in and capacity to apply scientific thinking to social issues for the purposes of informed action and critique … students learn to cross borders between specialist and more popular genres and readerships" (p. 190). Biosecurity is a topical socioscientific issue that is not particularly suited to scientific inquiry approaches, thus it can be difficult to teach in such a way that engages students. In addition, it situates the students' learning within a real-world context, thereby enhancing its relevance and fostering engagement with the topic. For these reasons, biosecurity is an ideal theme for this type of instruction.

The students' uploaded their stories to a dedicated BioStories' website, where they could be viewed and evaluated by their peers. The students accessed this website throughout the project. It contained all necessary resources, including the BioQuiz (i.e., a student questionnaire), digital resources (i.e., links to information about particular biological incursions supplied by government departments), story templates that guided student use of digital resources in the composition of stories, student artefacts (i.e., completed stories that were uploaded), and peer reviews of the uploaded stories.

This study adopted a triangulation mixed methods design in which both qualitative and quantitative data were generated and merged to develop a deeper understanding of the research problem (Creswell, 2005). Triangulation designs combine the strengths of both types of data, in that quantitative data enables the identification of trends that can be generalised across the sample population, while qualitative data facilitates a deeper understanding of the context (Creswell, 2005). In this study, quantitative analysis of the students' written artefacts (i.e., Parts A, B and C, as well as a sample of their science writing prior to their participation in the project – a report on a disease that affects a system in the human body), and their affect toward science and science learning, were complemented by qualitative techniques (namely, a detailed case study, and student and teacher interviews) that probed the students' conceptual science understandings and their perceptions of learning science.

The study was conducted in Semester 1, 2008 (i.e., May to July) in a co-educational urban school in Australia, with 152 9^{th} grade students and their teachers. The participants represented eight intact science classes, and their average age was 14 years.

In addition to authoring their BioStories, the participating students also completed the BioQuiz, an online, Likert-style questionnaire, on two occasions: once prior to commencement of the project, and once upon completion. The instrument consists of 29 items organised in six subscales that examine the students' interest in learning about science, their capacity for particular science-related tasks (science self-efficacy), their perceived personal and general value of science (i.e., two separate subscales), their familiarity with biosecurity issues, and their attitudes toward biosecurity. The BioQuiz was adapted from the internationally validated 2006 PISA Student Questionnaire administered to 15-year-old students (OECD, 2006); however, as significant modifications were made (e.g., a new subscale was created, *Attitudes toward biosecurity*), and the instrument was implemented with 9^{th} grade students, its reliability and validity was further scrutinized for this particular cohort of students.

Principle component and item reliability analyses conducted in SPSS, confirmed the six-factor structure of the BioQuiz, on the basis of their corresponding items: *Interest in learning science* (ILS), *Science self-efficacy* (SSE), *Personal value of science* (PVS), *General value of science* (GVS), *Familiarity with biosecurity* (FB), and *Attitudes toward biosecurity* (AB). Each factor demonstrated excellent Cronbach's alpha reliability (or internal consistency) at pre- and posttest: ILS, 0.90 and 0.90; SSE, 0.85 and 0.89; PVS, 0.88 and 0.88; GVS, 0.85 and 0.87; FBS, 0.81 and 0.88; and AB, 0.89 and 0.90. Changes in mean scores for each subscale were investigated using paired-samples *t* tests to determine statistical significance. Independent-samples *t* tests were also conducted to explore any possible gender or class interaction effects.

Quantitative analysis of the students' BioStories was facilitated by a number of specifically-designed scoring matrices which produced numerical scores that reflected their developing scientific literacy. A derived scientific literacy score was calculated to serve as an indicator of the students' conceptual understandings related to biosecurity, while a fundamental scientific literacy score was produced to reflect their ability to write short stories about biosecurity (i.e., a simple fundamental sense of scientific literacy).

A single science class was selected as the focus of a detailed case study, based on a range of performances demonstrated in the BioQuiz, and discussions with the class teachers. Three BioStories written by each student in this class were the subject of analysis. A sample of their science writing prior to their participation in the project was also analysed.

The students' responses to the BioQuiz (*N*=152) and artefacts authored by the case study class (*N*=26), were quantitatively analysed for evidence of their developing scientific literacy (i.e., conceptual science understanding, and affect toward science and science learning). Qualitative analysis of semi-structured interviews with students in the case study class, and with the science teachers (*N*=7), in addition to classroom observations, were used to complement and gain a deeper understanding of the quantitative findings.

Findings

Quantitative Results – BioQuiz Analysis.

Analyses of the BioQuiz data were conducted to address the question, to what extent did students' participation in the BioStories' project enhance their interest in learning science, familiarity with biosecurity issues, attitudes toward biosecurity, and their perceived self-efficacy with science-related tasks, and personal and general value of science? A number of *t* tests were performed as a means of addressing this question by investigating significant interactions identified by univariate tests, and their impact on BioQuiz scores.

Did BioQuiz Scores Overall Change from Pretest to Posttest?

Paired-samples *t* tests demonstrated an improvement in BioQuiz scores from pre- (M = 13.2, SD = 2.49) to posttest (M = 14.10, SD = 2.36), $t(176) = -6.38$, $p < .01$. Effect size, as measured by Cohen's *d*, was 0.48, which is indicative of a medium effect (Cohen, 1988).

Did BioQuiz Scores for Each Subscale Improve from Pretest to Posttest?

A statistically significant improvement was observed in the interest in learning science [$t(152) = -5.66$, $p < .01$, $d = .42$], science self-efficacy [$t(152) = -3.11$, $p = .002$, $d = .23$], personal value of science [$t(152) = -3.06$, $p = .003$, $d = .23$], general value of science [$t(152) = -4.59$, $p < .01$, $d = .34$] and familiarity with biosecurity items [$t(152) = -4.40$, $p < .01$, $d = .33$] (Table 1). Small to modest effects were observed in each case, the largest of which was observed for interest in learning science (d = 0.42), which represents the greatest improvement pretest to posttest. No statistically significant change in the attitudes toward biosecurity items was observed, $t(152) = -0.23$, $p = .82$.

Independent-samples *t* tests found no differences in the ways in which girls and boys responded to the BioQuiz, and no significant class differences. Together, these findings suggest that the BioStories' project was implemented uniformly across classes, and there were no observable differences in the ways in which boys and girls responded to the BioQuiz.

Table 1. Significant results of the paired-samples *t* tests, which examined changes in students' mean BioQuiz scores, pretest to posttest. Results for attitudes toward biosecurity are not shown, as no significant change was observed for this subscale.

Variable 1	Mean (SD)	Variable 2	Mean (SD)	*t* value	df	Sig.	Cohen's d
Pre-interest	2.56 (0.70)	Post interest	2.84 (0.64)	-5.663	152	.000*	0.42
Pre-self-efficacy	2.99 (0.67)	Post self-efficacy	3.14 (0.60)	-3.106	152	.002*	0.23
Pre-general value	3.00 (0.60)	Post general value	3.18 (0.53)	-4.592	152	.000*	0.34
Pre-personal value	2.83 (0.74)	Post personal value	2.96 (0.66)	-3.057	152	.003*	0.23
Pre-familiarity	2.21 (0.73)	Post familiarity	2.54 (0.84)	-4.400	152	.000*	0.33

* Significant at the 0.008 level (2-tailed).

Quantitative Results – BioStories Analysis.

Unlike the previous analysis, the BioStories authored by students in a single science class were analysed. Analysis of the BioStories was conducted to address the fundamental question, to what extent is students' scientific literacy enhanced through their participation in the BioStories' writing tasks? More specifically, three research questions were investigated:

1. Were there statistically significant improvements in students' derived scientific literacy scores across Parts A, B and C of their BioStories?
2. Were there statistically significant improvements in students' derived scientific literacy scores from their pre-writing sample, to Parts A, B and C of their BioStories?
3. Were there statistically significant improvements in students' fundamental scientific literacy scores across Parts A, B and C of their BioStories?

Following the summary of students' BioStories' scores presented below, the results of a series of dependent-samples *t* tests are organised according to the above research questions.

Summary of Students' BioStories' Scores

Descriptive statistics for the students' BioStories' scores are presented in Table 2. In order to facilitate comparisons of students' derived scientific literacy and fundamental scientific literacy scores across the four writing tasks (i.e., pre-writing, Part A, Part B, Part C), they were converted to a percentage of the highest possible score attainable for each task. As evidenced in the table, the mean Part C scores were considerably lower than those for the other writing tasks. The highest mean scores were obtained for Part B.

Table 2. A summary of the descriptive statistics for each of the variables explored via dependent samples *t* tests.

Variable	Mean	N	SD
Pre-writing derived scientific literacy	51.00%	26	19.99
Part A derived scientific literacy	58.65%	26	21.44
Part B derived scientific literacy	74.04%	26	9.30
Part C derived scientific literacy	39.11%	25	18.74
Part A fundamental scientific literacy	68.42%	26	15.79
Part B fundamental scientific literacy	73.26%	26	14.49
Part C fundamental scientific literacy	51.45%	25	15.64

Note. Although there were 26 students in the case study class, one student was absent for the Part C task, hence *N*=25 for the Part C variables.

Were there Significant Improvements in Students' Derived Scientific Literacy Scores across Parts A, B and C of their BioStories?

A significant improvement in students' derived scientific literacy scores was observed from Part A (*M* = 58.65%, *SD* = 21.44) to Part B (*M* = 74.04%, *SD* = 9.30), *t*(26) = -4.33, *p* < .01 (Table3). Effect size, as measured by Cohen's *d*, was 0.85. A large effect size is particularly positive in the context of the current study, as research in educational settings tends to produce smaller effects (Tabachnick & Fidell, 2007).

Table 3. Significant results of the dependent-samples *t* tests, which examined changes in students' derived scientific literacy scores across the three BioStories' tasks.

Variable 1	Variable 2	*t*	*df*	*p*	*d*
Part A derived scientific literacy	Part B derived scientific literacy	-4.326	26	.000*	0.85
Part A derived scientific literacy	Part C derived scientific literacy	4.523	25	.000*	0.89
Part B derived scientific literacy	Part C derived scientific literacy	11.170	25	.000*	2.19

* Significant at the 0.01 level (2-tailed).

Were there Significant Improvements in Students' Derived Scientific Literacy Scores from their Pre-writing Sample, to Parts A, B and C of their BioStories?

So that comparisons could be made pre- and post-intervention, a sample of the students' writing prior to their participation in the BioStories' project was also analysed (i.e., a report on a disease that affects a system within the human body). A significant improvement was found in students' derived scientific literacy scores from pre-writing (*M* = 51.00%, *SD* = 19.99) to Part B, *t*(26) = -6.39, *p* < .01 (Table 4). A large effect (*d* = 1.25) was observed. A significant decrease was observed from pre-writing to Part C, *t*(25) = 2.80, *p* = .01, *d* = 0.55 (a medium effect). No significant difference was found between students' pre-writing and Part A derived scientific literacy scores.

Table 4. Significant results of the dependent-samples *t* tests, which examined changes in students' derived scientific literacy scores across the pre-writing and BioStories' tasks. The results for pre-writing to Part A are not shown, as they were not significant.

Variable 1	Variable 2	*t*	*df*	*p*	*d*
Pre-writing derived scientific literacy	Part B derived scientific literacy	-6.389	25	.000*	1.25
Pre-writing derived scientific literacy	Part C derived scientific literacy	2.801	24	.010*	0.55

* Significant at the 0.01 level (2-tailed).

Were there Significant Improvements in Students' Fundamental Scientific Literacy Scores across Parts A, B and C of their BioStories?

Analyses revealed a significant improvement in students' fundamental scientific literacy scores from Part A (*M* = 68.42%, *SD* = 15.79) to Part B (*M* = 73.26%, *SD* = 14.49), $t(26) = -3.29$, $p < .01$, $d = 0.65$ (a medium effect) (Table 5). A significant decrease was observed in students' fundamental scientific literacy scores from Parts B to C (*M* = 51.45%, *SD* = 15.64), $t(25) = 10.40$, $p < .01$, $d = 2.04$, and Parts A to C, $t(25) = 6.04$, $p < .01$, $d = 1.18$ (a large effect in both cases).

Table 5. Significant results of the dependent-samples *t* tests, which examined changes in students' fundamental scientific literacy scores across the three BioStories' tasks.

Variable 1	Variable 2	*t*	*df*	*p*	*d*
Part A fundamental scientific literacy	Part B fundamental scientific literacy	-3.291	25	.003*	0.65
Part A fundamental scientific literacy	Part C fundamental scientific literacy	6.038	24	.000*	1.18
Part B fundamental scientific literacy	Part C fundamental scientific literacy	10.402	24	.000*	2.04

* Significant at the 0.01 level (2-tailed).

This finding indicates that the BioStories' project had no significant impact on students' simple fundamental sense of scientific literacy (i.e., their ability to write stories about biosecurity) (Norris & Phillips, 2003). Despite the lack of any obvious gains in the students' simple fundamental scientific literacy, it can be said that their expanded fundamental sense of scientific literacy (i.e., the ability to infer meaning from texts) did indeed develop through their participation in the project, as the students successfully interpreted and transformed scientific information in order to construct hybridized scientific narratives. Furthermore, students' demonstrated ability to infer meaning from scientific texts and transform them into BioStories will be reflected in their conceptual understandings articulated at interview. It is reasonable to assume that if the students' understandings are largely problematic, that their expanded fundamental sense of scientific literacy is also questionable.

Qualitative Results – Summary of Students' Conceptual Understandings Articulated at Interview

Analysis of student and teacher interview data provide evidence to support two claims in relation to the students' developing scientific literacy: (1) most students demonstrated deeper levels of conceptual science understandings at interview (in terms of relevant biological concepts, and issues pertinent to biosecurity), than they expressed in their written stories; and (2) students became more aware of biosecurity issues through their participation in the BioStories' project. Specifically, students explained correctly some of the environmental, social and economic impacts of the biological incursions that featured in their BioStories; that is, concepts that weren't elaborated, or, in some cases, evident, in their writing. These students elaborated their understandings or introduced and explained new concepts that were not expressed in their stories, which has implications for making judgments about students' developing scientific literacy, based on their writing alone. Furthermore, students' awareness of biosecurity issues, such as the impacts of introduced species, the potential threat of biological incursions that are yet to reach our shores, and the need for quarantine, increased through their participation in the project.

Qualitative Results – Summary of Participants' Perceptions of their Experiences in the Project

Analysis of interview data provide evidence to support three claims in relation to the students' interest and enjoyment over the course of the project: (1) students' comments at interview suggest that they enjoyed writing stories in science as it presented a new way of writing in science lessons that enabled them to exercise their imagination and creativity while learning new concepts pertaining to biosecurity; (2) the writing of BioStories enabled students to take ownership and play an active role in the learning process, which enhanced their interest and enjoyment in the learning activities, as well as the development and retention of students' conceptual understanding relating to biosecurity; and (3) the BioStories' project engaged diverse learners as it enhanced the accessibility of science learning, particularly for students who identified themselves as not enjoying science, or experiencing difficulty in science.

Both student and teacher interview data provided abundant evidence that students enjoyed writing stories in science, using their imagination and creativity, and writing differently in science while learning about something new (i.e., biosecurity). Students also enjoyed accessing information technologies in order to research, construct and upload their BioStories. Students' comments indicated that BioStories engaged diverse learners by enhancing the accessibility of science learning for those students who admitted to not enjoying science, and those that found regular science quite difficult. These students felt that they enjoyed and could better grasp the concept of writing a narrative that incorporated scientific information, as opposed to writing a scientific report. Furthermore, the student-centred nature of the BioStories' project, in which students researched and authored their own stories about biosecurity, not only enhanced their interest and enjoyment of the project, but also appeared to contribute to the development and retention of conceptual science understandings, as evidenced by the students' recall and elaboration of relevant concepts pertinent to biosecurity at interview.

Discussion & Concluding Remarks

In seeking answers to the research questions articulated earlier in this paper, two claims have been synthesized from the results of quantitative and qualitative data analyses:

1. Students' awareness and conceptual understanding of issues relating to biosecurity were enhanced through their participation in the BioStories' project.

2. Students’ affect toward science and science learning (specifically, their interest in learning science, science self-efficacy, and their perceived personal and general value of science) improved through their participation in the BioStories’ project.

Students’ awareness and conceptual understanding of issues relating to biosecurity were enhanced, and students’ affect toward science and science learning improved through their participation in the BioStories’ project. Quantitative analysis of the students’ written artefacts, and their responses to the BioQuiz, demonstrated an improvement in selected aspects of their affect toward science and science learning, and the development of conceptual understandings pertaining to biosecurity. Qualitative analysis of both teacher and students interviews provided triangulating evidence to support these findings, particularly as the students could successfully articulate their conceptual understandings and their experiences and perceptions of learning science through the writing of BioStories.

The findings of this study support extensive calls for the utilization of diversified writing-to-learn strategies in the science classroom, and for researchers of authentic classroom environments to understand the writing-learning connection (Rivard, 1994). Specifically, the gains in students’ conceptual science understandings and affect toward science and science learning provide a compelling argument for the inclusion of writing practices that engage students in the construction of hybridized narrative genres in the science classroom. Furthermore, the utilization of different kinds of writing tasks in science will eventuate in different kinds of learning, and promote different views of scientific literacy. BioStories can be used to examine how students use and produce science knowledge to respond to a need or concern pertinent to their individual or community’s future, which better aligns with expanded goals of scientific literacy.

The findings of this study also have implications for the assessment of scientific literacy in a writing-to-learn context. The student interviews revealed a different depth of understanding than was evident in the BioStories, which suggests that multiple assessment strategies are required in combination in order to gain a fuller picture of the students’ developing scientific literacy. Although it was expected that students’ levels of understanding would be reflected in what they wrote, it was found that interviews with individual students showed deeper conceptual understandings, and at the same time, they also identified evidence of superficial or problematic understandings that were omitted from their writing.

Interviews are useful tools for revealing alternative conceptions, and can also provide positions to serve as the basis for debates, which can help to resolve opposing conceptions (White & Gunstone, 1992). In a classroom situation, interviews may provide students with a useful forum through which to verbalise their science understandings in a way that cannot be fully realised through writing

Prior to the current study, the use of hybridized writing that integrates scientific information with narrative storylines, and the role of positive affect in this context, had not been investigated in the context of writing about socioscientific issues. The literature regarding the negotiation of socioscientific issues in the science classroom emphasises the development of scientific knowledge through data interpretation, analysis of conflicting evidence, and argumentation (i.e., a process of making and justifying claims and conclusions) (Sadler, 2004a). In addition, a number of studies that have investigated the role of emotion and affect in engaging students in the negotiation of socioscientific issues that present moral and ethical dilemmas have examined the role of emotion (particularly empathy) in informal reasoning in the context of genetic engineering issues (e.g., Sadler & Zeidler, 2004, 2005b; Zeidler & Schafer, 1984).

Unlike these earlier studies, the current research suggests that broadening the types of writing with which students engage in the context of socioscientific issues, to include hybridized scientific narratives, can be valuable in developing students' conceptual understandings, and at the same time, a more positive disposition toward science. Traditional scientific genres, such as expository and argumentative text, position students to adopt an objectivist standpoint (i.e., that of an 'outsider'). Conversely, the construction of narratives positions students as 'insiders'; particularly as they are able employ their natural, everyday discourse to negotiate the issue (Avraamidou & Osborne, 2009). As one student commented at interview, "The writing we normally do in science, you can't say 'I' or 'we', 'they'". Students often encounter difficulties writing in the third-person style typical of scientific genres, which can discourage them from writing in science (Wellington & Osborne, 2001). As narratives are the genre with which most students are familiar, they offer opportunities to connect students' personal experiences with science ideas, and thus encourage them to express their thoughts in written language through being personally engaged (Hand, Prain, & Yore, 2001; Wellington & Osborne, 2001). The students are therefore more likely to perceive their story-writing experiences as interesting and personally relevant (i.e., more 'real'), which will, in turn, strengthen their engagement with the socioscientific issue, and encourage the development of a more positive affective disposition toward science.

The results of this study indicate that writing differently about socioscientific issues by merging scientific and narrative genres holds great potential for the development of scientifically literate future citizens. These findings support the inclusion of hybridized scientific narratives in the science curriculum, as this type of writing can be used to broaden the genres with which students engage in the negotiation of socioscientific issues, as the development of positive affect toward science and science learning can encourage students' participation in the discourse of science. Further work is to be done into the role of positive emotions in the negotiation of socioscientific issues.

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Appendix A

Crikey! Part A—Extract

Since Steve Irwin's fatal encounter with a stingray in 2006, each September 4 is usually a sad day for Jennifer. On this particular spring day strolling between biology lectures at uni, Jennifer fondly remembered her first meeting with the legendary environmentalist, affectionately known around the world as the Crocodile Hunter ….

Suddenly there was a commotion at one of the checkpoints. A Customs Officer was trying to persuade a reluctant passenger to part with some prohibited plants he had brought with him from the US.

"You know," Steve started as he watched the passenger try to argue his way out of trouble. "Biosecurity and quarantine are so important to our country. We know how devastating it has been for our vulnerable ecosystems when **XX** (e.g., **fire ants**) got into the country somehow; it ruined **YY** (e.g., communities of native lizards and skinks)," he explained.

"How on Earth could something like that have such a terrible impact?" Jennifer asked.

"Well," Steve continued energetically, "…………………….."

Your task: Write 150-250 words in order to complete the story. Your teacher will allocate you one of the following scenarios, from which to insert the relevant XX and YY species above. Be sure to research your biological incursion (XX species) by exploring the associated websites and reading the scientific information, before completing Part A of "*Crikey!*"

Your story must be **informative**, and **include scientific information**. In the conversation that you complete between Steve and Jennifer, aim to address the following information:

- What the biological incursion is.
- Its country of origin.
- How it entered Australia.
- The problems it caused or continues to cause for native and/or commercial species or eco-systems (i.e., its impacts).
- The difficulties scientists and farmers face controlling the pest, or how the pest was brought under control.

Remember: Using the XX species allocated to you, Steve is trying to help Jennifer understand the importance of quarantine….

SCENARIO 1: XX= Fire Ants, YY= communities of native lizards and skinks
http://www.dpi.qld.gov.au/cps/rde/dpi/hs.xsl/4790_4538_ENA_HTML.htm
http://www.environment.nsw.gov.au/pestsweeds/FireAnts.htm