EMOTIONALLY INTENSE SCIENCE ACTIVITIES

Abstract

Science activities that evoke positive emotional responses make a difference to students' emotional experience of science. In this study, we explored 8th Grade students' discrete emotions expressed during science activities in a unit on Energy. Multiple data sources including classroom videos, interviews and emotion diaries completed at the end of each lesson were analyzed to identify individual student's emotions. Results from two representative students are presented as case studies. Using a theoretical perspective drawn from theories of emotions founded in sociology, two assertions emerged. Firstly, during the demonstration activity students experienced the emotions of wonder and surprise; secondly, during a laboratory activity students experienced the intense positive emotions of happiness/joy. Characteristics of these activities that contributed to students' positive experiences are highlighted. The study found that choosing activities that evoked strong positive emotional experiences, focused students' attention on the phenomenon they were learning, and the activities were recalled positively. Furthermore, such positive experiences may contribute to students' interest and engagement in science and longer-term memorability. Finally, implications for science teachers and pre-service teacher education are suggested.

Keywords: Emotions; Middle school science; Science activities; Demonstrations; Laboratory work; Emotion diary; Sociology of emotion

Introduction

> Science is conducted and learned with the full range of emotions present in all human pursuits, including joy, wonder, amazement, surprise as well as anxiety, anger, fear and hopelessness (Sinatra, Broughton, & Lombardi, 2014, p. 415).

The pursuit of science affords opportunities for research scientists to experience the full range of emotions described above, yet there is limited classroom research available to inform teachers about the range of students' emotional experiences or how they should respond to their students' emotional arousal. The impact on students' interest in science and subsequent choice of science in the senior years (Lyons, 2006; Tytler, 2007) is another important focus of classroom research.

In the past, science education research has focussed on conceptual understanding without reference to the role of emotions. Such an omission has meant that student emotions, which influence how they react to learning experiences, have been under-researched (Alsop & Watts, 2003). In fact, between the years 2001-2011, less than 10% of the articles published in the three top science education journals have dealt with emotional perspectives on teaching and learning science (Fortus, 2014). Importantly, students' emotions are now understood to be a central part of learning (Alsop & Watts, 2003) and engagement (Milne & Otieno, 2007) in science. More recently, studies on emotions in science education have focussed on three areas; firstly, the emotional climate (or collective shared feelings) of a pre-service teacher education class and a year 7 class (e.g., Bellocchi et al., 2014; Tobin, Ritchie, Oakley, Mergard, & Hudson, 2013) secondly; teachers' emotions during the implementation of senior science inquiry tasks (e.g., Ritchie et al., 2013) and thirdly, emotional expressions of students in science classes (Ritchie, Tobin, Hudson, Roth, & Mergard, 2011; Roth, Ritchie, Hudson, & Mergard, 2011; Tomas & Ritchie, 2012). The first two studies contributed understandings about practices that produced high quality experiences for pre-service teachers as well as practices that produced both high and low emotional climate in a year 7 class. The second study revealed emotional states experienced by senior science teachers when supervising Extended Experimental Investigations (or open-inquiry investigations). The third set of studies used students' emotional expressions to identify positive classroom transactions in science classes. Additionally, research on emotions includes studies on the emotional complexities, challenges and tensions associated with teaching (Intrator, 2006; Zembylas, 2002, 2004); the differences in positive and negative emotions experienced by male and female science teachers (Borrachero, Brigido, Mellado, Costillo, & Mellado, 2014); the importance of emotional labour in science teaching (Zembylas, 2003); the importance of emotions, feelings and moods in science classroom interactions (Flávia, Teixeira, & Mortimer, 2010); and the emotion of joy as related to the learning process in physics (Laukenmann, Bleicher, Fuβ, Gläser-Zikkuda, Mayring, & von Rhöneck, 2013). Such research is new and developing, however, previous research does not examine students' discrete emotions during specific science activities. We need further studies in middle school classrooms to find out what amazes and delights students, what causes happiness and joy, and the nature of the activities that contribute to these positive emotions. While we know that positive emotions have been associated with student learning (Schutz & Pekrun, 2007), we do not know much about the science activities that evoke specific emotions and the impact on students' memory of the experience.

Initially, one broad question guided our study: What types of classroom activities evoke positive emotions in students? As the study evolved revealing further information through meso and micro-analyses, two more focussed questions emerged:

1. What were the positive emotions experienced by the students?
2. What were the characteristics of the activities that contributed to students' positive emotions?

Furthermore, the teacher's responses to the expressed emotions are revealed providing further insights into the classroom interactions that elicited strong emotions in middle years students.

A Theoretical Perspective on students' discrete emotions

Defining emotions and measuring them in a meaningful way has been a constant challenge for emotion researchers in both social and behavioural sciences (Scherer, 2005). In fact, defining emotions remains "elusive" and sociologists have used a variety of terms interchangeably to denote a specific affective state such as feeling, mood, sentiment, expressiveness, and emotion (Turner, 2007, p. 1). For this study, we accept Turner's (2007) position that only through "outlining the varieties and types of emotions that are aroused among humans" can we gain a better understanding of emotion and develop insights into what leads people to "think and act in particular ways" (p. 2).

Research on emotions in education is important because neuroscience research has highlighted connections between cognition and emotion:

> [t]he neurobiological evidence suggests that the aspects of cognition that we recruit most heavily in schools, namely learning attention, memory, decision making and social functioning are both profoundly affected by and subsumed within the processes of emotion. (Immordino-Yang & Damasio, 2007, p. 3)

Finding connections between students' emotions and the aspects of cognition suggested above needs "to evolve over the next years in ways benefiting education and society" (Pekrun & Schutz, 2011, p. 314). Gooty, Gavin and Ashkanasy (2009) reinforce this notion by stating "examining discrete emotions is not just a fruitful avenue for research but also quite necessary" (p. 835). The research is necessary if we are to understand how emotions contribute to students' memory of the event – an important aspect of cognition (Immordino-Yang & Damasio, 2007).

Turner's (2009) sociological theory of emotions is founded on the premise that the dynamics of specific emotions and the social organization that causes the arousal of discrete emotions are important in theorizing about human emotions. He explains there are sociocultural conditions that generate intense emotions, for example a student may experience surprise while viewing a science demonstration that impacts on other students in the class causing a ripple effect of emotional expressions. The social and cultural environment of the classroom affects the dynamics of face-to-face encounters and the larger social structures in which students' emotional expression occurs. Turner asserts that understanding the sociocultural origin of discrete emotions may afford knowledge about how these emotions affect the micro- (e.g., in face-to-face interactions), meso- (e.g., classroom procedures) and macro- (e.g., school policy) levels of social reality.

Emotions can be aroused in humans at varying levels of intensity from low- through medium- to high- intensity states. Often emotion researchers categorize the emotions into two valenced states; that is, positive and negative (see e.g., Stets, 2010). Consequently, happiness would be valenced as positive whereas fear and anger would be negative (Turner, 2002). Using valence to identify emotions is too broad for understanding the emotions expressed by students in classrooms. Therefore, we have chosen to identify students' discrete emotions (e.g., happiness, surprise). Gooty et al. (2009) explained that this is necessary because if all negative (or positive) discrete emotions were considered the same, we may lose sight of "the fact that different processes drive each of them, and that different outcomes can result from them too" (p. 835).

Most researchers agree on four primary emotions that all humans experience: anger, fear sadness and happiness (Turner, 2009). Other emotions that are often included as primary are disgust and surprise while shame and guilt can be found on several lists too (see e.g., Emde, 1980; Izard, 1977, 1992). Turner (2007) argues that at some point in human evolution, our ancestors' neuroanatomy was naturally selected to favour humans' capacity to combine emotions. Based on the work by Plutchik (1962, 1980) who originally conceptualized how to "mix" emotions to produce new emotions, Turner (2007) refers to the mixing of emotions as "elaborations." (p. 3). He explains how different amounts of primary emotions mix together "in some unknown neurological way" to create "first-order" elaborations of primary emotions (p. 7). For example, the emotion of wonder could be "a greater amount of satisfaction-happiness combined with a lesser amount of aversion-fear" (Turner, 2007, p. 8). Other emotions like "interest, anticipation, curiosity, boredom, and expectancy" are less likely to be primary emotions and may be "cognitive states" (Turner, 2007, p. 3).

A recent study by Hadzigeorgiou (2012) explored how to evoke a sense of wonder in 9th Grade science students. He distilled from a large body of literature three categories that formed a theoretical framework for identifying "students' experience of wonder in their learning process" (p. 993). Firstly, he acknowledged the aesthetic and emotional dimensions of surprise, astonishment and admiration as characteristics of wonder. Drawing on the work of Burke (1990) he explained astonishment as "the mind so entirely filled with its object that it cannot entertain any other" (p. 53). Accordingly, students may experience wonder when they express surprise and astonishment in science about a phenomenon. Secondly, Hadzigeorgiou suggested there was a cognitive component necessary for the arousal of a wonderous mood, which he described as an awareness or conscious learning "that makes something usual and ordinary to be seen as unusual and extraordinary" (p. 989). Students who demonstrate an awareness of the beauty of natural phenomena, or an awareness that some phenomena exist or that their knowledge is incomplete, demonstrate this characteristic of wonder. Thirdly, for wonder to be experienced there is a change in outlook or perspective. By experiencing wonder, students see the phenomenon differently. This could be evident during an activity where science explanations create a new way for students to view the phenomenon being taught (e.g., air pressure). Essentially, emotions are "relatively short-lived" in contrast to low-intensity moods, which "have little impact on behaviour" and can be "maintained for much longer periods of time without showing adverse effects" (Scherer, 2005, p. 702). We acknowledge that emotions can vary over time; for example, what may begin as wonder for a student may change to surprise and amazement when the outcome of the science activity is contrary to what was expected. However, Hadzigreogiou's categories are useful for identifying a wonderous mood that may follow a student's intense emotional experience of surprise or wonder.

Activities in Science

As students move from elementary to high school, their attitude to science becomes less positive with many choosing not to continue science beyond the compulsory years of schooling (Abrahams, 2007; Goodrum, Druhan, & Abbs, 2012; Haste, 2004; Logan & Skamp, 2008; Lyons & Quinn, 2010; Masters, 2006; Speering & Rennie, 1996). This decline in interest is of concern since students' decisions about the pursuit of science subjects and careers are forming in the middle years (Lyons & Quinn, 2010; Speering & Rennie, 1996). While many initiatives have been tried (e.g., context-based science, project-based science, problem-based learning) to engage students in science, recent research has shown that it is the type of activity that is important for maintaining students' interest in science rather than the content topic or learning goal (Swarat, Ortony, & Revelle, 2012). Such research highlights "the role of activity in constructing interesting learning environments" and the importance of choosing activities students regard as highly interesting such as laboratory work, experiments or project work (Swarat, et al., 2012, p. 515). Two types of activities uniquely associated with science lessons are laboratory work and demonstrations. These activities offer structures in which to investigate students' discrete emotions.

Laboratory Activities

Past research has shown that despite laboratory activities being regarded as an important and necessary part of science education, students often fail to recall the experiment accurately or understand the relationship between the purpose of the investigation and the design of the experiment (Abrahams & Millars, 2008). Previous studies have highlighted the lack of intellectual development, inquiry, problem-solving skills or opportunities to construct knowledge of phenomena and related scientific concepts through laboratory activities (Hofstein & Lunetta, 2004; Tobin, 1990). Furthermore, students struggle to make the connections between the experiment and previous learning and they are unable to link their observations with ideas (Hofstein & Lunetta, 2004). Also, students cannot see the discrepancies between their own concepts, the concepts of their peers and those of the scientific community (Millar, 2004; Tasker, 1981; Tobin, 1990). While practical work engages students in the short-term, students do not sustain this interest to study science past the compulsory years (Abrahams, 2007).

The impact of laboratory work on student learning depends on a variety of contextual factors; for example, a study by Randler and Hulde (2007) showed that students demonstrated a better retention of science ideas when a learner-centered approach was adopted for experiments in soil ecology rather than a teacher-centered approach. Also, by articulating clearly the "purpose" of the experiment, achievement of that purpose was more likely (Hart, Mulhall, Berry, Loughran, & Gunstone, 2000). Furthermore, practical work can increase students' motivation and sense of ownership of their learning (Johnstone & Al-Shuaili, 2001). Despite research indicating the strengths and weaknesses of laboratory work, these studies do not address the "effect of affect" in laboratory work (Alsop, 2005, p. 3) or unpack at the meso and micro-level, the characteristics of laboratory work that contribute to students' emotions.

Demonstrations

Demonstrations are used in science to focus attention on a natural phenomenon (such as air pressure) for the purpose of stimulating inquiry. As a visual aid, they help students in the process of concept formation or as an example of the application of a principle (Eccles, 1963). Implementation in the classroom usually involves the teacher or a student conducting the science demonstration while the whole class observes what happens (Milne & Otieno, 2007). One type of demonstration, known as a "Discrepant Event" encourages cognitive dissonance for students when the outcome is "contrary to what the learner expects" (Liem, 1987, p. xxxiv). The unexpected outcomes may generate interest and lead to scientific explanations that are constructed between the teacher and students for the observed phenomenon.

While there have been past criticisms of the value of demonstrations as a pedagogical tool in science classrooms (see e.g., Roth, McRobbie, Lucas, & Boutonné, 1997; Shepardson, Moje, & Kennard-McClelland, 1994), recent research has found that demonstrations have a positive effect on students' engagement, emotional energy and their learning of science. A study by Milne and Otieno (2007) applied the sociology of emotions to the analysis of classroom conversations and actions during demonstrations, showing that demonstrations elicited greater student engagement and positive emotional energy, more sophisticated use of the symbols associated with chemistry and a willingness from students to move between describing the phenomena and submicroscopic explanations. Another study by Buncick, Betts and Horgan (2001) found that physics demonstrations could be used to introduce concepts that connect different sections of the introductory physics course together. Furthermore, Beasley (1982) found that students' attention and task involvement increased during demonstration lesson segments.

Few studies (e.g., Bellocchi & Ritchie, 2015) have examined students' discrete in-the-moment emotions experienced during demonstration activities. One recent study by Researcher 1 and Bellocchi and Ritchie (2015) focused on the two specific emotions of pride and triumph as experienced by students during classroom interactions. The importance of extending this work for a sharper focus on emotional arousal during particular activity types is necessary because "[i]ndividuals often remember more emotional events than nonemotional ones" (Kensinger & Schacter, 2010, p. 602). Furthermore, these events are more likely to be remembered with detail (Kensinger & Schacter, 2010). Immordino-Yang & Damsio (2007) argue that emotions strongly affect students' memory of what they have learnt, with memory being an important component of cognition.

Identifying emotions in Grade 8 students: Methods

In this single case study design (Stake, 2006) we were immersed in a Grade 8 science class for a 10-week period when they learnt about Energy. Ethnographic data were collected including videos, interviews, field notes and students' emotion diaries[1] completed at the end of each lesson. We selected the lessons as identified by the students' emotion diaries initially where there was a peak in interest as recorded by students. In such a way, the interest rating (included as a scale at the bottom of the emotion diary) was used as a heuristic to identify the lessons in which students may have expressed intense emotions. Furthermore, we were alerted to the lessons where a large percentage of positive emotions and comments were recorded on the emotion diaries. These lessons were chosen because the multiple data sources indicated that they stood out as including emotionally intensive activities more than the other lessons during the 10-week term (see Appendix 2). Following this, we used video analysis, ethnographic field notes and student interviews to determine students' discrete in-the-moment emotions during those lessons. The analytical techniques are described in more detail below, and are separated into meso-level (i.e., observation, interview, emotion diaries) and micro-level (i.e., prosody analysis, analysis of facial expressions and use of emotive words). Firstly, we discuss how students identified and recorded their emotions in the emotion diaries. [1]

Prior to beginning the study, the first author worked with the students in a 50-minute interactive workshop assisting students to identify their emotions. She gave a detailed explanation of each emotion drawing on real-world examples to situate the expressed emotion in a context; e.g., "frustration may occur when there is interference with your activity or you are unable to complete the task you are working on". She explained the physiological reaction that may occur when experiencing an emotion; that is, you can recognise an emotion when you experience a particular feeling or a bodily change such as a change in your heart rate or breathing. After the explanation, students were given a practice emotion diary to complete for the preceding lesson, and the researcher addressed questions during this time. A whole-class discussion followed where various students volunteered to share their emotions as recorded in the diary. The first author responded to the students' examples elaborating with suggestions for scenarios that may evoke the specific emotion or challenging students to reflect on whether they had recorded the correct emotion. In such a way, we were confident that students could discern accurately which emotion label/s they were assigning to their experiences, when it occurred, and what may have triggered the emotion/s. These emotion diaries were the starting point for our analysis.

Meso-level analyses

Initially, students' emotion diaries were analysed for evidence of lessons of high interest as well as the discrete emotions connected to specific activities. Based on Turner's work, we included 10 discrete emotions that were agreed by a panel of researchers as the most salient to include on an emotion diary for students. They included happiness/joy, sadness/disappointment, anger/irritation, anxiety, disgust, pride, wonder, enthusiasm, frustration, and embarrassment. Next to each emotion was an emoticon (face showing the emotion). Students identified the classroom circumstances that evoked the arousal of this emotion through instructions that read

[1] The emotion diary, adapted from Zembylas's (2002) diary, is a template given to students at the end of each lesson for them to record their emotions during the lesson. Ten emotions were listed on the template happiness/joy, sadness/disappointment, anger/irritation, anxiety, disgust, pride, wonder, enthusiasm, frustration, and embarrassment.

"please say, in your own words, **what you were doing, what happened when you experienced the emotion**, and **at what or whom** the emotion was directed". Since Turner (2009) classified interest and boredom as "cognitive states" rather than emotions, there was a scale added at the bottom of the page for students to rate their interest level in each lesson on a scale from 1 (very bored) to 10 (very interested).

The novelty of completing the emotion diaries declined as the term progressed causing students to record a smaller number of emotions experienced during the activities. However, the emotion dairies were very useful for this research since students identified lessons of high interest as well as episodes within lessons that evoked strong discrete emotional responses to activities. When the lessons that corresponded to high interest were identified through the diaries, we replayed the video recordings to find the relevant episodes where students expressed intense emotions. Selected episodes were analysed at the intermediate (meso) level through observations of students' expressed emotions and interactions. These salient episodes were transcribed and analysed at the micro-level (see below). When the researchers were convinced through the triangulation of data, of the students' expressed emotion, case study students were interviewed and relevant excerpts were replayed for their interpretation. Furthermore, in-class interviews were conducted during the lessons and captured on video cameras, which contributed to the body of evidence. Even though many researchers are satisfied with the broad grain size and high levels of inference required for meso-level analysis, we were intent on using finer-grained techniques (i.e., micro-level analysis) to reduce the level of inference as much as possible to complement our more interpretive analysis (see Tobin & Ritchie, 2011).

Micro-level analyses

Since body movement and facial expressions play an important role in emotion communication (Dael, Mortillaro, & Scherer, 2012), micro-analytical techniques were used to determine students' facial expressions using Ekman and Friesen's (2003) Facial Action Coding System (FACS), and body movements and gestures (see Harrigan, Rosenthal, & Scherer, 2008). Frame-by-frame analysis occurred of students' facial images, gestures and body movements. For example, to confirm the emotion of happiness as recorded in students' diaries, we looked for one aspect of the facial expression where "the corners of the lips were drawn back and slightly up" (Ekman & Friesen, 2003, p. 103) as well as their conversations and gestures before, during and after the expressed emotions. The combination of face and context in emotion judgments is important (Ekman, Friesen, & Ellsworth, 1972). Transcripts were made of the interactions, and where relevant, tone of voice and pauses were measured. When there was an obvious change in a student's vocal expression or emotion we used prosody analysis on the voice sound track using PRAAT software (http://www.praat.org) (Dael, et al., 2012). Prosody analysis allowed us to measure the pitch ($F_{0,}$ in Hertz [Hz]) or the extent to which the sound or tone was high or low. In particular, we looked at the increase in F_0 that aligns with the emotion of elated joy (see e.g., Scherer, 2003; Harrigan et al., 2008) to confirm students' expression of happiness/joy. The conventions of conversation analysis (Roth & Hsu, 2010) were applied to the transcriptions (see Table 1). Facial expressions, gestures, body movements and actions of the group were noted alongside the related turns of speech. Tentative assertions were formed based on this analysis that were confirmed or disconfirmed with further micro-level analysis of facial and vocal expressions. Furthermore, both the FACS and prosody analysis were used to reinforce or triangulate the discrete emotions identified from the multiple methods employed. From this analysis of 29 lessons and 12 different activities, two activities stood out where students consistently recorded the positive discrete emotion of "happiness/joy" – i.e., laboratory work and demonstrations. Further analysis revealed other positive emotions such as "surprise" and "wonder."

Insert Table One here

Context: The school, the science unit and the two students

The school was situated in an inner city suburb of Brisbane, Australia, with a total of 1150 students from Grades 8 to 12. The students came from broad socio-economic backgrounds with 15% of students from non-English speaking backgrounds. The Grade 8 science class consisted of 17 boys and 11 girls and students typically were aged between 12-13 years. The class was chosen for the study because the teacher was willing to be involved. The timetabling within the school resulted in all students in the class studying advanced mathematics hence predominantly they were strong academic performers. Parents or guardians for all students in the study signed ethical permission forms that allowed video and audio recordings, interviews and the collection of data relevant to the study. The University through which the study was conducted granted ethics approval.

The context for this science unit was Coal Seam Gas as an alternative energy source. Such a topical socioscientific issue of national debate in Australia, afforded opportunities for connections between classroom science and the real-world. The unit explored concepts related to energy such as energy transfer and transformation, measurement of energy as well as current issues of alternative energy sources. The unit consisted of 29 lessons that were approximately 50 minutes long, which included a variety of activities such as computer-based lessons where students researched the impact of Coal Seam Gas mining on farming communities in Queensland, teacher-led lessons where students discussed issues and concepts that were summarised on a power-point, video lessons as well as outdoor activities and laboratory activities (see Appendix 2 for a full summary). Other relevant concepts discussed for students' understanding of methane gas specifically, and gases more generally, were the properties of gases (e.g., pressure) and types of gases.

The research presented focuses on two students, a male student Ashley and a female student Jackie. Ashley was drawn to the attention of the researchers early in the study for three different reasons. Firstly, on a closer examination of his emotion diaries he rarely recorded positive discrete emotions with 6 out of 8 written entries in the first three weeks referring to science lessons as "no fun" or "boring" or "we had to write." Secondly, he overtly displayed a positive emotion by clapping his hands in the second lesson while researching information on the computer because he had "found what coal seam gas was" (Interview). Thirdly, such contrasting information caused us to initially ask the teacher about his behaviour in science lessons and the teacher replied:

> T: [ ], disruptive, disengaged and he gets distracted easily and he is the one that you have to drive to be on task and if there was something [that] could distract him or he could do, to not to be on task he would do it (Interview).

Once Ashley had been identified as a case study, his interactions in class were scrutinised. From our meso observations and moment-to-moment analysis of 29 science lessons, using 2-3 cameras and 1-2 audio recorders, Ashley rarely volunteered answers in class or participated when the teacher was directing the lesson. We decided that focussing on Ashley's discrete emotions in science lessons might provide information about emotional arousal for students who are disengaging from science.

In contrast to Ashley, Jackie was a capable student who worked hard to achieve good results in science. The teacher regarded her as an "A" student in the previous term's work (unlike Ashley who was described as a "B" or "C" student) (personal correspondence). She stood out early in the research project for the following three reasons; firstly, she recorded positive emotions in the emotion diary with 7 out of 9 positive written entries in the first three weeks such as "[science is] my favourite subject", "a fun lesson" or "I found it [the science lesson] very interesting;" secondly, she displayed emotions through her gestures and facial expressions frequently in class; and thirdly, despite being a good student in science, her participation varied. In lessons she recalled as "fun", she participated with enthusiasm; however, in other lessons she described disinterest: "I hate listening to the teachers I really zone out" (Interview). We decided that the selection of Jackie as a case study would add breadth to the range of emotional experiences studied.

In addition to presenting the two case studies, we began by inspecting the peaks and troughs in interest for the entire class through a graphical representation of the interest data (see Appendix 1 and 2). While a full analysis of this graph is beyond the scope of this paper, this preliminary analysis provided a picture of the variation in interest across lessons. This was used as a heuristic for identifying lessons in which students may have expressed intensive emotions rather than a definitive assessment of students' perceptions of their situational interest. Video recordings of lessons that were of high interest were viewed initially followed by inspection of contrasting data from lessons with similar activities that attracted lower student interest. A brief description of all lessons is in Appendix 2.

We use the two cases to reveal how the emotions were aroused in the class during the demonstration lesson and laboratory activity. Following this, we present whole-class data for the same activity. We argue that the positive emotions associated with the episodes experienced during the activities, contributed to students' memory of them. We are not discounting negative emotions as also being remembered (Baumeister & Bratslavsky, 2001) however on balance, it is better for students to experience more positive emotions than bad for a longer term positive association with science learning. We return to negative emotions in the discussion section of the paper.

Results

Assertion One: During the demonstration activity students experienced the emotions of wonder and surprise

Students recorded the "egg in the bottle" activity as the most interesting in the emotion diaries. In fact, out of 29 lessons in this unit, the "egg in the bottle" demonstration scored the highest average interest rating of 8.39 (see Appendix 1) compared with lessons such as lecture-style lessons with power points (5.25) and computer room activities (6.75). Ashley's comment in the emotion diary for this demonstration activity was "it was interesting" representing one of six positive comments from the whole term. Furthermore, Jackie recalled being "really curious" about the "egg in the bottle" demonstration (Interview). Jackie and Ashley's verbal and written comments coupled with our ethnographic observations, diary analysis and extensive video analysis, highlighted the importance of more closely analysing this activity where students' interest peaked.

The Demonstration

The teacher conducted the demonstration outside the classroom on a table. When the teacher began, Ashley moved forward in close proximity to the science equipment communicating preparedness to watch the demonstration. The teacher lit a strip of paper and placed it in the conical flask and put the egg on top. By doing this he afforded students the opportunity to observe the effects of differential pressure without any prior explanation of what might happen. The following excerpt highlights the variety of emotions experienced by the students. Yet, the most intense emotion experienced by Jackie and Ashley was surprise:

Excerpt 1 – Jackie and Ashley's surprise

01	S1	It's gonna burst
02	Ashley	O:::::: ((His F_0 rising from 190 to 600 Hz while staring at the egg))
03	Tom	What the
04	S2	ew that's /?/
05	Jackie	ew[www ((runs towards the table and squats down in close proximity to the demonstration))
06	Ss	[Aauuhahhh ((a number of students screaming))
07	S2	What the hell
08	S3	ew that's disgusting (from far)
09	Teacher	A:::nd (as the egg begins to enter the flask)
10	Ashley	((bends forward towards the flask while smiling))
11	Jackie	Eww eww that's disgusting ((her upper lip raised and slightly forward))
((Now the egg is being elongated as it is falling inside the flask))		
12	Jackie	Aauh ((she utters as soon as the egg "plopped" into the flask covering her wide open mouth and running away screaming for 3.2 seconds))
13	Michael	sir you didn't explain before you did it? Now I'm excited

Jackie's surprise in the demonstration was evident after she ran to the table in turn 05 to be closer to the demonstration. As the egg was forced into the flask in turns 09-12 she said "eww..that's disgusting" while her upper lip was raised and slightly forward indicative of the emotion of slight disgust (Ekman & Friesen, 2003, p. 71). However, once the egg "plopped" into the flask (turn 12) her jaw dropped, she placed her hand over her mouth screaming "Aauuh" (see Figure 1) for 3.2 seconds, she turned and ran away from the table. At this moment, her facial expressions changed showing the emotion of amazed surprise as defined by Ekman and Friesen (2003) indicating that Jackie was surprised the egg went into the flask. Her initial reaction of disgust had blended with surprise evident in her "getting-away-from" response (Ekman & Friesen, 2003, p. 66). Furthermore, identification of Jackie's surprise was verified in a follow-up interview when she said:

> Also when you learn something new [it] is fun, like I know that egg experience, like when we were learning I know it's pressure and I was like "oh pressure" and I hate I don't like pressure stuff and then we just because the teacher did egg stuff I was amazed at it and then I learnt more about it and made me more interested. (Jackie, Interview)

Not only was she "amazed" at the demonstration but she recalled the phenomenon of pressure as an aspect of the demonstration. Scherer (2005) confirms that amazement is implied when referring to the emotion of surprise. Hence, Jackie's use of the word "amazed" can be used to describe the emotion of surprise.

Insert Figure One here

Ashley was emotional during this episode too. His surprise was evident initially from his utterance "ooo.." with the fundamental frequency (F_0) rising from 190 to 600 Hz (turn 02). From this point onwards his mouth was slightly open (turn 02) which changed to a smile (turn 10). His jaw was dropped and at the same time the corners of his lips were drawn back showing a "happy/surprised" expression (Ekman & Friesen, 1975). While other students' utterances suggested surprise such as, "what the" (turn 03) and "what the hell" (turn 07) and "Aauh" (turn 6), the camera was not zoomed in sufficiently to identify their facial expressions. Of the six students that can be seen on the camera, four have facial expressions similar to Ashley showing the "happy/surprise" expression and the remaining two are smiling. At the end of the demonstration the teacher held up the conical flask and said "come and check it out it is not even the same shape anymore." The students who were sitting under the tree stood up and moved towards the table calling out comments such as: "that's awesome" "look at that" or asking question after question: "sir, do you have to take the shell off" "how you gonna take the egg out?" Clearly, students' interest in the phenomenon was aroused after this first attempt. In particular, Jackie and Ashley were showing positive emotions indicative of students who were enjoying the experience. Many students in the class experienced positive emotions during the "egg in the bottle" demonstration with 20 out of 24 students (who completed the emotion diary) ticking the "happy" emotion with a written explanation. One representative written comment explaining the cause of the emotion was "when we did the experiment about pressure."

In a follow-up interview Jackie was asked to explain the emotions she experienced during the demonstration and she replied "wonder would be one." When asked "what do you mean by wonder?" she said:

> just how, actually I know now, but then I didn't know how the egg the bottle [sucked] the egg and that was all like really I was really curious how that worked and I was a little bit of disgust because like it was disgusting and there was also joy 'cause it was fun. (Follow-up Interview)

In this interview excerpt, Jackie recalled wonder and a curiosity about the demonstration. This was confirmed through Jackie's facial expressions and utterances as evidenced in the vignette, along with her interview comments, suggesting she was experiencing the emotion of wonder. Furthermore, applying Hadzigeorgiou's (2012) framework for the presence of a wondrous mood rather than an emotional state, three pieces of evidence reinforce our attribution of wonder to Jackie's actions. Firstly, she was surprised when the egg went into the bottle; secondly, her comments indicated that the demonstration led to an awareness of the phenomenon; and thirdly, she described a change in her outlook by the comment "I know now, but I didn't know."

Jackie was not the only student who experienced wonder during the demonstration. Five other students ticked "wonder" in the emotion diaries with the following sample comments: "what we were learning", "how it worked" and "what happened to the egg." Interestingly, Jackie could recall the activity positively in two follow-up interviews, three weeks and five months after the activity. The "egg in the bottle" activity not only evoked a sense of wonder for students but was a memorable classroom event. We claim that for students to experience surprise and wonder, the choice of activity is important.

There were three characteristics that possibly contributed to students' wondrous response. Firstly, the students were exposed to the demonstration without any prior explanation of what might happen enabling the "surprise" experience. Secondly, the natural or spontaneous fluid conversations (Bellocchi, Ritchie, Tobin, Sandhu, & Sandhu, 2013) that flowed during the demonstration allowed emotive utterances to be shared contributing to the build-up of a positive atmosphere. Thirdly, the emotions generated under these sociocultural conditions may have contributed to the teacher's pedagogical response, which was to prolong the positive experience with a repeat demonstration (Turner, 2007). In such a way, the teacher made in-the-moment pedagogical decisions that afforded students the opportunity to see the demonstration again while highlighting the science concepts.

After the "egg in the bottle" demonstration, the teacher continued a 2:02 minute question and answer session that explained the movement of the warm air out of the flask creating a pressure differential for the egg. In such a way, he focussed student attention on the particle theory related to the demonstration. We found three characteristics of the demonstration activity that contributed to students experiencing wonder: novelty, natural interactions, and the spontaneous pedagogical response of a repeat demonstration that focussed students' attention on the science concepts.

This demonstration was exceptional because we observed an occasion when the students were preparing for another outdoor activity led by the teacher that did not elicit such positive emotions. The students were required to make a paper plane and fly it. The lesson was conducted at the end of the term to teach concepts such as air pressure and energy transformations during flight. From the moment-to-moment video analysis of students at the beginning of this lesson, there were many expressions of boredom with some students leaning their head on the desk, yawning and appearing to be disengaged with the activity. We identified this as an important episode because students displayed these negative emotions initially. Furthermore, the overall average interest of 7.40 was less than the previous "egg in the bottle" outdoor activity of 8.39. We conducted three focussed interviews five months after the activity with Jackie, Ashley and another student, Tony. We asked them, "do you remember what you learnt from that activity?" Jackie made the following insightful comment:

> Jackie: [I] don't think we learned anything from that lesson, it was just building an aeroplane and then flying it, which we can all do in our spare time and it was also windy so it wasn't fun because it didn't work as well. (Follow-up interview)

She further explained, "I don't even remember what the point of that aeroplane [activity] was," reinforcing an important outcome of Hart et al.'s (2000) research. On this occasion, Jackie entered an extra box for boredom in her emotion diary and wrote, "boring to listen to the teacher" suggesting Jackie's emotional experience of science was influenced by whether she was learning something new. Interestingly, all three students were unable to recall what they learnt or the relevance of the activity. In particular, Ashley said it was "boring at the start of it" because "we were just setting up the plane and stuff [and we] didn't have anything to do." When Tony was asked why the interest recorded on the emotion diary was lower for the class than the previous activity he said, "it's a paper plane I guess just a common thing that people do to paper as well, people have done ever since they are like year 2, so doing it at year 8 is like OK it's a paper plane, so what, yeah OK?"

Despite the video analysis revealing many students' lack of engagement during the indoor part of the activity, when they went outside to fly the planes, they appeared to be enjoying themselves and having fun. Interestingly, we found from the emotion diaries completed at the end of the lesson, a number of students reported the plane activity as "fun" because it was "a prac" or an "experiment" or it was fun "flying the planes." However, for Jackie and Ashley, the plane activity did not have any of the characteristics of thein the bottle" demonstration that made it so successful. It lacked the essential ingredients of suspense, surprise, wonder, newness, the unexpected and any relevant science discussion associated with explaining the discrepant event (Liem, 1987). Such a contradictory example supports our claim that for students to experience surprise and wonder, the choice of the activity is important as well as the salient characteristics described above.

Assertion Two: Laboratory activities where students experienced intense positive emotions were memorable

> I found it quite amazing how much energy was just in [a] banana chip, it's pretty (pause) impressive (student comment in follow-up interview).

This comment by a student expressed his "amazement" at the amount of energy in a banana chip calculated after students completed a laboratory activity where they burnt a banana chip. In fact, there were 23 out of 24 students who ticked the emotion of "happiness/joy" with 15 related positive comments in the emotion diaries for the banana chip experiment. The one student who did not tick "happiness/joy" was unhappy with receiving an assignment to complete for science, however, she still ticked "enthusiasm" and wrote the comment "for lighting a banana chip." Ashley recorded the emotion of "happiness/joy" and wrote the positive comment "fun lesson we got to make fire." This lesson was identified for closer scrutiny because 23/24 students rated it positively and the average interest level was very high.

The Experiment

As soon as group work began, Ashley went straight to the laboratory bench poised with matchbox and matchstick in hand while the other group members (Peter, Matthew, Monty and Jack) collected the laboratory equipment. All five group members were mutually focussed on the setting up of the apparatus demonstrating a positive approach from the outset. During the 6.16-second excerpt below, positive emotions were displayed frequently through the fluent conversations between Ashley and his group. Interestingly, Ashley was not only positively engaged in the activity, but also he took the lead on occasions, even correcting an "A" student when necessary. The following excerpt shows Ashley's positive emotions with the task and his leadership with the group.

The excerpt occurred 1 minute and 22 seconds into the group activity when Ashley began the preparation to light the banana chip.

Excerpt 3: Ashley's happiness, positive participation and leadership

01	Matthew	Clockwise mate, clockwise (referring to Jack tightening the retort stand)
02	Peter	Set it on fire
03	Monty	[<u>set it</u> whoo oo((raises match up to show group members))
04	Ashley	[Are you ready, now you can measure it]
05	Matthew	19 Degree (Celsius) ((measuring the temperature of the water with the thermometer – Others are recording the temperature, Ashley has match

		positioned on matchbox ready to light))
06	Ashley	Everyone:: stand ba:ck
07	Monty	19 Degree (Celsius) ((as he writes this in his worksheet))
08	Jack	You are got to strike it hard ((demonstrating with his arm actions how Ashley should light the match))
09	Peter	Set yourself on fire Ashley
10	Ashley	Yeah, I know ((strikes the match stick))
11	Monty	O'o'h [ski::ll]
12	Matthew	[oh that's good stuff]
13	Monty	I would laugh if it burned up
14	Peter	All of a sudden it combusts because /?/ ((All students observing Ashley lighting the match))
15	Ashley	Oo () I couldn't catch on fire () woo'a Je'ss ((fire gets bigger-giggle from group members))
16	Matthew	Put the thing out it's on fire
17	Ashley	Jesus
18	Monty	Oh oh
19	Matthew	It's on fire
20	Peter	Ashley is that supposed to happen? ((referring to the large fire))
21	Ashley	Yeah yeah, ((Peter leans forward to blow out the match and Ashley simultaneously smiles and leans in to blow out the match too))
22	Matthew	Here you go ((looking at the banana chip on fire))
23	Ashley	Hehe ((holding the match and looking, Peter blows it and it goes out. Ashley smells the match))

Ashley experienced happiness during this episode. He held a smile (see Figure 2) and his utterances demonstrated his enjoyment such as "oo, I couldn't catch on fire, woo'a Je'ss" in turn 15 and "Hehe" in turn 23. Furthermore, he led the group at times; for example, in turn 04 he told everyone to measure the temperature. At the 2:30 minute mark (turn 23), Ashley held the matchstick up for the group to see. Ashley's face at this instant was captured in Figure 2. The corners of his lips were drawn back and slightly up, the lips were parted and his mouth was open showing his teeth. He was showing naso-labial folds which were wrinkle lines running from the nose out and down the area beyond the corners of the mouth. These naso-labial folds are a characteristic of the happy facial expression. The Duchenne smile was pronounced since it had intensified the naso-labial folds raising Ashley's cheek. Also, the skin below the lower eyelid was pushed up lifting the cheek far enough to narrow the eyes. Based on such evidence, Ekman and his colleagues would propose that Ashley's cheek-raising smile was uniquely associated with enjoyment (Ekman, 2003; Ekman & Rosenberg, 2005).

Insert Figure Two here

The teacher afforded students the freedom to complete the experiment without close monitoring for the first 3:02 minutes during which the excerpt above occurred. Following this he visited the group three times to direct their attention to the scientific terminology (e.g., correct naming of the retort stand), scientific procedure (i.e., not to place the thermometer on the base of the test tube to record temperature) and the science calculation underpinning the activity. After the practical work was completed, the teacher asked Ashley's group to sit together to complete the worksheet that required the calculation of the Energy content of the banana chip based on the temperature increase in the water. The students collaborated helping each other because this was new work that had not been learnt before. Ashley demonstrated his ability to perform the calculation through the numerical calculation in his final submission (i.e., “77 x 42 = 2436 kJ”); and by explaining the calculation correctly in a follow-up interview when he said, “you got the amount of Celsius and then times it by 42 and that’s how much energy was in that banana chip.” Unfortunately, he used incorrect units in the calculation, which should have been Joules. This was one reason for his final grade of “B” assigned to this assessment task by the teacher. Furthermore, in this practical report he included legitimate reasons for scientific error such as “the banana chips were all different sizes so the energy varied” demonstrating an understanding of the scientific process.

On two occasions in follow-up interviews that occurred three weeks after the lesson and then five months after the lesson, Ashley recalled this experiment and the “egg in the bottle” demonstration as memorable science lessons. When asked why he remembered these lessons he said “because they were the most fun ones mm just seeing the result what happened to them.” Similarly, another 15 students referred to the “fun” aspect of the lesson and 16 students referred to the “fire.” A further 14 students ticked the emotion “enthusiasm” as well and 9 students wrote “for the prac” next to the tick. The banana chip laboratory activity scored the third highest interest score of 7.46 exceeded by the “egg in the bottle” and a siphon-constructing activity taught by a guest speaker. Unfortunately the camera was not focussed closely on Jackie’s group during the banana chip activity, however, she recalled this experiment as “fun” in a follow-up interview five months after the event and she completed the assessment task to an “A” standard.

Although Ashley claimed to enjoy the banana chip experiment, we observed one contrasting occasion when he did not participate positively in a laboratory activity. The class completed a closed-inquiry that required the mixing of 50 mL of methylated spirits with 50 mL of water to show the effect of the forces of attraction between molecules. Video analysis showed that in the introduction to this experiment the teacher spoke for 6.17 minutes with few teacher-student interactions. Ashley’s group was very noisy throughout the experiment and Ashley was in trouble for causing a stool to fall to the floor. The teacher instructed him to leave the group and work on his own. Unsurprisingly, Ashley’s emotion diary on this occasion had a tick in the “low” column for happiness/joy and “low” column for enthusiasm with the following written comments: “boring” and “no interesting event.” We identified three important differences between this activity and the banana chip activity: the relevance of the practical to the unit on “energy” was not explicit; all students observed the same result since it was a “closed” inquiry with one correct answer; and there was no “fun” or “risky” element like the banana chip experiment. For Ashley, a laboratory experiment that was “cookbook” such as the “metho in water” did not afford him the opportunity to experience emotions or engage him in the activity.

Summary and Discussion

Out of 29 science lessons, Ashley demonstrated the high intensity emotions of surprise and happiness/joy during two activities when his interest was heightened. The study shows that it was the type of activity and the way the activity was conducted that contributed to Ashley’s positive emotional arousal. Furthermore, the demonstration activity afforded Jackie the opportunity to wonder about the phenomenon of differential pressure, aroused strong positive emotions and her interest was heightened. Both students could recall the activities three weeks and five months after the event highlighting the importance of the choice of activity for producing intense positive emotional experiences and for longer-term memorability.

Whereas previous research has found that students engage positively with demonstrations (Milne & Otieno, 2007) and identified the learner-centred or hands-on component of laboratory activities as interesting (Holstermann, Grube, & Bögeholz, 2010; Randler & Hulde, 2007), we have extended this research by determining students' discrete emotions during these activities. We have shown that the choice of activity is important for producing the intense positive emotions of happiness/joy, wonder and surprise. In particular, we have found a link between students' heightened emotions and longer-term memorability of those activities. The link between emotions and memorability has not been investigated extensively before in science education. Furthermore, we have added to the work by Milne and Otiento (2007) and Olitsky (2007) by reporting students' discrete emotions of surprise, wonder and happiness/joy. Moreover, we have reported aspects of the teacher's pedagogical response to the expressed emotions highlighting the interactions between students' discrete emotions and the broader classroom context. Specifically, we have shown that in-the-moment pedagogical responses to the expressed emotions by the teacher were important for capitalising on the teaching and learning opportunity. For example, by repeating the demonstration the teacher could emphasise the particle theory as the explanation for the phenomenon of pressure. In the banana chip experiment, the teacher structured a connection to the energy calculation reinforcing for students the importance of the calculation for determining the energy content of the banana chip. Learning how to respond to students' heightened emotions and directing their attention to the science ideas may be a useful pursuit for classroom teachers and pre-service teachers alike.

Using Turner's position that "a sociological theory of emotions must explain how emotions are generated under sociocultural conditions operating at the micro-, meso-, and macro-level levels of social reality" (p. xi) we reason that if teachers are aware of the micro-level emotional responses of students like the teacher in this study, they can enact change at the meso-level creating further opportunities for learning and possibly longer-term memorability of the activity. By recognising students' emotional reactions through facial and vocal expressions of happiness/joy and wonder and surprise, they can respond with in-the-moment pedagogical choices that may afford a learning opportunity and contribute to longer-term retention of the activity. A limitation of this study is that it focussed on two case study students in one middle school science class. Further case study research is needed to examine if these heightened emotional experiences can enable students to recall the associated science ideas accurately. While the use of student emotion diaries may be too personal for students to share with their teacher, responding to students' expressed emotions with teacher-student conversations may reveal evidence of pedagogical approaches that engage or disengage students emotionally in science. Combining the multiple methods to assign the discrete emotions to students' expressions was a major strength of our study.

While these activities evoked positive emotions of high intensity, it is equally possible for students to experience intense negative emotions. Baumeister et al., (2001) reported that bad experiences or events have a greater impact on people than positive experiences across a range of psychological phenomena, however they concluded that "even though a bad event may have a stronger impact than a comparable good event, many lives can be happy by virtue of having far more good than bad events" (p. 362). For students to have a positive association with science, the positive and good interactions must outnumber the negative and bad (Baumeister et al., 2001). This paper shows two activities that afforded two case study students as well as many students in the class, the opportunity to experience positive emotions. We have emphasised the role of positive emotions in this study, because on balance it is better to be positive than negative for longer-term positive associations with science learning. We do not discount the importance of research on negative emotions in middle school science classrooms, which has begun. One recent study by Ritchie et al., (2015) showed that students could experience intense negative emotions such as disgust, and still be interested in the lesson topic. However, there is the need for more research to unpack at the micro-level how teacher-student interactions can contribute to students' transformation of negative emotions to more positive emotions and how this impacts on students' learning of science (see e.g., Bellocchi & Ritchie, 2015).

Turner's (2009) sociological lens emphasises the interplay between the dynamics of specific emotions and the sociocultural conditions that contribute to the expression of these emotions. Through this lens, we have identified students' positive emotions during specific classroom activities. We have used students' recall of their emotions as expressed in an emotion diary as well as their use of language, expressions, gestures, utterances to identify the discrete emotions of happiness/joy, surprise and wonder experienced during two science activities (Turner, 2007). To explain how such a lens informs our conclusions we return to one of Turner's 17 principles, 7B. In this principle, Turner explains that members of groups have "transactional needs" or "universal needs" that are sought during face-to-face interactions that can direct the flow of the interaction (p. 102). Including demonstrations and laboratory activities in science may afford opportunities for positive interactions in science and hence meet students' "transactional needs" such as enjoyment of and interest in the lesson as well as learning something new. This is especially relevant for students such as Ashley, who are beginning to turn-off science where frequent positive experiences may make science more appealing in the long-term. We are not advocating that every science lesson should be a demonstration or laboratory activity; however, we suggest that teachers and pre-service teachers can learn from this research and include activities that may evoke strong positive emotions, which are memorable for students and regarded as interesting. An application of this research for teachers may be when they are teaching difficult science concepts, the use of practicals and demonstrations may elicit positive emotions for students that help students recall complex concepts favourably.

Immordino-Yang and Damsio (2007) drew on earlier work of Damasio (1994) to explain that an emotional trigger such as the activity may cause a chain of physiological events that enables changes in both the mind and body such as "focussing of attention, calling up of relevant memories and learning the associations between events and their outcomes" (p. 7). These processes are important to science education. If frequent positive emotional experiences are occurring for students in science, and they remember them positively, then their perception of science may change. Internationally, this research will contribute to a better understanding of the activities that engage middle school students emotionally and are regarded as more interesting by students with a possible flow-on effect of greater participation in senior science subjects. After all, the continuing decline of students to study science and pursue scientific careers is an international concern (Osborne, Simon, & Collins, 2003).

Finally, at the macro-level, if schools encourage teachers to research their own practice and reflect on students' emotional responses through the use of tools such as emotion diaries and video analysis then pedagogical practices that capitalise on students' positive emotional responses could be sanctioned. School science syllabus documents that prioritise emotionally engaging activities, which are retrieved in thought by students as positive, are likely to be regarded as interesting and contribute to students' positive association with science (Turner, 2007).

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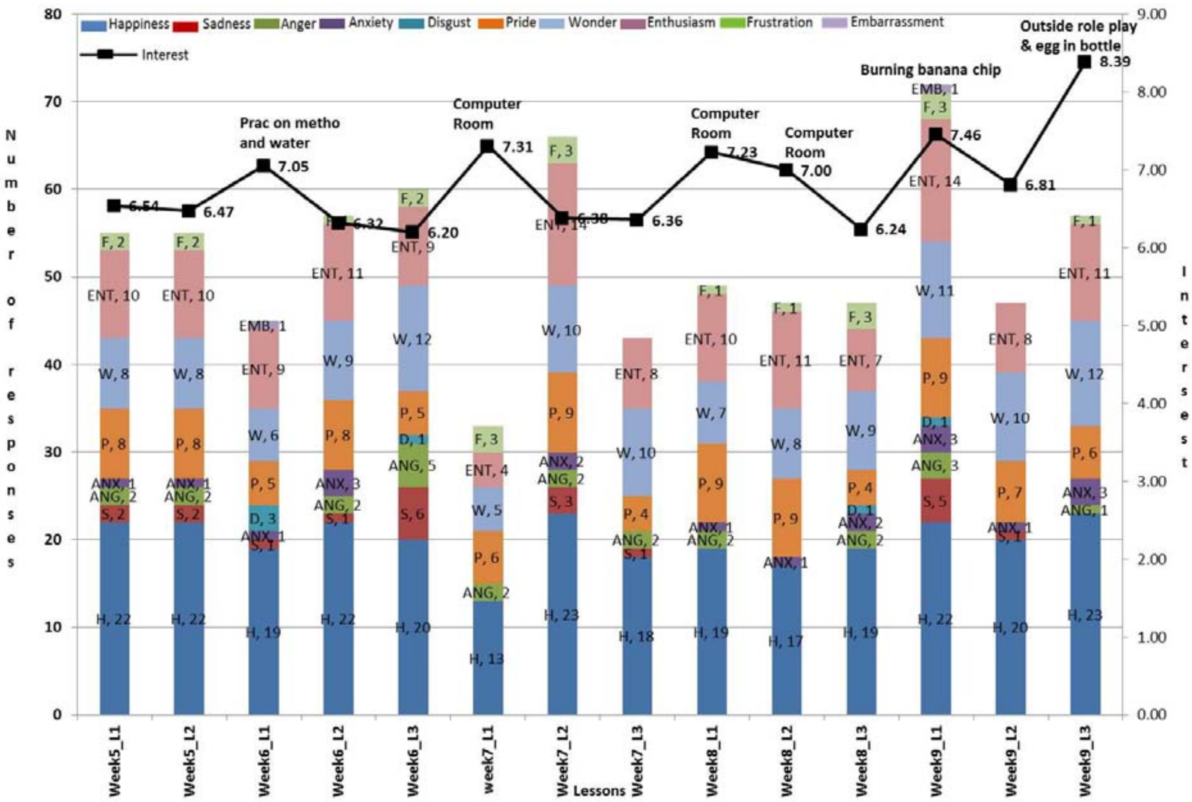
Appendix 1: *Graph of interest rating and emotions as recorded by students for Weeks 5-9*



Appendix 2: A brief description of the lessons in the unit: Micro-analysed lessons indicated

Lesson Number	**Description**	**Average Interest score as rated by students on a scale 1-10 on Emotion Diary (used for initial determination of lessons)**	**Activities that were analysed** (These activities were chosen because the multiple data sources indicated that they stood out as emotionally intensive activities more than any other lessons during the 10-week term)
1-Week 1/L1	Introduction to unit and videoos of CSG* mining. Carbon Dioxide gas production explained.	5.28	
2- Week 1/L2	Computer lesson researching CSG	6.57	Videos of the computer lab anlaysed + Audio recording : reveal positive emotion when students finding information about CSG. e.g. one student clapping when find out the meaning of CSG
3-Week 1/L3	Energy video viewed followed by general dicussion about energy	6.00	
4- Week 2/ L1	Teacher-led power-point (PPT) lesson with notes on types of energy (PE- Pontential Energy and KE – Kinetic Energy). Many tangential discussions on real-world links to energy such as energy-efficient cars. Roller-coaster picture used to explain changes in PE	4.86	

	and KE.		
5-Week 2/L2	Continued discussion on transer of energy (short lesson)	5.86	
6- Week 2/L3	Subsititute teacher – no recording but students completed the emotion diaries	4.64	
7- Week 2/L4	Biostory introduced as assessment task. Discussion about the story and the impact of CSG on farming communities.	6.29	
8- Week 3/L1	Teacher-led discussion with PPT on energy released during the burning of coal. Worksheet about using Biomass in Australia.	5.00	
9- Week 3/L2	Short class – Gala day	4.35	
10- Week 4/L1	Outdoor activity – throwing balls to determine changes in KE and PE	6.98	Videos of focus groups analysed + multiple data sources indicating emotionally intensive activity
11- Week 4/L2	Work on biostory in computer room	6.27	
12- Week 4/L3	Teacher-led discussion on assessment task plus videos on CSG and Energy followed by discussion.	6.74	
13- Week 5/L1	Teacher sick – worked on assessment task (biostory) and students completed emotion diaries	6.54	
14- Week 5/L2	Computer room – research on CSG and real-world discussions about gases released into environment	6.47	
15- Week 6/L1	Laboratory experiment on metho and water in groups- students finished task	7.05	Videos analysed – highest interest recorded so far + multiple data sources indicating emotionally intensive activity.
16- Week 6/L2	Computer room lesson as students worked on biostory	6.32	
17- Week 6/L3	Video – report from ABC on CSG. Discussion about reporting bias and family vs community perpsectives	6.20	
18- Week 7/L1	Computer room (some students missing today). Students finalising biostory assessment task.	7.31	Flip cam recordings analysed due to higher interest + multiple data sources indicating emotionally intensive activity
19- Week 7/L2	Teacher sick – Computer room lesson with substitute teacher. Students worked on assisgnment.	6.38	
20- Week 7/L3	Students saw a performance called “Rock me Galileo” before the lesson. Students devleoped a concept-map on what they learnt from the performance.	6.36	
21- Week 8/L1	Computer room lesson where students completed assessment task, many writing the story-Author one is walking around and chatting with students while students are working on their assessment task	7.23	Video Analysed- Author one chats with students were transcibed. Students reported that they had learnt a lot from biostory and they talk about what they had learnt. Ashley shows postiive emotions through a dance movement because he “won” an argument with Tony
22- Week 8/L2	Computer room – drafts of assignment read by teacher and feedback given to students	7.00	
23-Week 8/L3	Mix and match activity about the energy in food preparing students for experiment tomorrow.	6.24	
24- Week 9/L1	Laboratory experiment – students burnt a banana chip and calculated the energy content	7.46	Videos analysed due to highest interest rating so far + multiple data sources

	of the banana chip.		indicating emotionally intensive activity
25- Week 9/L2	Students writing up experiment from yesterday	6.81	
26- Week9/L3	Outdoor activity – role play on particle theory linking to movment of particles with high energy and low energy. Discrepant event – egg in the bottle. Discussion of gases, particle theory, pressure and energy.	8.39	Video analysis - highest interest score for whole term + multiple data sources indicating emotionally intensive activity
27- Week10/L1	Outdoor activity – aeroplane activity.	7.40	Video analysis -relatively high interst. However micro analysis of the video shows some students are showing signs of boredom and some were off task during indoor activity.
28_Week 10_/L2	Guest speaker – outdoor siphon acitivty conducted by guest speaker predominantly	7.83	
29 Week 10/L3	Follow-up from siphon acitivity – graph construction of data.	7.21	

*CSG: Coal Seam Gas mining

Table 2. *Transcription conventions used in manuscript (adapted from Roth & Hsu, 2010)*

Symbol	**Use**
underline	Indicates the speaker is emphasizing the underlined text
::	Colons are used to indicate prolonged sound with each colon representing 0.1 second
(0.7)	Timed pauses between utterances are indicated within parentheses
.pp	Each "p" represents an audible inhalation of 0.1 second
((text))	The text bounded by double parentheses represents non-verbal actions of the speaker
[text]	The text enclosed in [] is uttered simultaneously by two speakers

Figure captions:

1. Figure 1 – Jackie surprised
2. Figure 2 – Ashley happy