POSITIVE EMOTIONAL RESPONSES TO HYBRIDISED WRITING ABOUT A SOCIO-SCIENTIFIC ISSUE

Louisa Tomas[1] and Stephen M. Ritchie[2]

[1]James Cook University, [2]Queensland University of Technology

Dr. Louisa Tomas

Phone: +61 7 4781 6117

Facsimile: +61 7 4781 5699

Email: louisa.tomas@jcu.edu.au

Prof. Stephen M. Ritchie

Phone: +61 7 3138 3332

Facsimile: +61 7 3138 3985

Email: s.ritchie@qut.edu.au

Published:

Tomas, L., & Ritchie, S. M. (2012). Positive emotional responses to hybridised writing about a socio-scientific issue. *Research in Science Education, 42*(1), 25-49.

Abstract

In order to understand better the role of affect in learning about socio-scientific issues (SSI), this study investigated Year 12 students' emotional arousal as they participated in an online writing-to-learn science project about the socio-scientific issue of biosecurity. Students wrote a series of hybridised scientific narratives, or BioStories, that integrate scientific information

about biosecurity with narrative storylines, and uploaded these to a dedicated website. Throughout their participation in the project, students recorded their emotional responses to the various activities (N=50). Four case students were also video recorded during selected science lessons as they researched, composed and uploaded their BioStories for peer review. Analysis of these data, as well as interview data obtained from the case students, revealed that pride, strength, determination, interest and alertness were among the positive emotions most strongly elicited by the project. These emotions reflected students' interest in learning about a new socio-scientific issue, and their enhanced feelings of self-efficacy in successfully writing hybridised scientific narratives in science. The results of this study suggest that the elicitation of positive emotional responses as students engage in hybridised writing about SSI with strong links to environmental education, such as biosecurity, can be valuable in engaging students in education for sustainability.

Keywords: emotions, hybridised writing, socio-scientific issues, writing-for-learning.

Engaging Students' Emotions in Science Learning

Disengagement of school students in science and the scientific literacy of young adults are interrelated international concerns (Rennie & Goodrum, 2007; Tytler, 2007). While the development of scientific literacy (i.e., a willingness to engage in science-related issues, the ability to understand and apply scientific ideas, and draw evidence-based conclusions about scientific issues) remains a key priority of science education (OECD, 2006), the realisation of this aim is challenged by students' waning interest in school science. Many secondary students find the school science curriculum to be unimportant, disengaging, and irrelevant to their life interests and priorities (Rennie & Goodrum, 2007). By the time students reach the senior years of schooling, many do not elect to study science; a problem that is reflected in

declining enrolments in science classes beyond compulsory schooling (Lyons, 2006). This is a concerning trend because it threatens the development of a scientifically literate future citizenship that uses natural, scientific and technological resources responsibly for a sustainable future (Linder, Östman, Roberts, Wickman, Ericksen, & MacKinnon, 2010; Tytler, 2007).

In response to calls for teaching and learning strategies that promote the development of scientific literacy, and engage school students in the learning of science (Fensham, 2007; Prain, 2006), previous studies by Ritchie, Tomas and Tones (2011) and Tomas, Ritchie and Tones (submitted) have investigated the effects of a writing-to-learn science project on the development of middle school students' scientific literacy. The Year 6 students in the first of these studies wrote a series of short stories that merge scientific and narrative genres (i.e., hybridised scientific narratives) about the socio-scientific issue of biosecurity. The results from this mixed method, two year study support the argument that writing the sequence of stories enhanced students' familiarity with biosecurity issues, helped them to develop a deeper understanding of related biological concepts, and improved their interest in science (Ritchie et al., 2011). In a later study, the intervention was refined and extended with Year 9 students, who composed their stories with the support of a dedicated website, and uploaded them for peer review. The results from this study reinforced previous findings; specifically, significant improvements in students' derived sense of scientific literacy (i.e., their understanding of science concepts relevant to biosecurity), familiarity of biosecurity, self-efficacy, interest, and perceived personal and general value of science were reported (Tomas et al., submitted).

While these studies examined the learning potential of hybridised scientific narratives about a socio-scientific issue in middle school settings (i.e., Years 6-9), the value of this approach is yet to be explored in the senior years of schooling. Furthermore, while hybridised writing about biosecurity has been shown to enhance students' attitudes toward science and

science learning (Ritchie et al., 2011; Tomas et al., submitted), neither study focussed on the role of students' emotions in learning science in this context.

Emotion occupies a central position in understanding social life; it is the "glue" that binds members of society together (Collins, 2004). Turner (2002) theorised four primary emotions, three of which are negatively valenced (i.e., sadness, anger and fear) and one that is positively valenced (i.e., happiness). We consider it important to identify the emotions that occur in classrooms and how they mediate outcomes such as achievement of scientific literacy.

Despite the centrality of emotions in social reality, there has been a dearth of research connecting emotions to learning environments, and no published studies have been located on the relationship between emotions and learning in science classrooms during SSI activities. Specifically, in order to understand better the role of positive emotions in engaging students in science learning, this study investigates the following research question: What emotional responses were expressed by Year 12 students engaged in writing hybridised scientific narratives about the socio-scientific issue of biosecurity?

Our major aim in this project was to engage students in activities to change their "emotional relation to the subject matter – so as to better learn it…" (Rosiek & Beghetto, 2009, p. 183). This is significant work given: "The importance of engaging students' imagination rarely is given serious attention in schools and, instead, is often overshadowed by an emphasis on memorization or other standardized ways of knowing" (Rosiek & Beghetto, 2009, p. 183).

Emotions and Learning

Almost five decades ago, Vygotsky (1962) wrote: "We have in mind the relation between intellect and affect. Their separation as subjects of study is a major weakness of traditional psychology since it makes the thought process appear as an autonomous flow of 'thoughts

thinking themselves,' segregated from the fullness of life, from the personal needs and interests, the inclinations and impulses, of the thinker" (p. 8). Yet, Lewis (2008) asserted: "We need to give emotions the same status as cognitions. Just as cognitions can lead to emotions, emotions can lead to cognitions. The theory implies no status difference" (p. 745). Schutz, Aultman and Williams-Johnson (2009) also recognised this interrelationship when they highlighted that "affective experiences are intricately woven into the fabric of classroom experiences" (p. 195). While the important link between emotions and learning has been established on a theoretical level (e.g., Vygotsky, 1962), with several researchers reminding educators of its significance in recent times (e.g., Demetriou & Wilson, 2009), very few studies have focused on the role of student emotions in learning science.

In an ethnographic study of two chemistry classrooms in Brazil, Teixeira dos Santos and Mortimer (2003) showed how important it was for teachers to establish a positive climate to effect positive emotional arousal and attitudinal outcomes for students. Perhaps the study most relevant to our investigation, however, was conducted in an Australian university-situated laboratory experiment with volunteer (N=181, 12-15 year-old) mixed-achievement adolescents (Ainley, Corrigan, & Richardson, 2005). In this experiment, students were required to select for reading one from four science-related popular culture topics on-line. These included topics on dolphins, body image, U2 in Africa (solutions to problems of famine, debt, and AIDS), and F1 racing. Students declared their expected level of interest in the topic on a five-point Likert scale before commencing the reading task. As soon as the students indicated they were ready to move on to a different topic, they were asked to record their emotions by clicking one or more emotion icons (sad, interested, embarrassed, sorry, neutral, angry, surprised, happy, scared, bored, and disgusted) and the intensity of that emotion (on a five-point scale; 1=a little, 5=a lot). Unlike Turner (2007), and most other researchers of emotions, Ainley et al. (2005) included interest as an emotion. Unsurprisingly, except for the F1 Racing topic, students from the high achievement group were more likely to

complete the reading topics than students from the mainstream group. The topic of body image had the widest range of emotional responses while the topic of F1 racing had the narrowest range. Further analyses supported their main conclusion that: if the text is engaging initially, it is likely to sustain their interest. Alternatively, lack of interest is predictive of disengagement.

While a range of emotions evoked was recorded for each topic, no uniform relationship could be identified other than a link between interest and engagement. If interest is not a type of emotion, then this study still does not contribute to our understanding of student emotions and learning science, As well, the study was conducted in an idealised environment rather than in a real classroom. Nevertheless, there were some important implications for our study. From this study, we could expect students would have different levels of interest for various classroom activities (e.g., reading, writing, exploring the internet, talking), and these activities would arouse different sets of emotions. As described later, this would provide some methodological challenges. Before detailing these challenges and how the research design attempted to address these, we provide some important background material that further distinguished the study by Ainley et al. (2005) and our study. More specifically, our study focused on emotional arousal during writing tasks rather than reading tasks.

Writing about Socio-scientific Issues

While the ability to negotiate socio-scientific issues (i.e., significant social issues and problems with conceptual or technological links to science) may be considered an important aspect of scientific literacy (Kolstø, 2001; Sadler, Barab, & Scott, 2007; Zeidler, Sadler, Applebaum, & Callahan, 2009), scientific literacy itself can be enhanced if they form the subject of students' diversified writing tasks. Such writing can develop students' "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" (Prain, 2006, p. 190).

SSI education seeks to engage students in socio-scientific decision-making as a means of empowering them to deal with socio-scientific issues (Zeidler, et al., 2009). As such, discourse and argumentation are important features of the SSI literature (Sadler, 2004; Sadler & Zeidler, 2005; Zeidler et al., 2003; Zeidler et al., 2009). Another significant aspect of SSI education that distinguishes it from other theoretical frameworks in science education is the emphasis placed on students' moral development and the role of emotion in this context. A number of studies (e.g., Sadler & Zeidler, 2005; Zeidler & Schafer, 1984) found that emotions guided by care and concern for others, such as empathy and sympathy (i.e., moral emotions), are important in the exploration and resolution of socio-scientific issues. For example, empathy has been shown to facilitate students' engagement with controversial socio-scientific issues, such as reproductive cloning, as it enables students to adopt multiple perspectives and identify with the characters (such as an infertile couple) in the given scenarios (Sadler & Zeidler, 2005).

While these studies have examined the role of moral emotions in the negotiation of socio-scientific issues, the role of positive emotions in learning science in this context is yet to be investigated. Furthermore, engaging students in the writing of hybridised scientific narratives about a socio-scientific issue has only a recent history (see Ritchie et al., 2011) warranting further exploration in different contexts.

Methods

The current study was conducted with Year 12 Multi-Strand Science students. Multi-strand Science is an elective senior science subject in Queensland[1], which, unlike Physics,

[1] Multi-Strand Science is currently being phased out in Queensland, with 2011 being its last year of implementation with Year 12 students (QSA, 2009). The non-discipline-specific science syllabuses that supersede Multi-Strand Science are Science21 (2007) and the Science study area specification (2008).

Chemistry, Biology and Earth Science, is not discipline-specific. A two-year course of Multi-Strand Science is organised around five topics: energy, environmental studies, matter and materials, disease and society, and resource management (QBSSSS, 1998). For this reason, Multi-Strand Science is typically studied by senior students who wish to receive a general science education. As Multi-Strand Science aims to provide opportunities to "focus student attention on technological applications of scientific knowledge and on examination of economic, environmental, political and social consequences of those applications" (QBSSSS, 1998, p. 2), socio-scientific issues such as biosecurity are well placed within the curriculum.

The entire cohort of Year 12 Multi-Strand Science students at a co-educational suburban high school in Australia participated in the study (i.e., three classes, N=59). The BioStories project was conducted over an eight week period in Term 1, 2010 (February to March), and, at the school's request, was embedded in an existing unit of work, entitled *Environmental Studies*. This unit engaged students in learning about sustainable water resource management and examined concepts such as the biotic and abiotic features of ecosystems, water pollution, water resource management and conservation. The school's Head of Science elected to include the BioStories project as part of the *Environmental Studies* unit as a way of broadening the types of pedagogies employed by the school's Multi-strand Science curriculum, and diversifying the forms of representation with which the students engaged, as a way of enhancing their engagement with science.

The Year 12 students wrote a series of three BioStories – Parts A, B and C. The first two tasks required students to complete unfinished narratives about biosecurity through the provision of writing templates (see Ritchie et al., 2011), while the third and culminating task asked the students to compose their own unique BioStory. Through their engagement with the writing tasks, it was intended that students would learn 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). In doing so, the writing tasks required students to

engage with aspects of ecological sustainability (i.e., environmental impacts of particular biological incursions), as well as aspects of social and economic sustainability (i.e., impacts of the incursions on people and the economy). The socio-scientific issue of biosecurity complements this type of instruction, particularly as it is not suited to more traditional approaches to scientific inquiry, making it 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.

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 story templates that guided student use of digital resources in the composition of stories, digital resources (i.e., links to information about particular biological incursions supplied by Government Departments), student artefacts (i.e., completed stories that were uploaded), peer reviews of the uploaded stories, and an emotions survey (i.e., student questionnaire).

During the eight week period over which the project was conducted, six 70-minute science lessons were allocated to BioStories. Students researched, composed and uploaded their Part A BioStories during the first two weeks of the project. In Week 3, students were introduced to the Part B writing task, and commenced their research. In Weeks 4 and 5, no time was allocated to the project, as students participated in a field trip to a local catchment area where they completed associated summative assessment as part of the *Environmental Studies* unit. During this time, the students were required to draft their Part B BioStories for homework. In Week 6, Part B drafts were reviewed and amended for uploading. The students were also introduced to the Part C writing task, so that they could commence their research. In Weeks 7 and 8, students completed their Part C BioStories and uploaded them for peer evaluation. Students were required to review and post comments on some of their peers'

stories each time they completed a writing task, prior to commencing work on the following task.

This study adopted a triangulation mixed methods design, generating both qualitative and quantitative data to develop a deeper understanding of the research problem (Creswell, 2005). Quantitative analysis of the students' responses to an emotions survey was complemented by classroom video recordings and semi-structured interviews. As detailed later, four case students were selected for microanalysis of their classroom actions and emotional expressions.

Quantitative data source and analysis

The emotions survey is an online, Likert-style questionnaire that examined selected positive emotions. Fifty students (N=50) completed the survey at the end of each BioStories lesson. The students' responses were analysed quantitatively in order to determine which positive emotions where elicited most strongly by particular BioStories activities.

The emotions survey was adapted from the Positive Affect Negative Affect Schedule (PANAS), a valid and reliable measure of affect, which consists of two 10-item scales that reflect the general dimensions of positive affect (PA) and negative affect (NA) (Watson, Clark, & Tellegen, 1988). Although these terms indicate a strong negative correlation (i.e., that they are opposites), they are distinctive dimensions. High PA is characterised by feelings of high energy, interest, concentration and pleasurable engagement, while NA comprises a variety of aversive emotions, such as fear, nervousness, shame, guilt and anger (Watson et al., 1988). As this study was concerned with the role of positive emotions in learning science through the writing of BioStories, the emotions survey was drawn from the 10 items belonging to the PA scale: attentive, strong, inspired, alert, active, excited, proud, enthusiastic, determined and interested.

The internal consistency of this scale, established by Watson et al. (1988), is high (Table 1). Due to the small number of participants in the current study, a reliability analysis was not conducted for this group of students; however, as the psychometric data for the PA scale presented in Table 1 was generated by a group of undergraduate psychology students, we are satisfied that the characteristics of this group are sufficiently similar to those of Year 12 Multi-strand Science students (i.e., 16-17 years of age). While the students in this study were required to evaluate their positive emotions at the end of each BioStories lesson, the reliability of the PA scale is unaffected by temporal instructions (Table 1).

Table 1. Internal consistency reliabilities (Cronbach's α) for the Positive Affect (PA) scale of the PANAS instrument (Watson et al., 1988).

Time instructions	*N*	Cronbach's α Reliability PANAS PA scale
Moment	660	.89
Today	657	.90
Past few days	1002	.88
Past few weeks	586	.87
Year	649	.86
General	663	.88

Note: "Time instructions" refers to the point in time at which participants are asked to rate how they feel: *Moment* (at the present moment), *Today* (today), *Past few days* (during the past few days), *Week* (during the past week), *Past few weeks* (during the past few weeks), *Year* (during the past year) and *General* (in general) (Watson et al., 1988).

Students indicated the extent to which they felt each positive emotion on a five-point scale, and responses were scored such that a higher score represented a stronger positive emotional response:

Very slightly or not at all	1
A little	2
Moderately	3
Quite a bit	4
Extremely	5

In order to correlate these emotions with particular aspects of the project, the survey also required students to indicate which BioStories activities they had just completed: conducting research for a BioStory, composing or editing a BioStory, uploading a BioStory to the website, or reviewing and commenting on other students' uploaded stories.

Qualitative data sources and analysis

In this study, the findings from the quantitative analyses of the emotions survey data were merged with qualitative analyses of data generated by classroom video recordings and semi-structured interviews, as a way of strengthening the claims that emerged from the data. These data were generated in relation to four case students. The experiences of these students over the course of the project were investigated so as to provide a deeper understanding of their emotional responses as they learnt about biosecurity through their participation in the writing tasks.

The students were selected from a single Multi-strand Science class, nominated by one of the participating science teachers, Mr. Jackson[2]. They were chosen based on discussions

[2] Pseudonyms

with their teacher, such that they represented diverse levels of interest and engagement demonstrated in class. Three of the students, Angus[2], Mark[2] and Damien[2], had been studying Multi-strand Science since the start of Year 11, while Sarah[2] had just joined the subject as the start of Year 12, at the time the study was conducted.

During four of the six BioStories lessons, the case students were videoed as they participated in the writing tasks in Weeks 4, 6, 7 and 8 of the project. During these lessons, Tomas and Ritchie (i.e., first and second listed authors) adopted the role of participant observers in the science classroom, interacting casually with the students as they participated in the writing activities. One compact video camera recorded Angus and Mark while they worked, while a second video camera recorded Damien and Sarah. Each case student sat at a desktop computer along a single row of desks, side by side. The cameras were focused on the students' faces as they worked, to record outward expressions of emotions and emotional interactions with one another. Stylised representations of the students' facial expressions have been made from selected video frames as further evidence of their emotional responses during the project.

Spontaneous facial expressions are accurate indicators of emotions (Keltner & Ekman, 2000). While early studies have adopted self-report instruments in order to investigate the relationship between facial expressions and the experience of emotions (see Matsumoto, 1987), more precise facial coding systems have since been developed. One such system is the Facial Action Coding System (FACS) (Ekman & Friesen, 1978), an anatomically-based system which has been used extensively in empirical studies of facial measurement (Rosenburg, 2005). FACS measures all visible facial behaviours, and not just those related to emotions, which differentiates it from other facial coding systems. While early application of FACS required repeated viewing of facial movements in slow motion (Ekman & Oster, 1979), the system can now be applied using facial recognition software, provided that full-frontal images of subjects' faces are employed. As the video cameras in this study were

positioned to capture footage of pairs of students as they worked, the resultant images were side-on as opposed to frontal. For this reason, facial recognition software could not be applied in the analysis of the images. Instead, manual procedures for interpreting the students' facial expressions were applied according to Ekman and Friesen (1975).

Semi-structured interviews were conducted across three visits to the school up to eight weeks after the project was completed. Transcripts of these interviews (N=4) were qualitatively analysed for further insight into the emotions most strongly elicited by students' participation in the BioStories writing tasks. As well as direct questions about the emotions they experienced, students were also asked about aspects of their engagement with the project, so as to understand better the context under which particular positive emotions were elicited. As such, students were asked a number of questions at interview that explored their perceptions of learning science through the writing of BioStories, how they felt when they learnt about some of the biological incursions they were writing about, their experiences in reading and commenting on their peers' work, and having their own work reviewed; which activities stood out to them as being particularly positive and negative, and the strongest emotion they felt while working on the project. Open-ended questions that did not pre-empt student responses according particular themes were employed during the student interviews. For example, "What was the strongest emotion you felt during the BioStories project?"

Emotions Survey Results

Analysis of the emotions survey data was performed to determine which positive emotions were most strongly elicited through students' participation in the BioStories project. Table 2 presents a summary of the results. As can be seen from the data, strength (*M*=2.87, SD=1.09), pride *(M*=2.89, SD=1.21), determination (*M*=2.86, SD=1.22) and interest (*M*=2.83, SD=1.21) were the most salient emotions identified by the students, corresponding to a moderate level of elicitation. The emotion elicited least by students' participation in the project was

excitement *(M*=2.43, SD=1.14). The data therefore exhibits a small range between the minimum and maximum mean scores, with the majority of responses corresponding to the categories of "a little" and "moderately".

Table 2. Summary of all results from the emotions survey (N=50). The mode for each emotion has been shaded.

	Very slightly or not at all **1**	***A little*** **2**	***Moderately*** **3**	***Quite a bit*** **4**	***Extremely*** **5**	**Mean (SD)**
attentive	8.7%	34.8%	34.8%	15.7%	6.1%	2.76 (1.02)
strong	7.8%	32.2%	35.7%	13.9%	10.4%	2.87 (1.09)
inspired	15.7%	27.0%	31.3%	17.4%	8.7%	2.77 (1.17)
alert	13.0%	34.8%	30.4%	12.2%	9.6%	2.70 (1.14)
active	13.9%	34.8%	29.6%	13.0%	8.7%	2.68 (1.14)
excited	22.6%	33.9%	27.8%	8.7%	7.0%	2.43 (1.14)
proud	13.0%	28.7%	26.1%	20.9%	11.3%	2.89 (1.21)
enthusiastic	15.7%	29.6%	27.0%	17.4%	10.4%	2.77 (1.21)
determined	13.9%	29.6%	23.5%	22.6%	10.4%	2.86 (1.22)
interested	13.0%	32.2%	24.3%	19.1%	11.3%	2.83 (1.21)

Figures 1-10 present the mean scores for each individual emotion over the six BioStories lessons, to illustrate variations over the course of the project. In order to understand better the context from which these emotions emerged, Table 3 summarises the predominant activities that students undertook in each lesson, as drawn from the survey responses.

The graphs corresponding to attentive (Figure 1), active (Figure 5) and enthusiastic (Figure 9) exhibit little variation over the six lessons. The mean scores for these emotions varied little within the categories of "a little" and "moderately".

The graphs for each of the other emotions demonstrate different degrees of variation over the course of the project. The mean scores for inspired (Figure 2), proud (Figure 6), determined (Figure 7) and excited (Figure 8) each demonstrate a similar pattern in that they reflect a moderate level of elicitation across the BioStories lessons, with the exception of lesson 4, where there is a marked decline ($M \approx 2.00$). Excitement, in particular, exhibited the lowest mean score for any emotion over the course of the project during this lesson ($M=1.90$). Strength (Figure 3) was elicited in lessons 1, 2, 5 and 6 at moderate levels; however, it peaked in lesson 3 ($M=3.5$), before dropping sharply in lesson 4 ($M=2.31$). Like strength, interest (Figure 10) also exhibited moderate levels elicitation for the majority of the project; however, it demonstrated a marked drop in both lessons 3 and 4 ($M=2.22$ and $M=2.31$, respectively), before peaking in lesson 5 ($M=3.14$). Unlike the other positive emotions, alertness (Figure 4) peaked early in the project in lesson 2 ($M=3.0$), again dropping to its lowest level in Week 4 ($M=2.31$), increasing only marginally in lessons 5 and 6.

Table 3. A summary of the predominant activities performed by students during each BioStories lesson, drawn from the emotions survey.

BioStories lesson	**Predominant activities**
Week 1 – Lesson 1	Conducting research – Part A Composing or editing – Part A
Week 2 – Lesson 2	Composing or editing – Part A Uploading – Part A Peer review of stories Conducting research – Part B
Week 3 – Lesson 3	Conducting research – Part B Composing or editing – Part B
Week 4	*No BioStories lesson*
Week 5	*No BioStories lesson*
Week 6 – Lesson 4	Conducting research – Part B Composing or editing – Part B
Week 7 – Lesson 5	Uploading – Part B Peer review of stories Conducting research – Part C
Week 8 – Lesson 6	Conducting research – Part C Composing or editing – Part C Uploading – Part C Peer review of stories

An analysis of the activities in which students engaged at these key points in the project revealed that a marked increase in selected positive emotions corresponded to a transition into a new BioStories activity, while a sharp decline in students' positive emotions corresponded to an extended period of time in which they were participating in the same activity. Based on the survey data, three critical points in the project have been identified: lesson 2, lessons 3-4, and lesson 5. An analysis of the context of these critical points that may explain observed data are presented in the following section.

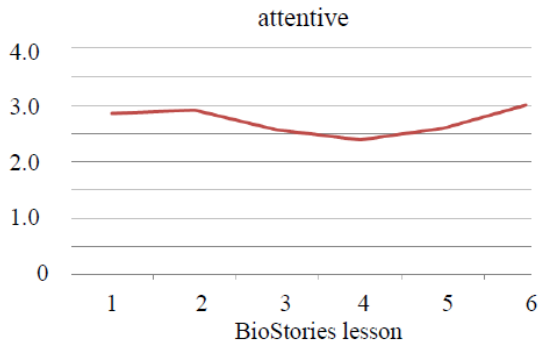


Figure 1. Mean levels of attentiveness across the six BioStories lessons.

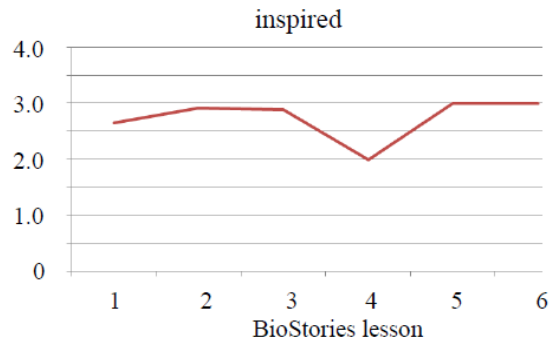


Figure 2. Mean levels of inspiration across the six BioStories lessons.

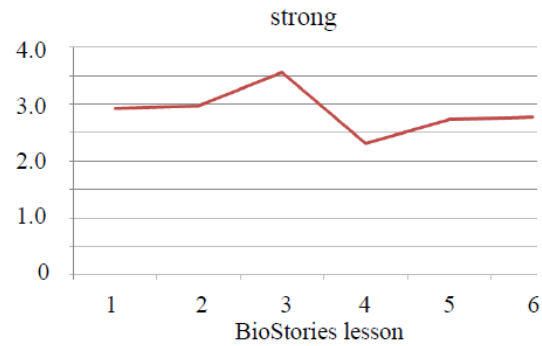


Figure 3. Mean levels of strength across the six BioStories lessons.

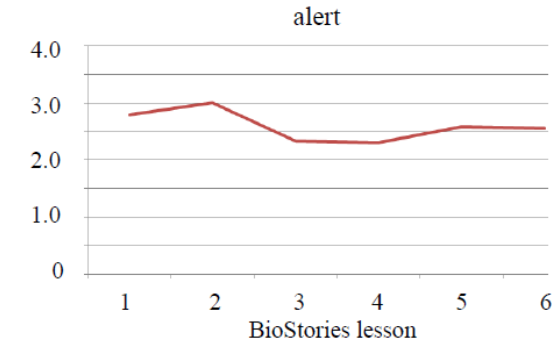
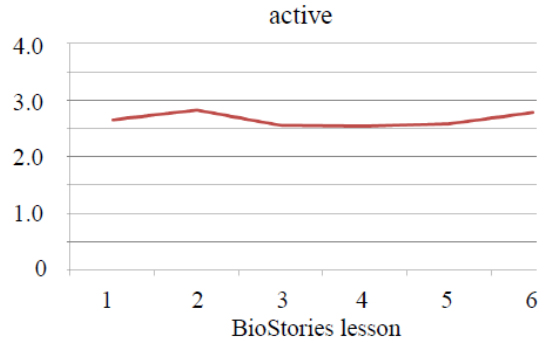


Figure 4. Mean levels of alertness across the six BioStories lessons.



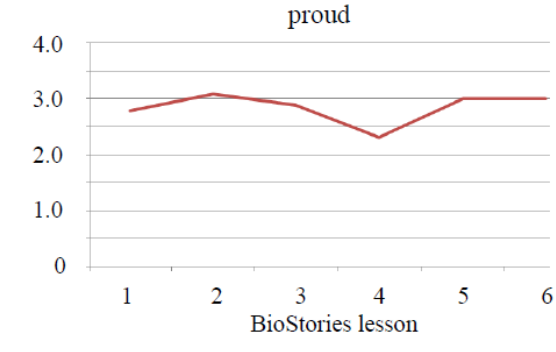


Figure 6. Mean levels of pride across the six

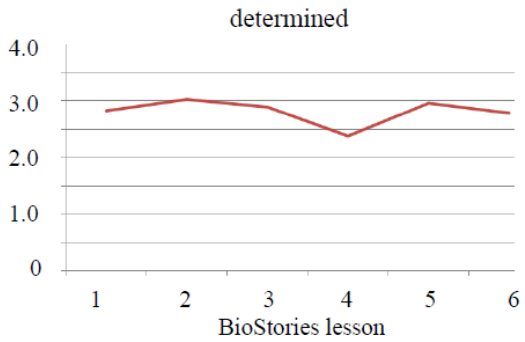


Figure 7. Mean levels of determination across the six BioStories lessons.

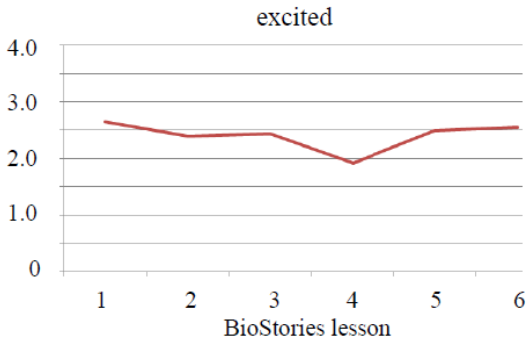


Figure 8. Mean levels of excitement across the six BioStories lessons.

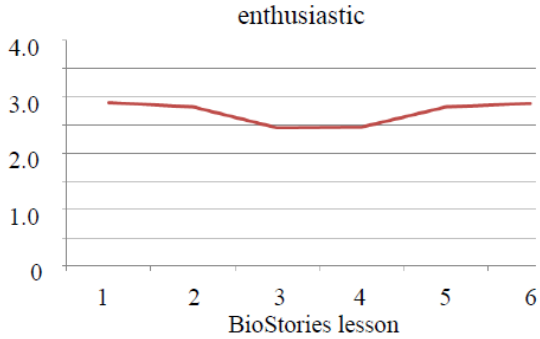


Figure 9. Mean levels of enthusiasm across the six BioStories lessons.

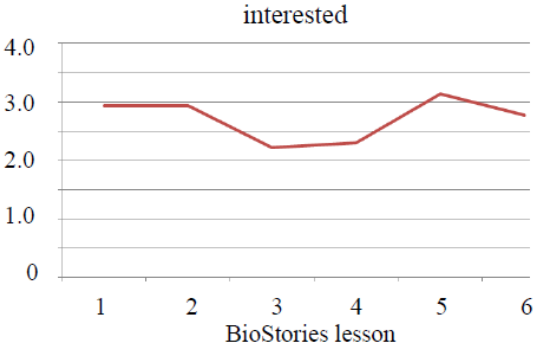


Figure 10. Mean levels of interest across the six BioStories lessons.

Analysis and Discussion of Emotions Arising from the Project

Data generated by the emotions survey revealed that BioStories activities in lesson 2, lessons 3-4 and lesson 5 contributed to a sharp increase or decline in seven of the positive emotions examined: alert, inspired, excited, proud, determined, strong and interested. Lesson 2 of the project saw a marked increase in the mean level of alertness elicited by the BioStories project (Figure 4, M=3.14). A similar pattern was not observed for any of the other positive emotions that were surveyed. An analysis of the activities in which students were engaging at this time, as well as consideration of the topic with which they were engaging, provides some insight into why this may have been the case.

In the first lesson, students were conducting research for their Part A BioStory, or composing or editing the story itself. In lesson 2, some students were still composing or

editing their work; however, most students had completed Part A, and were uploading their stories, and reading and commenting on their peers' work. Some students had begun conducting research for Part B. Lesson 2 was the first lesson in which students engaged in peer evaluation of their BioStories, which may account for the increase in levels of alertness during this lesson. Reading and commenting on other students' stories, and receiving comments about their own work, may have induced higher levels of self-awareness with regards to their learning and the stories they were composing. As Sarah explained at interview, the strongest emotion she felt during the BioStories project was alertness, elicited by the peer review process; however, she also linked feelings of alertness to her newfound awareness of biosecurity issues:

01 Researcher: What was the strongest emotion you felt during the whole process?

02 Sarah: Probably alert, alert about everything I'm doing with this, but alert about the problems that are going on around the world like bird flu. I learnt so much about that 'cause I've been curious about it, so it made me more alert about my surroundings and about ... more alert about my study habits and more alert of what other students do and what other students think of my work.

Lesson 4 of the project revealed a moment in which Sarah was completing the Part B writing task and was researching some additional information about the impacts of avian influenza to complete her story. When she discovered the economic cost of a bird flu outbreak, she was visibly surprised (Figure 11a, b), and was compelled to share her knew knowledge with Damien:

03 Sarah: Holy moley! Look! Look at what would happen to our economy… [8] 4.4 million, no trillion dollars would be lost. [9] That is ridiculous.

In Figure 11a, Sarah's dropped jaw and parted lips and teeth show no sign of tension of the mouth, which denotes surprise (Ekman & Friesen, 1975). The intensity of the surprise is indicated by the extent of the jaw drop, which suggests that Sarah was quite surprised by what she had just found. Specifically, the words that accompanied her expression (i.e., *Holey Moley!*") signify astonished surprise, which is congruent with her apparent disbelief as she was alerted to the economic cost of a potential avian influenza outbreak (Ekman & Friesen, 1975).

Figure 11a, b. Images of Sarah expressing her surprise as she learnt about the economic impact of a potential bird flu outbreak.

Within a few seconds of her initial surprise, Sarah's facial expression changed once she evaluated the new information she had just learnt (Figure 11b). This new expression, characterised by a surprised brow (i.e., slightly raised brows that present small lines on the forehead) accompanied by a disgust mouth (i.e., when the corners of the lips are pulled downwards very slightly) reveals surprise with sceptical disbelief (Ekman & Friesen, 1975).

This indicates that Sarah was incredulous and somewhat sceptical of the cost of a bird flu outbreak, particularly as this particular facial expression can be symbolic of disbelief or negation (Ekman & Friesen, 1975).

Like Sarah, Angus, Mark and Damien also commented on their increased awareness of the ecological impacts of biological incursions developed through their participation in the project. As Angus explained while reviewing his Part A BioStory about cane toads, "it shows you how something small can affect a whole ecosystem". A similar sentiment was echoed by Mark and Damien, who explained that prior to writing their BioStories, they did not comprehend the extent of the problem caused by the biological incursions they were studying. When asked how he felt when he learnt about some of these impacts, Damien explained, "Kind of like a number of different things. Like, it was cool learning about it, but it also sucked, I mean, that this is happening."

Interviews with the case students revealed that reading other students' BioStories online was useful, not only to learn about other biological incursions, but to assist them in the subsequent writing tasks. For Damien, reading other BioStories helped him to devise ways of better incorporating science ideas into his writing (turns 05 and 07):

04 Researcher: So what did you think about reading other people's stories?

05 Damien: I liked it a lot more, like knowing how they did something. It would give me ideas for Part B or Part C or something.

06 Researcher: Okay. So did you take some ideas onboard to help you?

07 Damien: Yeah, just like maybe how to do a part differently, like a question to ask the person who's giving the information, so it prompts like them to say the science behind something.

In this way, reading other students' stories alerted Damien to particular techniques that he could use in his own writing. For Sarah, the peer review process helped her to develop confidence in her own work:

> 08 Sarah: I got benefit from when people looked at your things [*i.e., BioStories*] and rated it. Yeah, I got lots of benefit from that, 'cause it's a rating from your peers. I was getting ... like everyone was rating mine pretty highly and that gave me the confidence that I'm doing is right, and you have the confidence to help other people. If the teacher can't get around then you're there to help.

For different reasons, as exemplified by Damien and Sarah's comments, the peer review process increased students' awareness of their own writing, and studying a new topic alerted them to issues related to biosecurity. A decrease in overall levels of alertness in lesson 3 may have been an artefact of students' developing familiarity with both the topic and the BioStories project itself.

Lessons 3 and 4 presented the next critical point in the project for a number of the positive emotions surveyed. Five of these emotions demonstrated a marked decrease in their mean scores in lesson 4 of the project: inspired, strong, proud, determined and excited (Figures 2, 3, 6, 7, and 9, respectively). Just prior to this, in lesson 3, the mean score for strength peaked (M=3.50). The pattern for interest (Figure 10) differed slightly, in that a decrease in the mean score was also observed earlier, in lesson 3 (M=2.22).

In Week 3 of the project (i.e., lesson 3), students were primarily engaged in conducting research for the Part B writing task, or composing or editing their Part B BioStory. In the two weeks that followed, the students did not participate in a BioStories lesson at school, as they were required to undertake a field trip as part of the *Environmental Studies*

unit. During this time, students were instructed by Mr. Jackson to complete a draft of Part B, so that upon return to the classroom in Week 6 (i.e., lesson 4) they could conduct a final edit of their work, upload their BioStory and commence research for the Part C writing task. When students did return to class in lesson 4, most students were still at the same point in the project as they were three weeks prior, in lesson 3, as they had not completed their Part B homework. It is likely that returning to the same BioStories activities after this time elicited lower levels of positive emotions, as they were unable to progress to a new activity.

The lowest overall mean for a positive emotion during the project was recorded in Week 4 for excitement (M=1.90). The BioStories writing tasks were largely completed individually, as students worked at their own computers. During the BioStories lessons, Tomas (i.e., first listed author) observed limited student interactions and discussion around the work being completed. It is not surprising, therefore, that solitary writing tasks, irrespective of an interesting topic, would elicit little excitement. Nonetheless, while the overall data speaks of low levels of excitement, the interview suggests that the experiences of individual students differed. For example, in the following excerpt, Damien explained that he was excited by the prospect of learning something new (turn 09), when he was asked which emotions he felt most often:

09 Damien: I guess a bit of interest and excitement, learning about the science and everything.

10 Researcher: What interested you the most?

11 Damien: Learning about it, like just a whole range of things, learning about how the introduced species came into Australia and how to eradicate them.

12 Researcher: So what was exciting about the project?

13 Damien: I don't know, it's just exciting when I learn something new.

The final critical point in the project, as indicated by the survey data, was lesson 5. For this lesson, the mean score for interest peaked (*M*=3.14), following a decline in lessons 3 and 4. An analysis of the classroom activities at this time revealed that during lesson 5, most students were commencing work on the Part C writing task. Unlike Parts A and B, in which students were required to write a story that completed a given scenario about a biological incursion, Part C required students to compose a unique BioStory of their own; that is, students selected the biological incursion on which their story was based (Parts A and B provided a selection from which students could choose, or they could identify another), and created their own plot and characters. This created interest among the students, who talked with one another about the biological incursions they wanted to write about, and the possibilities of a new storyline. This lesson was therefore different from the previous BioStories lessons in that the transition to a new writing task appeared to induce greater levels of interest than the other tasks, resulting in increased levels of social interactions among the students around the activity. These social interactions would have further enhanced students' interest and engagement in the lesson.

An example of one such interaction was observed in lesson 4 of the project, when Angus had just commenced work on the Part C writing task. Mr. Jackson was roaming around the room, checking that students were on-task, when he pulled up a seat behind Angus to check on how he was going. They began talking about what Angus's story was going to be about, when Mr. Jackson made reference to a science-fiction movie (turn 14):

14 Mr. Jackson: Are you putting some Star Wars references into this one?

15 Angus: Ah, no, not in this one. [*smiling*]

16 Mr. Jackson: I hope your last one [*i.e., Part C BioStory*] has some Star Wars in it. It's open season for Star Wars in the last one.

17 Angus: Yeah [*laughs*]

18 Mr. Jackson: You can use any characters. You could have, like, something from the Dagobah system [*fictional planet*].

19 Angus: Oh yeah [*laughs*]

20 Mr. Jackson: That's a pretty interesting place in terms of life forms, isn't it?

21 Angus: Yeah. [*laughs*] Maybe a huge dragon.

Although this interaction between Angus and Mr. Jackson may seem trivial, the act of sharing a joke as Angus was devising a storyline for the Part C BioStories task elicited a positive emotional response (Figure 12). An analysis of Angus's facial expression reveals happiness, which is shown by a cheek-raise (Duchenne) smile (Ekman & Friesen, 1975). Duchenne smiles are uniquely associated with positive emotion (Ekman, Davidson, & Friesen, 1990). The corner of his lips are drawn back and up, and his mouth is open, and the naso-labial folds extending out from the nose and down the area beyond the corners of the mouth are characteristic of happiness and joy (Ekman & Friesen, 1975). There are also a number of features of Angus's expression that indicate the intensity of his happiness. The intensification of the naso-labial folds and raised cheek that has narrowed the eyes denotes a pronounced smile. The skin below the lower eyelid is also pushed up, with lines formed below the eye and 'crow's feet' formed at the outer corner (Ekman & Friesen, 1975).

Angus's happy expression is mirrored by Mr. Jackson, who is also displaying enthusiasm as shown by the way in which his lips are parted and teeth are together in a grin, with a slight raised brow and open eyes (Ekman & Friesen, 1975). The conversation that Mr. Jackson initiated with Angus about the possibility of including science fiction references in his Part C BioStory does indicate that he was interested and enthusiastic about his work, and the positive emotions that arose from this interaction are likely to have enhanced Angus's interest in the lesson. Importantly, this interaction with Mr. Jackson initiated further

conversations with Mark and Damien about creating interesting characters and storylines. For example, Mark commented that a particular line in Angus's Part C story, derived from the science-fiction reference, was "witty", which led to a conversation about what Angus had planned for the next part of his story.

While the survey data suggest that the level of interest elicited by the project was generally small to moderate (Figure 10), the interview data obtained from the case students provide evidence that there were several features of the project that stimulated their interest. An analysis of the data revealed three themes that engaged students' interest: engaging with the socio-scientific issue of biosecurity; writing hybridised scientific narratives in science; and enhanced feelings of pride and self-efficacy.

Figure 12. An image of Angus sharing a joke with Mr. Jackson in relation to the Part C writing task.

The notions of engaging with the socio-scientific issue of biosecurity and writing hybridised scientific narratives in science were significant talking points at interview for the case students, as they hadn't encountered these aspects of the project previously in school. As Angus explained:

22 Researcher: What was the strongest emotion you think you felt during the whole process?

23 Angus: Oh, probably my interest in the topic, and writing stories was fun. Yeah, it was a better way to do it than reports and stuff.

24 Researcher: Have you written stories in science before?

25 Angus: No.

26 Researcher: So would you have been interested if you wrote a report on cane toads, for example?

27 Angus: Probably not.

For Mark, his interest in the topic motivated him to do his best, as did the autonomy that writing a story afforded, and communicating his understanding in a different way:

28 Mark: I did try a lot harder in BioStories than I do in other things, just 'cause it was a lot more interesting than normal Multi-strand topics, and being able to write what you want instead of having to follow a format, instead of it just being boring, just information.

Mark's comment about writing in such a way wasn't just "boring information" suggests that writing in a genre other than the traditional scientific genres encountered in the classroom, such as scientific reports, was important in capturing his interest. Indeed, engaging with the genre of hybridised scientific narratives was an important issue for all of the case students at interview. For Damien, it was challenging to communicate scientific ideas in the form of

dialogue between characters, but he experienced a sense of satisfaction after explaining the autonomy that writing stories in science afforded (turns 33-36):

29 Researcher: How did you feel about writing stories?

30 Damien: It was better than writing a report.

31 Researcher: Yeah?

32 Damien: I enjoyed it a *lot* more.

33 Researcher: Okay, so what did you enjoy about it?

34 Damien: The freedom. It didn't have to just stick to a structure. I can make my own structure just as long as it had science in it.

35 Researcher: So even though you found it difficult to include the science in dialogue...

36 Damien: Yeah, it was worth it.

Like Damien, Sarah also appreciated the autonomy of writing stories. When asked her perceptions of the BioStories project, she explained:

37 Sarah: Overall it was a good process. I enjoyed it. It sort of gives you the freedom of bending it [*i.e., the story*] the way you want it to bend it, and finding out how to look at a thing and go okay, this is how I'm going to do it, and if it doesn't work out, so be it.

Mark explained that he found writing stories in science and being creative easier than engaging with the more "formal" genre of essays (turns 38-41, 44-45), particularly as he

could adopt natural, everyday discourse in order to communicate scientific ideas in conversational prose (turns 42-43):

38 Researcher: How did you find it incorporating science into the stories that you wrote?

39 Mark: I found it a lot easier than writing pure scientific sort of essays.

40 Researcher: What's easy about it?

41 Mark: It's just more creative.

42 Researcher: How did you find it using dialogue between characters in a story about science?

43 Mark: Still a lot easier than writing essays because you can just ... it's as if you're talking to a friend, you can say something and then they'll reply how a normal person would.

44 Researcher: What do you find difficult about writing essays?

45 Mark: It's just they have to be all formal.

Angus also found it easier and more enjoyable to write a BioStory than a scientific report (turns 46-47), as he could choose the content and structure of his stories (turns 48-49):

46 Researcher: How would you compare writing like this way compared to other ways that you usually write in science?

47 Angus: Oh, that's easier. It's like it flows easier and it's more fun than a report.

48 Researcher: Okay, why did this appeal to you?

49 Angus: Well, you could put the information you wanted to put in it and put it in what order you wanted, instead of having it in blocks and paragraphs and really long stuff.

Writing BioStories was the first time Sarah had written conversational prose in science before. When asked what she thought about this, she explained that she enjoyed writing in the first person of a narrative, and how to communicate science through natural, everyday discourse. Interestingly, the notion of employing such discourse was something that Sarah did not associate with science, as indicated by her perception that science is a "serious" subject:

50 Sarah: I think it's good because you kind of get sick of writing in third person. You learn how to ... basically, if someone asks you about something, you learn how to have a conversation with them in a way they understand how science works. It's good because it gives you a break from science and how you have to be really 100 per cent serious.

Sarah's comment that writing BioStories taught her how to have a conversation about science is also significant, as the ability to communicate science to diverse audiences for diverse purposes maybe considered an important aspect of scientific literacy (Hand, Prain, Lawrence, & Yore, 1999).

In addition to the interest evoked by writing hybridised scientific narratives about biosecurity, students' comments at interview also suggest that the positive experience of successfully writing stories in science enhanced their sense of self-efficacy, which served to further engage their interest. When asked about the strongest emotion she felt during the BioStories project, in addition to feeling alert, Sarah also experienced pride:

51 Sarah: It made me proud, like I thought I did well.

52 Researcher: So you felt pride?

53 Sarah: Yeah, ‘cause I felt like I was doing it right and because I became ... I haven’t done science since Year 9 so to come to this and get high marks has made me feel good about what I’m writing, ‘cause at first I was, like, oh, I don’t know what to write about, and that sort of thing, and I got positive feedback from the teacher and everything, so I just went with how I knew how to do it.

Indeed, Sarah did receive positive feedback about her work from her teacher. In the final lesson of the project, Mr. Jackson was collating the students’ BioStories to ensure that all required work had been submitted. After reviewing Sarah’s writing tasks, he walked over and commented on the high standard of her work:

54 Mr. Jackson: Sarah, that’s very impressive work.

55 Sarah: Yeah?

56 Mr. Jackson: Yeah, that’s very, very impressive work. Well done. [*Pats Sarah on the shoulder*]

57 Sarah: Thanks, Sir.

This interaction, depicted in Figure 13, elicited a positive emotional response from Sarah, who was visibly pleased by the feedback. Her Duchenne smile reveals happiness, as indicated by her pronounced naso-labial folds and parted lips which are drawn back and up (Ekman &

Friesen, 1975). This positive acknowledgement of her work from Mr. Jackson pleased Sarah and is likely to have contributed to her feelings of pride described at interview.

Figure 13. An image of Sarah as she received positive feedback about her BioStories from Mr. Jackson.

For Sarah, doing well in the project was empowering; however, she also associated this success with a negative experience. Sarah was the only case student who identified any aspect of their experience of the project to be negative. While she enjoyed the project, she also achieved an A[3] in Multi-strand Science for each of the three writing tasks. As a relative newcomer to the class, Sarah was concerned about how achieving well in BioStories positioned her among her peers:

58 Researcher: Did any activity stand out for you as being negative?

59 Sarah: No, nothing was negative in the actual research, it's just ... 'cause I came into a new class and stuff, I think people were like intimidated because I ... well, as the teacher said, I set the bar for everyone to

[3] Student assessment is rated on a scale of A to E, where A is the very best grade attainable for any given task, and E is the lowest grade. C represents a passing grade.

move up to, sort of thing. That's probably the downside 'cause I didn't ... I thought I was working at my normal pace, whereas other people thought I was showing off or something.

In spite of this negative perception, successfully writing stories in science made Sarah feel proud, particularly when she received positive feedback from her teacher. Similarly for Mark, completing the project elicited a sense of accomplishment and pride (turns 60-62). When asked if any of the BioStories activities stood out for him as being particularly positive, he explained:

60 Mark: I think when you finish your final story and you've written it and you read it and you think that's a pretty good piece of work, that's quite positive.

61 Researcher: So when you think back to the project, what was the strongest emotion you generally felt?

62 Mark: I think achievement. I achieved quite a lot.

For Damien, writing BioStories was a challenge, so completing the tasks successfully was an important accomplishment that enhanced his self-efficacy in science (turn 66):

63 Researcher: What did you think about writing a story in science?

64 Damien: It was challenging [*laughs*], definitely challenging for me, but it was good.

65 Researcher: So what was good about the experience?

66 Damien: Well, I liked to overcome things that are difficult and so being able to write not necessarily a good story, but just a story with science in it was good, a sense of achievement.

Reading positive comments about his BioStories is also likely to have contributed to Damien's enhanced self-efficacy. While this was writing stories in science was an affirming experience for Damien, completing the emotions survey also stood out to Damien as being a positive experience, as it presented an opportunity to express how he felt (turns 68-72):

67 Researcher: Do any of the activities you did during the BioStories project stand out to you as being particularly positive?

68 Damien: The positive feedback from the stories was good, and the quizzes where you could put your emotions down and say how you felt.

69 Researcher: The emotions survey?

70 Damien: Yeah. How do I put it? It's … you're able to have your say about how you felt about everything.

71 Researcher: So you appreciated giving some feedback about how the project made you feel?

72 Damien: Yeah.

Conclusions

Very few studies have focused on the role of student emotions in learning science. As Damien's comment at interview captures:

> The positive feedback from the stories was good, and the quizzes where you could put your emotions down and say how you felt …you're able to have your say about how you felt about everything.

This study investigated the extent to which writing hybridised scientific narratives about the socio-scientific issue of biosecurity elicited positive emotional responses in the context of a Year 12 Mulit-strand Science class. Data were generated through students' responses to an emotions survey completed at the end of each BioStories lesson, video recordings of four case students working on the project (from which snapshots of expressions of emotions were drawn) and semi-structured end-of-project interviews with these students. Collectively, these data provide evidence that pride, strength, determination, interest and alertness were the most salient positive emotions elicited through students' participation in the BioStories writing tasks. Furthermore, analysis of the interview data revealed three themes that engaged students' interest: engaging with the socio-scientific issue of biosecurity; writing hybridised scientific narratives in science; and enhanced feelings of pride and self-efficacy.

The survey data revealed that pride *(M*=2.89, SD=1.21) was the strongest positive emotion experienced by students during the study, which was triangulated by interview data generated by the case students. Sarah, Damien and Mark each commented that successfully writing stories in science elicited feelings of pride, self-efficacy and a sense of achievement, particularly when their success was recognised by their teacher, as was the case with Sarah.

A marked decrease in students' inspiration, pride, strength, determination and excitement was reflected in the survey data in lesson 4 of the project. It is likely that this was

an indication of students' waning interest as they returned to the same writing task after a two-week break from the project. It would seem, then, that in order to maintain a positive disposition toward their work, students need to feel that they are making progress and experiencing success. For example, an increase in students' mean levels of strength in lesson 3, as demonstrated by the survey data, may have been due to increased feelings of self-efficacy after successfully completing the Part A writing task.

According to the survey data, interest peaked in lesson 5 of the project at a time when students were commencing the Part C writing task. This task afforded students an opportunity to compose a unique BioStory of their own. For the case students, this created interest as they talked and joked with one another about the possibilities for their new story. An analysis of the video data revealed increased levels of social interactions among the case students during this lesson, which would have further enhanced students' interest and engagement in the lesson.

In addition to the interest stimulated by the introduction of the Part C writing task and the subsequent social interactions that ensued, writing about the socio-scientific issue of biosecurity also interested students, and they enjoyed engaging with the hybridised scientific narrative genre. Angus (turns 22-27), Mark (turn 28) and Damien (turns 29-36) revealed that writing BioStories stimulated their interest as they did not enjoy writing more traditional scientific genres, such as scientific reports. Mark, for example, explained that he was interested in being able to write what he wanted, "instead of it just being boring, just information" (turn 28). It has been suggested that stressing the rules of formal scientific language can serve to disengage students, as it is "a recipe for dull, alienating language" (Lemke, 1990, p. 1999), and indeed, both Mark (turns 38-45) and Sarah (turn 50) appreciated the opportunity to adopt natural, everyday discourse in their stories in order to communicate their science understandings. In particular, Sarah's frustration with writing in third-person supports Wellington and Osborne's (2001) claim that students often encounter difficulties

writing in the passive style typical of scientific genres, which can, in turn, discourage them from writing in science.

Although writing hybridised scientific narratives elicited interest and enjoyment, writing BioStories was a challenging experience nonetheless, as exemplified by Damien's comments at interview (turns 63-66). In constructing their BioStories, the students transformed the scientific information within the websites, shaped their emerging understandings of this information, and re-presented these understandings in a new context – hybridised narratives about biosecurity. Through the process of producing new constructions and representations of reality, the students transformed and reproduced particular conventions of the available resources (i.e., government websites containing scientific information, the narrative genre, and students' natural, everyday discourse), through the creative application and combination of these conventions. It is not surprising that Damien, for example, felt that this process of transformation was challenging, as he had never written hybridised scientific narratives prior to his participation in the project. In particular, students were transforming scientific information and re-presenting their understandings in the form of short stories, an entirely new context, far removed from the original genre in which the information was presented. When students are required to utilise scientific resources to reproduce scientific genres, transformation is minimised, as students can simply reproduce information that they may not understand in a similar context or genre. In contrast, writing a short story that contains scientific information requires considerable transformation, as explained by Mark (turns 38-45) and Sarah (turn 50), as they are required to merge their developing scientific understandings with their everyday, natural discourse. It is likely that meeting this challenge in order to successfully write their BioStories contributed to the feelings of pride and self-efficacy described by the case students at interview.

Overall, the project did not elicit much excitement, the lowest overall mean for which was recorded in Week 4 (M=1.90). The BioStories writing tasks were largely completed

individually, as students worked at their own computers with limited interactions and discussion around the work being completed. Not surprisingly, students' participation in solitary writing tasks appeared to elicit little excitement, in spite of their engagement with an interesting socio-scientific issue. Nonetheless, while the survey data overall speaks of low to moderate levels of attentiveness, activeness, enthusiasm and excitement, comments by the case students at interview suggest that the experiences of individual students differed. Importantly, students articulated emotional responses to particular aspects of the project that weren't reflected in the survey data, or provided further insight into why they experienced particular emotions. For example, Damien explained that for him, learning something new elicited excitement (turns 09-13), while Sarah felt that the strongest emotion she felt during the project was alert, as she became more aware of issues relating to biosecurity, as well as what others thought of her work through the peer review process (turns 01-02).

End-of-project interviews conducted with the case students and analysis of their facial expressions provided a deeper insight into the emotions elicited through their participation in the BioStories writing tasks, than the survey data alone. As the survey was completed at the end of each BioStories lesson, it did not capture emotions as they were experienced at particular moments in time, such as the sharing of a joke between Angus and Mr. Jackson (turns 14-21), or when Mr. Jackson provided Sarah with positive feedback about her work (turns 54-57). Analysis of student and teacher facial expressions revealed moments in time in which surprise and scepticism (Figure 11a,b), and happiness and enthusiasm (Figures 12 and 13) were experienced by the participants. It seems, then, that a survey that requires students to provide an overall evaluation of particular emotions retrospectively fails to capture the moments that are emotionally significant; moments that elicit heightened levels of positive or negative emotions.

In this study, analysis of participants' spontaneous facial expressions provided further evidence of the positive emotions they experienced as they engaged in the BioStories project.

This analysis was performed manually as the side-views of students' faces captured while they worked did not facilitate the application of facial recognition software. To enable such analysis in the future, subsequent studies of students' emotions as they are learning science will require the positioning of video cameras such that frontal images are obtained.

Our aim in this project was to engage students in SSI activities to change their "emotional relation to the subject matter – so as to better learn it…" (Rosiek & Beghetto, 2009, p. 183). While this study begins to illuminate the ways in which writing hybridised scientific narratives about a socio-scientific issue elicits positive emotions, and the role that these emotions play in engaging students in science learning, further research is required to advance our understanding of the relationship between emotion and cognition in science classrooms, particularly in the context of students' developing scientific literacy. In addition, while this study begins to examine the ways in which teacher-student and student-student interactions contribute to the emergence of positive emotions, further research in this area warranted. Such investigations will require the identification of innovative approaches to measuring and analysing participants' emotions in classes implementing SSI activities, including those that measure emotional responses to SSI activities as they unfold, moment by moment.

References

Ainley, M., Corrigan, M., & Richardson, N. (2005). Students, tasks and emotions: Identifying the contribution of emotions to students' reading of popular culture and popular science texts. *Learning and Instruction, 15*, 433-447.

Britner, S. L., & Pajares, F. (2006). Sources of science self-efficacy: Beliefs in middle school students. *Journal of Research in Science Teaching, 43*(5), 485-499.

Collins, R. (2004). *Interaction ritual chains*. Princeton, NJ: Princeton University Press.

Creswell, J. W. (2005). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (2nd ed.). Upper Saddle River, NJ: Merrill Prentice Hall.

Demetriou, H., & Wilson, E. (2009). Synthesising affect and cognition in teaching and learning. *Social Psychology Education*, 12, 213-232.

Durkheim, E. (1995/1912). *The elementary forms of religious life*, trans. K.E. Fields. New York: Free Press.

Ekman, P., Davidson, R. J., & Friesen, W. (1990). The Duchenne smile: Emotional expression and physiology II. *Journal of Personality and Social Psychology, 58*, 342-353.

Ekman, P. & Friesen,W.V. (1975). *Unmasking the face: A guide to recognising emotions from facial expressions*. Englewood Cliffs, New Jersey: Prentice Hall.

Ekman, P. & Friesen,W.V. (1978). *The Facial Action Coding System*. Palo Alto, California: Consulting Psychologists Press.

Ekman, P., & Oster, H. (1979). Facial expressions of emotion. *Annual Review of Psychology, 30*, 527-554.

Fensham, P. (2007, May). Competencies, within and without: New challenges and possibilities for scientific literacy. Paper presented at the Linnaeus Tercentenary 2007 Symposium, Uppsala University, Sweden.

Hand, B., Prain, V., Lawrence, C., & Yore, L. (1999). A writing science framework designed to enhance science literacy. *International Journal of Science Education, 21*(10), 1021-1035.Lewis, M. (2008). Self-conscious emotions. Embarrassment, pride, shame, and guilt. In M. Lewis, J. M. Haviland-Jones, & L. Feldman Barrett (Eds.), *Handbook of emotions 3rd ed.* (pp. 742-756). New York: The Guilford Press.

Keltner, D., & Ekman, P. (2000). Facial expression of emotion. In M. Lewis and J. Haviland-Jones (Eds.), *Handbook of emotions* (2nd ed.), pp. 236-249. New York: Guilford Publications Inc.

Kolstø, S. D. (2001). Scientific literacy for citizenship: Tools for dealing with the science dimension of controversial socio-scientific issues. *Science Education, 85*(3), 291-310.

Kuppermintz, H. (2002). Affective and cognitive factors as attitude resources in high school science achievement. *Educational Assessment, 8*(2), 123-137.

Lau, S., & Roesner, R. W. (2002). Cognitive abilities and motivational processes in high school students' situational engagement and achievement in science. *Educational Assessment, 8*(2), 139-162.

Lemke, J. J. (1990). *Talking science: Language, learning and values*. Norwood, N.J.: Ablex Publishing.

Lewis, M. (2008). Self-conscious emotions. Embarrassment, pride, shame, and guilt. In M. Lewis, J. M. Haviland-Jones, & L. Feldman Barrett (Eds.), *Handbook of emotions 3rd ed.* (pp. 742-756). New York: The Guilford Press.

Linder, C., Östman, L., Roberts, D. A., Wickman, P-O., Ericksen, G., & MacKinnon, A. (Eds.). (2010). *Exploring the landscape of scientific literacy*. London: Routledge.

Lyons, T. (2006). The puzzle of falling enrolments is physics and chemistry courses: Putting some pieces together. Research in Science Education, 36, 285-311.

Matsumoto, D. (1987). The role of facial response in the experience of emotion: More methodological problems and a meta-analysis. *Journal of Personality and Social Psychology, 52*, 769-774.

OECD. (2006). Assessing scientific, reading and mathematical literacy: A framework for PISA 2006. Paris: OECD Publications.

Pintrich, P. R., & DeGroot, E. V. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology, 82*(1), 33-40.

Prain, V. (2008). Researching effective pedagogies for developing the literacies of science: Some theoretical and practical considerations. In M. C. Shelley II, L. D. Yore & B. Hand (Eds.), *Quality research in literacy and science education: International perspectives and gold standards* (pp. 151-167). Dordrecht, The Netherlands Kluwer Academic Publishing.

Queensland Board of Senior Secondary School Studies (QBSSSS). (1998). *Multi-strand science: Senior syllabus*. Retrieved 12 October 2010 from the Queensland Studies Authority website: http://www.qsa.qld.edu.au/downloads/senior/snr_multi-strand_sc_98_syll.pdf

Rennie, L. J., & Goodrum, D. (2007). *Australian school science education National Action Plan 2008–2012, Volume 2. Background research and mapping*. Canberra: Australian Government Department of Education, Science and Training.

Ritchie, S. M., Tomas, L., & Tones, M. (2011). Writing stories to enhance scientific literacy. *International Journal of Science Education, 33*(5), 685-707.

Rosenberg, E. L. (2005). Introduction: The study of spontaneous facial expressions in psychology. In P. Ekman and E. L. Rosenberg (Eds.), *What the face reveals: Basic and applied studies of spontaneous expressing using the Facial Action Coding System (FACS)* (2nd ed.), pp. 3-18. Oxford, New York: Oxford University Press.

Rosiek, J., & Beghetto, R. A. (2009). Emotional scaffolding: The emotional and imaginative dimensions of teaching and learning. In P. A. Schutz & M. Zembylas (Eds.), *Advances in teacher emotion research. The impact on teachers' lives*. Dordrecht, The Netherlands: Springer Press.

Sadler, T. D. (2004). Informal reasoning regarding socio-scientific issues: A critical review of research. *Journal of Research in Science Teaching, 41*(5), 513-536.

Sadler, T. D., Barab, S. A., & Scott, B. (2007). What do students gain by engaging in socio-scientific inquiry? *Research in Science Education, 37*(4), 371-391.

Sadler, T. D., & Zeidler, D. L. (2005). The significance of content knowledge for informal reasoning regarding socio-scientific issues: Applying genetics knowledge to genetic engineering issues. *Science Education, 89*(1), 71–93.

Schutz, P. A., Aultman, L. P., & Williams-Johnson, M. R. (2009). Educational psychological perspectives on teachers' emotions. In P. A. Schutz & M. Zembylas (Eds.), *Advances in teacher emotion research* (pp., 195-212). Dordrecht, The Netherlands: Springer Press.

Teixeira dos Danstos, F. M., & Mortimer, E., F. (2003). How emotions shape the relationship between a chemistry teacher and her high school students. *International Journal of Science Education, 25*, 1095-1110.

Tomas, L., Ritchie, S. M., & Tones, M. (submitted). Attitudinal impact of hybridized writing about a socio-scientific issue. *Journal of Research in Science Teaching*.

Turner, J. H. (2007). *Human emotions: A sociological theory*. New York: Routledge.

Tytler, R. (2007). Re-imagining science education: Engaging students in science for Australia's future. Australian Council for Educational Research. Retrieved 20 July, 2007 from: http://www.acer.edu.au/documents/AER51_ReimaginingSciEdu.pdf

Vygotsky, L. (1962). *Thought and language*. Cambridge MA: MIT Press.

Watson, D., Clark, L.A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology, 54*(6), 1063-1070.

Wellington, J., & Osborne, J. (2001). *Language and literacy in science education*. Buckingham: Open University Press.

Zeidler, D., Osborne, J., Erduran, S., Simon, S., & Monk, M. (2003). The role of argument

during discourse about socio-scientific issues. In D. L. Zeidler (Ed.), *Science & Technology Education Library, Vol. 19, The role of moral reasoning on socio-scientific issues and discourse in science education* (pp. 97-116). Dordrecht: Kluwer Academic Publishers.

Zeidler, D. L., Sadler, T. D., Applebaum, S., & Callahan, B. E. (2009). Advancing reflective judgment through socio-scientific issues. *Journal of Research in Science Teaching, 46*(1), 74-101.

Zeidler, D. L., & Schafer, L. E. (1984). Identifying mediating factors of moral reasoning in science education. *Journal of Research in Science Teaching, 21*(1), 1-15.