Exploring emotional climate in preservice science teacher education

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Abstract: Classroom emotional climates are interrelated with students' engagement with university courses. Despite growing interest in emotions and emotional climate research, little is known about the ways in which social interactions and different subject matter mediate emotional climates in preservice science teacher education classes. In this study we investigated the emotional climate and associated classroom interactions in a preservice science teacher education class. We were interested in the ways in which salient classroom interactions were related to the emotional climate during lessons centered on debates about science-based issues (e.g., nuclear energy alternatives). Participants used audience response technology to indicate their perceptions of the emotional climate. Analysis of conversation for salient video clips and analysis of non-verbal conduct (acoustic parameters, body movements, and facial expressions) supplemented emotional climate data. One key contribution that this study makes to preservice science teacher education is to identify the micro-processes of successful and unsuccessful class interactions that were associated with positive and neutral emotional climate. The structure of these interactions can inform the practice of other science educators who wish to produce positive emotional climates in their classes. The study also extends and explicates the construct of *intensity of emotional climate.*

Keywords: emotional climate · emotion · science teacher education · interaction ritual theory

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In science education, emotions should be given the same level of importance as cognition in learning and research (Zembylas 2005) because emotions are woven into the fabric of classroom life (Schutz, Aultman and Williams-Johnson 2009). Extensive research through the use of the Achievement

Emotions Questionnaire (AEQ; Pekrun, Goetz, Frenzel, Barchfeld, and Perry 2011) in university classes has shown that relationships exist between students' self-reports of nine discrete emotions (e.g., enjoyment, pride, anxiety) with engagement and learning. Some specific aspects of learning such as motivation, learning strategies, self-regulation of learning, and academic performance are associated with positive emotions. This led Reinhard Pekrun, Thomas Goetz, Anne Frenzel, Petra Barchfeld, and Raymond Perry (2011) to suggest that university educators need to heed their students' emotions. Studies have also focused on the emotional experiences of university professors. Professors' emotions are related to their pedagogical styles with positive emotions experienced by those that adopt student-focused approaches and negative emotions associated with professor-led approaches (Trigwell 2012). For example, when novice university professors report anxiety this tends to be associated with transmissive pedagogies.

In a comparison of the emotional experiences of elementary and secondary school teachers, Andy Hargreaves (2000) reports that greater physical and professional closeness, which produces higher levels emotional intensity, is reported by elementary teachers than secondary teachers. Professional distance is likely to be even greater at the tertiary level of education where classes are larger than school classes and professors and students meet less frequently than their high school counterparts. Hargreaves argues that stronger emotional bonds between teachers and students could be a basis for high-quality learning.

An important factor related to emotions and teaching is the ability of a teacher to "read" (Hargreaves 2000) individual students and entire classes and adjust their practice appropriately. It is clear that emotions shape the learning process for both the professor/teacher and students and that professors require skills at reading the emotions experienced by individual students as well as collective states of emotional arousal— or emotional climate (EC)— of their classes. In order to read and interpret the emotions produced by classes and by individual students it is first necessary to understand what micro-processes of interaction and class activities contribute to the production of different emotions and EC. This led us to explore the question: How do class activities and the micro-processes of social interaction relate to EC in a preservice science class?

Emotional Climate

The collective state of emotional arousal produced by a class is referred to as the emotional climate (EC; Tobin, Ritchie, Oakley, Mergard and Hudson 2013). EC is produced when members of a group or organization develop an enhanced sense of collective identity and decreased sense of self. EC has been conceptualized in various ways in contexts including educational psychology (Whitall 1949), elementary and early childhood education (e.g., Evans, Harvey, Buckley and Yan 2009), and, more recently, science education (Tobin et al. 2013).

John Whitall's (1949) work focuses on the social-emotional climate of classes. He was the first to conceptualize student-student and teacher-student interactions, which were the focus of classroom climate research, under the banner of social-emotional climate (SEC). Thus, SEC was defined as a collective phenomenon. Whitall operationalized SEC by proposing that it influenced a) the 'private world' of an individual, b) the morale of the group, c) what meaning is attributed to group and individual activities, d) whether a problem is approached in an objective manner, and e) the interpersonal interactions within the group. In his work, priority was given to the teacher's interactions with students and less focus was placed on student-student interactions.

More recent formulations view EC as developing at the interface between the teacher's and students' feelings and it is related to the teacher's skill in managing the complex interactions arising within a class (Evans et al. 2009). EC is produced by the microsocial processes of individual classrooms that are focused on social interactions between students, and teachers and students. A key point of similarity in all definitions of EC is that it relates to the state of emotional arousal between members of a group.

EC is valenced in that positive EC is associated with collective states of happiness, joy and a sense of group belonging, whereas negative EC relates to sadness, fear, and/or anger within the group (Tobin et al. 2013). The valenced nature of EC is analogous to emotional valence (Turner 2007), which theorizes that three of the four primary emotions (i.e., sadness, anger, fear) experienced by individuals are negatively valenced and happiness, a fourth primary emotion, is positively valenced. When individuals or groups of people do not express or feel emotions, they are said to be in a neutral state. Emotions and EC are products of interaction rituals that, in turn, determine the strength of relationships between groups of people (Collins 2010) such as a class.

Theoretical perspectives for research on emotional climate

Interaction rituals and EC

The sociological theory of emotions articulated by Jonathan Turner (2007) also embraces interaction ritual theory because social interactions produce emotional energy (Collins 2004). According to Randall Collins (2004), interaction rituals require four conditions: 1) two or more people must be present and experience one another's bodily presence either consciously or subconsciously; 2) there are boundaries to outsiders that tell participants who is included and excluded from interactions; 3) there is focus of attention on common objects or activities, and participants become mutually aware of this focus; and 4) a common mood or emotion is shared. Through the successful combination of these four conditions, interaction rituals produce successful interactions. When successful interaction rituals are repeated they link together to produce interaction ritual chains. The emotional energy experienced by individuals during social interactions is fuelled by and in turn fuels collective emotional experience – or EC – of the group. Individuals will then seek to reproduce successful interaction rituals in future interactions in order to reproduce positive emotional energy. A key factor in the success of rituals is the intensity of the emotional experience between the participants. Low intensity emotions are unlikely to encourage individuals to seek out similar interactions in the future whereas high intensity experiences result in stronger adherence to group symbols and feelings of solidarity (Collins 2010).

Successful interactions in social life lead to positive emotional energy in individuals (Collins 2004) and positive EC in groups (Tobin et al. 2013) and are characterized by high solidarity conversations that are manifest through the rhythmic features of talk and body movement (entrainment) and a lack of formal rules during interaction. High solidarity conversations resemble "…friendly chatting or animated discussions among friends" (Collins 2004, p. 69). Such interactions can be thought of as *natural rituals* that are formed from a build up of mutual focus and emotional entrainment, and lacking stereotyped, ceremonial procedures. Ceremonial procedures, on the other hand, are referred to as *formal rituals*. Interactions can begin as one type, for example a formal ritual, but can easily convert to the other types, such as natural, if some event erupts during the formal ritual. Conversely, transient natural rituals that are successful become reproduced over time to become

formal rituals with participants regenerating the mutual focus, emotions and symbols of the original ritual.

Classrooms are littered with formal and informal rituals and there is a constant flux between these forms of ritual. A typical formal ritual that pertains to most educational settings is Initiate-Respond-Evaluate structure of interaction. Natural rituals can occur when students engage in side conversations during lessons or when teachers engage individuals or the class in less stereotyped forms of interaction such as asking about the weekend or some movie the students may have seen. The success or failure of either of these rituals depends on a range of factors. Rituals can *fail* when there is a low level of collective effervescence, lack of momentary buzz, and little or no shared entrainment. Additional factors that signal failed rituals include little or no feeling of group solidarity, no respect of group symbols, and low emotional intensity. A growing body of research in middle school and high school science education settings has established links between successful class rituals and positive EC and emotions. We turn to this literature to identify key themes that have informed our study of preservice science teacher education.

Emotional climate and emotions research in science education

Positive emotions are produced in science classrooms through dialogic interactions, laughter and humor, synchronized body movements, and changes to the prosodic characteristics of the participants' vocal expressions (Ritchie, Tobin, Hudson, Roth and Mergard 2011). Negative emotions are produced during interactions that involve univocal interactions, cranky teaching, and when participants tried to establish power relationships over one another (Tobin et al. 2013).

Stephen Ritchie et al. (2011) explored the emotions and associated class interactions of a middle-school teacher's science class. The teacher experienced negative emotions during univocal interactions (i.e., interactions where one speaker dominated the conversation) and positive emotions during dialogic interactions (cf. Wertsch and Toma 1995). Dialogic interactions were those in which a speaker's utterance built on the ideas contained in the utterance of a previous speaker. An example of a dialogic interaction from Ritchie et al.'s (2011) study was related to the following exchanges between the teacher (Vicky) and a student (Trish):

Vicky: ((With raised eyebrows)) Did you know that some Indigenous people say that the rain spirits are crying sad when it is raining

Trish: Or it could be God is just watering his garden or something

Vicky: God is watering his garden

This exchange was coded as dialogic because Vicky's first utterance built on a previous conversation between the students Trish and Narelle (not shown in the exchange above) about clouds. Positive emotional energy was observed between the interaction participants in this exchange making this a successful interaction. Successful class interactions experienced by Vicky, such as the exchange above, led her to experience feelings of positive emotions. These interactions created a structure (Sewell 2005) that she reproduced successfully to generate positive EC at times when interactions fell flat in her class. The term *structure* refers to the cultural schemes that are simultaneously the source and the outcome of social practices (Sewell 2005). For example, interactions fell flat when conversations were dominated by a single speaker and became univocal. By recreating the structure of dialogic interactions Vicky turned these conversations around and experienced positive emotions as a result of doing this.

In a similar way in which the structure of Vicky's interactions was changed, a high school physics teacher changed his class laboratory practices after a positive emotional experience (Ritchie, et al. 2013). The teacher discovered the advantages of a student group deviating from his set protocol for an experiment that involved electric circuits. Rather than following the prescribed method, the students explored different combinations of light bulbs and wires and observed the effects of these changes. Although the teacher was initially frustrated at the students' "deviant" behavior, he was surprised at the observations that the students had made. The teacher later shared the groups' findings with the rest of the class and reshaped future class laboratory activities to reproduce the initial "deviant" event. Thus, the original event created a structure for more open forms of inquiry that the teacher reproduced successfully to foster positive emotional energy during future class activities.

Catherine Milne and Tracey Otieno (2007) identified class structures that produced positive

EC in their study of Otieno's high school chemistry class. They identified a positive emotional environment–a collective state of emotional arousal akin to EC–when the teacher engaged students through the use of practical demonstrations. Milne and Otieno (2007) reported positive effects on student engagement and emotional energy in the class as a result of the demonstration. In relation to class interactions, the structure of demonstration lessons afforded students opportunities for developing mutual focus of attention on observed phenomena. The structure of demonstration lessons also provides the conversational resources for scaffolding submicroscopic chemical explanations of the observations in subsequent class activities.

Kenneth Tobin et al. (2013) highlighted interactions that produced positive emotional energy and EC at the collective level in the same teacher's (i.e., Vicky) class as Ritchie et al.'s (2011) study. In particular, Tobin, et al. explored the EC of a beginning teacher's middle school science class. They established that positive EC corresponded with class interactions "…in which the teacher and students collaborated, demonstrate[ed] emotional attunement, and mutual focus" (p. 28). These successful interactions were characterized by verbal and non-verbal actions including short pauses between speakers (indicating cultural fluency), mutual focus of attention, mimicry, collective laughter and joking. During such interactions, classroom power structures were different from those when EC was negative. Negative EC was recorded during *cranky teaching*, which occurred when the teacher tried to regain control of the class and the class interactions tended to follow an initiate-respond-evaluate pattern. The teacher tended to be louder than in other interactions and adopted particular postures and other bodily orientations as she aimed to regain control of the class. For example, the teacher tilted her head back and increased the volume of her instructions to the students. EC was rated negative when the teacher or students attempted to maintain control over one another (e.g., during cranky teaching) and when other class members were reduced to being spectators rather than participants during classroom discussions.

In higher education, first year university students reported positive emotions when they began to cope with the demands of university (Beard et al. 2005). Students who were not successfully coping with the demands of their freshman year reported negative emotions. Although the students in Colin Beard et al.'s (2005) study were not preservice science teachers, their findings suggest that

aspects of students' emotional experiences impacted their levels of engagement with university learning experiences. A limitation of their study was that the focus on individual students reporting their own emotional experiences does not provide an indication of the collective EC produced in the moment during classroom interactions.

Instruments like the AEQ mentioned in our introduction have yielded critical information about the kinds of emotions experienced by university students and how these relate to learning (Pekrun et al., 2011). However, the use of discrete emotions means that information about collective emotional climate during instruction was not measured. Although the questionnaire provides an analysis of different emotional valences there is no clear indication of the role that intensity of emotions plays in students' perceptions of university classes. Interaction ritual theory predicts that the intensity of emotions during interactions is a key factor in determining their success or failure. In our study, we seek to extend current understandings of emotions in university classes by combining multiple methods to analyze EC during instruction that measure both valence and intensity of EC.

Emotions research is an area that requires investigation in higher education (Beard, Clegg and Smith 2005) because there is evidence to suggest that student approaches to learning correlate with their emotional experiences of their courses (Trigwell, Ellis and Han 2011). Research in science education has focused on the emotions of individual teachers (e.g., Zembylas 2005), and one study has explored the EC developed in a middle school science class (Tobin et al. 2013). However, studies of the EC of preservice science teacher education classes are lacking. This leaves the landscape of EC in preservice classes relatively unexplored. Understanding the social interactions within university classes can help us to understand better the kinds of activities that produce varying intensities of EC and are likely to encourage student participation with learning activities.

The research contexts on emotions and EC in science and general education research discussed in this section have focused mostly on the experiences of beginning teachers rather than preservice science teachers. Furthermore, little is known about students' in the moment perceptions of EC in their preservice science teacher education classes. The focus of Tobin et al.'s analysis in relation to EC was on the valence (i.e., positive or negative) and the types of class interactions associated with this. An issue that remains unaddressed in the research literature is whether the

intensity as well as valence of EC has significant relationships with the types of class interactions. Furthermore, given that a team of expert observers in Tobin et al.'s study rated EC it is not clear how students perceive EC of classes during different types of class interactions.

We identify and detail the micro-processes of successful and unsuccessful interactions that produce EC in a preservice science class as students engage in debates about science-based issues. Our study shows that the intensity of EC (i.e., very positive, positive or neutral) was a significant factor associated with successful and unsuccessful interactions rather than the valence of EC (i.e., positive or negative). Based on our findings we extend current theorizations of EC by refining the construct of *intensity of EC* to account for our empirical observations. This work is important because focusing on EC can lead to greater self-awareness for science teacher educators of the relationship and codependence of successful interactions and EC. Our results offer ways in which teacher educators can structure activities and interactions that are likely to foster high intensities of positive EC.

Context and aims of the study

Our research aims were to explore and characterize class interactions associated with EC of a preservice science education class. The specific research questions were: "What micro-processes of interaction are associated with positively valenced EC and negatively valenced EC?" and "To what extent do formal and informal class rituals relate to the valence and intensity of EC?" As part of a unit focused on socioscientific issues (SSI; Zeidler, Sadler, Simmons and Howe 2005), taught by Alberto (i.e., the first listed author), the class investigated how debates on SSI could be used to engage high school students with science.

Class debates on SSI

During the course of the semester the class studied a range of pedagogies associated with SSI education that included argumentation (through debating), ethical decision-making, and the science, technology and societal dimensions of SSI (cf. Zeidler, et al. 2005). The purpose of using debates on SSI (or *case-based issues*; Zeidler et al. 2005) was to illustrate an alternative strategy for engaging school students with science as suggested by Russell Tytler (2007) who recommended a greater variety of engaging pedagogies to allay declining student interest in science, technology, engineering, and mathematics school subjects. It has been demonstrated that debates on SSI can engage school

students with science (Zeidler, Sadler, Applebaum and Callahan 2009). Students in Alberto's class studied ways in which to frame ethical and moral decision-making around *case-based issues* to inform their debate arguments and future teaching practices.

Students prepared for the debates during the semester by selecting an SSI, researching the science and technology involved with the issue, researching the social implications of the issue, identifying the moral/ethical dimensions of the issue, and learning to present debate arguments. Alberto provided guidelines for structuring debate arguments and explained debate etiquette, such as being respectful to other speakers' points of view. No provisions were made for the audience to engage with the speakers during the presentations. The class debates took place during two lessons at the end of the semester as part of their culminating activity for assessment.

Research design

This study is modeled on event-oriented inquiry (Tobin and Ritchie 2012). Consistent with this mode of inquiry we identified events and class interaction rituals associated with classroom EC and describe these through a combination of narrative and empirical methods. We investigated the EC and interactions in Alberto's class through multiple methods as recommended by Kenneth Tobin and Stephen Ritchie (2012). There is a need for multi-method, qualitative studies for the investigation of emotions and classroom climate in education because the majority of existing research has relied on single methods (e.g., interviews, emotion diaries, climate scales; Pekrun and Schutz 2007). Furthermore, Reinhard Pekrun and Paul Schutz (2007) encouraged the development of measures of *climate* for classroom-based research on emotions. By adopting similar methods to Tobin and Ritchie we build on and extend the growing body of research on EC in science education.

Participants

Fourteen of the sixteen students in the class volunteered to participate in the study. The participants consisted of 13 females and 2 males in the age range of 19-35. Students divided themselves into affirmative and negative teams for the debate presentations on three SSI: climate change, genetically modified (GM) foods, and nuclear energy alternatives.

Data sources and analysis

Participants rated the valence and intensity of class EC using individually assigned keypads (i.e.,

clickers) at intervals – or segments – for the 3 minutes preceding their click (cf. Tobin et al. 2013) during two lessons towards the end of semester. During a 30-minute session before data collection, EC was explained to the class as a collective state of emotional arousal in which very high EC is associated with a heightened sense of positive emotional energy (Collins 2004) and creating an uplifting positive feeling within the class. Negative EC was explained to lead to decreases and negative emotional energy in individuals and creating a sinking feeling within the class. The operation of the clickers was described and students practiced inputting their ratings 2-3 times before the data collection began. Each student was given an instruction sheet to remind them of what each number on the clickers meant and that they were rating the class EC.

Students entered their EC ratings during lessons by pressing a number on the clickers to indicate their perceptions of the classroom EC intensity; 5= very positive; 4= positive, 3= neutral, 2= negative, and 1= very negative. Therefore, ratings of 5 and 4 corresponded with positive EC valences and ratings of 2 and 1 corresponded with negative EC valences. Mean EC values for the 3-minute time intervals were subsequently graphed to capture variation in EC for each time interval during the course of the lessons. Graphs of the mean EC ratings provided a heuristic device for identifying salient classroom interactions in video data.

Maryam (i.e., author 4) recorded detailed field notes of observations during and after the debate lessons in addition to the aforementioned data sources. Alberto maintained post-lesson reflections throughout the semester and these were discussed regularly with the other authors and his students. These reflections not only informed Alberto's teaching but also helped in our reconstruction and interpretation of classroom interactions. All of the authors were involved in the interpretation of data. During data analysis we identified class participants who were salient to the claims of the study. We invited these participants to perform member checks of our claims by checking the accuracy of our interpretations and critique our representation of their actions in this manuscript. One student responded to the invitation stating that we had accurately represented the class interactions.

We recorded classroom interactions using two video cameras. Video data were analyzed by replaying video clips to identify interactions and classroom *events* (Sewell 2005) that coincided with the EC ratings. Because events can modify structures, to understand and explain events it is necessary

to study what structural changes – such as changes to EC or class interaction rituals – they bring about and how these changes are put into operation. We identified salient events in video data that corresponded with changes to EC. Events were then analyzed to identify non-verbal conduct such as confident and synchronized body movements, eye contact, facial expressions and vocalizations demonstrated by participants in the micro-details of interaction as indicative of group solidarity (Collins 2004). For example, we searched for evidence of mutual focus of attention by checking the video data for the body and head orientations of students. We also analyzed facial expressions to determine whether the students' faces indicated emotions of the same valence as their EC ratings (e.g., smiling when rating positive EC).

Transcripts of class interactions were coded using the conventions of conversation analysis (ten Have 2007) as shown in Appendix A. PRAAT software (http://www.fon.hum.uva.nl/praat/) was used to assist with the coding of vocalizations in the transcripts by identifying voice pitch, speech rate and power intensity of words and utterances (Roth and Hsu 2010) and to assist in the identification of the emotional states of the speakers.

Production of EC during classroom interactions

We present two claims in this study: *engaging debate presentations* and *natural rituals* produced positive EC, and *formal rituals* produced decreases in EC. Beginning with a discussion of class EC in relation to the debate topics we then detail the different events and interaction rituals associated with variations in EC.

EC during debates on SSI

The mean EC ratings associated with the debate topics were positive: climate change, EC= 3.6, *SD*= 0.7; nuclear energy, EC= 3.8, *SD*= 0.9; and GM foods, EC= 3.6, *SD*= 0.5. These results show that there was no appreciable difference in EC ratings based on the debate topics. In addition, for each debate, no relationship was observed between EC ratings during arguments by the *affirmative team* or the *negative team.* Because the debates were structured activities – or formal rituals – with rules for presenting counter arguments, these structures did not permit students (i.e., debaters or the audience) to interact spontaneously in ways that could elevate emotional energy and cause swings in students'

perceptions of EC. In this way the debate rules structured class interactions and variation in EC. Even though the debate topics may evoke negative emotions from the general public in some cases, variations in EC in this class were not associated with debate topics.

Variations in EC during debate lessons

In this section we outline the events and interaction rituals that coincided with EC ratings. Debating lessons were associated with positive EC. However, there was considerable variation in EC during the course of the individual lessons as indicated by the range of mean EC for each debate (debate 1, EC range= 2.6-4.5; debate 2 EC range= 3.4-4.4; debate 3, EC range= 2.8-5.0). Figure 1 provides a graphical representation of mean EC ratings for each 3-minute interval – or segment – for debate 1 that exemplifies the variations in EC that characterized the three debates.

Figure 1 About Here

Even though the mean EC for debate 1 (EC= 3.6) indicated an overall positive climate, figure 1 shows that the EC ratings varied during the course of the debate- 1 lesson. These variations coincided with different events and interaction rituals the class engaged during the debate lesson. Similar variations occurred in Tobin et al.'s study.

Contradictions to the generally positive EC during the debate lessons were identified in lesson segments that corresponded with negative EC. There were only four cases of negative EC observed in this study, three of which occurred during debate 1 (i.e., intervals 6, 11, 17, figure 1) and the fourth occurred during debate 3. All four cases of negative EC coincided with flat debate presentations; that is, presentations where speakers spoke in very soft voices, when they read notes to the class, stumbled in their speech, or did not appear to master the concepts of their argument. These presentations were classified as *flat* because the audience demonstrated little focus on the speaker (e.g., did not face the speaker). During the three debates the greatest variation in EC ratings occurred between the ranges of positive EC to very positive EC (i.e., EC= 3.1-5.0). Therefore, the variation in EC ratings was associated predominantly with positive valence (i.e., >3). The discussion in the next section is focused on the class events and rituals that produced positive EC within this positive to very positive range.

Interaction rituals and class activities associated with EC

We identified two types of ritual – *natural* and *formal* – and three kinds of class activities that coincided with participants' EC ratings. The class activities included *debate presentations, voting on debates,* and discussions about *educational implications* for using debates in school teaching. Natural rituals corresponded with voting discussions. Formal rituals corresponded with debate presentations and discussions about educational implications for using debates in school teaching.

An overview of the class activities is provided here as a context for the detailed analyses in the next section. *Debate presentations* refer to lesson segments when students presented their arguments to the class (e.g., intervals 5-18, figure 1). Alberto initiated these via a verbal announcement such as "we're good ta'go." Debates were classified as formal rituals because the kinds of interactions permissible between the class members were governed by the debating rules. *Voting discussions* took place after the debates had finished (e.g., intervals 19-20). Typically, the audience applauded the debate presenters and then straw votes were initiated to decide who had won the debate. This was followed by a discussion focused on why the audience had voted in particular ways. Voting discussions were classified as natural rituals because they were not part of the activities planned by Alberto. Instead, the idea for voting to identify the winners of the debates arose spontaneously after the first debate and the votes were then reproduced in the second and third debates. The debate lessons ended with a discussion about the *educational implications* for using class debates in the preservice teachers' future school classrooms (e.g., intervals 21-23). That is, students were asked to reflect on their experiences with participating in the debates and to discuss how the experience could inform their future teaching. Class activities generally followed an initiate-respond-feedback (IRF) pattern with Alberto initiating the activities. For example, Alberto initiated the discussions about educational implications, students then responded with their ideas, and Alberto then completed the IRF pattern either by summarizing the students' ideas or following up with another question. For this reason, discussions about educational implications were classified as formal rituals.

Over the course of the three debates, EC decreased when debates started (e.g., interval 5) and then varied depending on each debater's presentational style. High positive EC ratings were reported during *voting discussions* (e.g., intervals 19-20). Negative EC was recorded during flat debate

performances (e.g., intervals 6, 11, and 17) and decreases in EC occurred during discussions about *educational implications* (intervals 21-23).

Engaging debate presentations as events that produced positive EC

Engaging debate presentations were defined as those where the presenter interacted with the audience by asking questions, provoking the audience with comments or PowerPoint™ slides, demonstrating an understanding of their topic, or using humor. Such presentations were classified as *engaging* because the audience responded to the speakers through mutual focus of attention throughout the presentation and responded to a presenter's points (e.g., laughing at humorous points). The structure of the debates did not afford the audience opportunities to engage directly with the debaters. The audience sat silently listening to the presentations and their perception of EC was typically between neutral and positive (EC range= 3.0-3.7). Engaging presentations were events that disrupted the formal structure of debating, during which the audience listened silently to the debaters, by eliciting a vocal response from the audience concomitant with a rise in EC ranging from positive to very positive (EC range= 3.7-4.4).

One example of an engaging presentation was Kai-Ying's argument. The highest mean power intensity during debate 1 (4.9 μWatts/m^2, interval 9, figure 1) occurred when Kai-Ying yelled and joked about the audience removing their shoes and clothes in order to engage them. The power intensity from the audience's laughter was 2.5 μWatts/m^2, which represented the highest power rating registered during lesson 1. This high state of emotional energy and high level of collective effervescence (through collective laughter) aligned with Kai-Ying's engaging presentation. Video analysis revealed that there was mutual focus of attention among the audience as evidenced by their body positions directed towards Kai-Ying and the smiles on their faces matching her smile. The positive EC corresponding with Kai-Ying's performance supported the argument that positive EC was associated with engaging debate performances.

A second example of an engaging performance was Charles's presentation during debate 3 (cf. interval 5, figure 2).

Figure 2 About Here

Figure 2 shows an increase in EC rating at interval 5 that corresponded with Charles commencing and delivering his presentation. The significance about the relevant difference between Charles's and Kai-Ying's presentations is that in the latter case the EC increased in conjunction with the increased power intensity as Kai-Ying yelled and joked. In contrast, Charles spoke very softly as evidenced by the decrease in power intensity during the delivery of his argument. The power intensity produced by the speaker before Charles was 0.4 μWatts/m^2 (interval 4). The intensity decreased to 0.2 μWatts/m^2 when Charles began his presentation (interval 5). This observation suggests that loud outbursts, such as Kai-Ying's yell, can contribute to a positive EC but they are not essential. During Charles's presentation the average EC was 4.2, which represented one of the highest ratings recorded during the third debate.

Despite the low power intensity of Charles's voice, his argument remained engaging because of his mastery over the content of his topic, the melodic nature of his voice, his hand gestures, use of humor, and the eye contact he made with the audience. Mutual focus on Charles was observed among the audience as they turned towards him and smiled during parts of his presentation. Charles's speech rate also increased as he concluded his presentation with a joke about not having enough time to continue his list as Alberto was showing him the remaining time on a stopwatch. When he joked, he pointed directly at Alberto and smiled, an action that results in the audience responding with smiles and laughter (i.e., collective effervescence). Similar to Kai-Ying's presentation, Charles's presentation included three instances of humor that generated a positive response from the audience. Thus, he enacted an engaging performance through his knowledge of the topic in conjunction with verbal and non-verbal behaviors that produced mutual focus in the audience. Two similar instances of engaging performances that coincided with positive EC ratings were also identified during debate 2.

Debate presentations were univocal interactions because only the presenter had the right to speak during their presentation. During these univocal interactions, variations in class perceptions of EC coincided with the presenter's ability to engage their audience.

Voting for the debate winners: a ritual that produced positive EC

Voting discussions followed a general pattern that began with straw votes to decide the debate winners followed by justifications for voting choices by the audience. The range of mean EC during voting for the three debates was between positive and very positive (EC= 3.9-5.0). From figure 1, the EC ratings were high and rose between intervals 19 and 20 (EC= 3.9-4.1) as students voted and justified their votes during debate 1. The idea for straw votes arose in a casual manner after debate 1 (cf. interval 19, figure 1, EC= 3.9) as represented in turn 3 of extract 1. Alberto initiated the voting by making the statement "So I think we definitely have to go to an audience vote on this."

Extract 1 Voting on debate 1 winners

Turn	Speaker	Transcript
1.	Alberto	anyway: ah:: let's congratulate our debaters folk=
2.	Students	=((students clap))
3.	Alberto	so i think we definitely need to go to an audience vote on this (0.44)
4.	Students	ºoh noº oh(hh) oh[((indistinguishable sources)) (1.24)
5.	Alberto	whaddya reckon? (1.1)

The utterance in turn 3 and the colloquial expression *whaddya reckon*, in turn 5, indicate that the invitation to a vote was initiated in an unplanned and casual manner. The tone set by Alberto reflects a *natural ritual* rather than a formal one as suggested by results from classroom climate research (i.e., Mazer and Hunt 2008) that showed that an instructor's use of slang and colloquialism positively impacts classroom climate. Similarly, Alberto's use of the expression *whaddaya reckon* could have given students the impression of an informal and comfortable classroom climate that invited them to participate in a natural rather than a formal ritual.

Alberto used the following words in his opening utterances for the votes on the three debates; *so* (debate 1)*, all right* (debate 2), and *well* (debate 3). The speech rate and frequency of his voice were higher than the speech rate and frequency for words used when he started a formal discussion.

Prosodic characteristics of his voice during formal discussions are discussed in more detail later. The prosodic features of Alberto's voice (i.e., frequency and speech rate) during the voting discussions corresponded with emotions of happiness/joy (Juslin and Scherer 2008) and this is consistent with the video data where he could be seen smiling. The combination of his colloquial expressions, tone of voice, and facial expressions were interpreted as having initiated the informal tone of the voting discussions and establishing these interactions as natural rituals.

Alberto agreed to have votes after debates 2 and 3 based on a student's request to vote. The fact that a student initiated the voting discussion suggested that this type of discussion became a symbol that was imbued with positive emotional energy after debate 1, which in turn energized the student to initiate the voting discussions after debates 2 and 3. In this way voting discussions became events during debates two and three because they disrupted the classroom power structure that normally involved Alberto initiating IRF interactions.

We classified the voting discussions as successful interactions because they involved positive EC and emotional energy for students and they involved dialogic interactions. Extract 2 represented the voting discussion after debate 1 that corresponded with intervals 19-20 in Figure 1. The transcript in extract 2 contains evidence that the class was engaged in dialogic interactions. An example of a dialogic interaction was evident in turn 15 when Kate outlined a counter argument to the first student respondent as acknowledged in her opening statement "I say mainly the opposite reason to Student 1." This statement was an example of dialogue because Kate has formulated her utterance on the basis of the utterance of a previous speaker. Other students were then invited to comment and the discussion continued. Another student picked up the discussion after turn 21 from Charles's point about why she had voted for one of the teams, thereby reproducing the structure of a dialogic interaction.

Extract 2 Post-debate 1 voting discussion

Turn	Speaker	Transcript
14.	Alberto	so what about the nay-sayers, uh:: who said the nay-sayers have it and why?
15.	Kate	i sa:y mainly the <opposite reason> of Student 1, i

		think ... they explained it(.) ... a lot more(.) like(.) in detail coz um(.) the affirmative described climate change↑ a:nd the greenhouse effects↑ but they ((pointing to the nay-sayers)) described global warming s::o:: <different definitions> º((inaudible)) º ((turns 16-17 omitted))
18.	Alberto	=oh you haven't decided (1.1) anyone from this ((turns toward students at his left)) table? (1.5)
19.	Charles	we:ll (0.3) i'm kinda split, coz actually i'v- i personally would've been on the affirmative side <but i think> the negative side made a <better argument>(0.1) ahh: presented their argument better anyway [ah-
20.	Alberto	[in what way?
21.	Charles	well↑ (1.1) um, the affirmative were↓ (0.4) were quite↑ good↓, a-a:s <you described> they-they kind of go through the greenhou::se effect and th<at sort of science whereas> the negative side kind of attacked the argument a little bit more

During the course of the discussion presented in extract 2, the EC ratings were positive (EC= 3.9-4.1 at turns 15-21; cf. intervals 19-21, figure 1). During debate 3, the highest EC value (EC= 5.0) for any debate was recorded during the voting discussion. Laughter and smiling were also observed. There was also evidence of mutual focus from the alignment of bodies and heads toward the speaker and of the smiles among participants during voting discussions that indicated the group experienced positive emotional energy. Thus, the voting discussions provided a structure for class interactions that was imbued with positive emotional energy and also involved dialogic interactions.

EC decreased during formal rituals

During voting discussions the class interactions were structured like natural rituals. That is, the interactions resembled conversations between friends (Collins 2004). This structure was disrupted when Alberto initiated discussions about educational implications about the use of debates in science classrooms. Discussions about educational implications were classed as formal rituals because they were interactions initiated by Alberto that followed IRF-type patterns. During these events, he asked students to reflect on their experiences with the debates and to think about how this could inform their future practices in school classrooms. Discussions about educational implications (interval 21, figure 1 and interval 13, figure 2) were characterized by decreases in speech rate when compared to interactions such as during the voting discussions. During the educational implications discussions, there were large segments of univocal interactions typically initiated by Alberto. His utterances contained a large number of pauses, longer pauses when compared to voting discussions, and changes in his prosody or tone of voice. In contrast, during voting discussions, there were dialogic interactions characterized by few pauses between speakers.

EC decreased during discussions about *educational implications*. Discussions about educational implications were events because they disrupted the natural ritual structure during voting discussions and restored the IRF structure of formal class rituals. The mean EC for these discussions was in the low positive range (EC range= 3.3-3.7). Extract 3 contains the opening to the discussion about educational implications at the end of debate 1. In turn 1, Alberto opens the discussion with "no::w putting this back <into the context> of you as <science teachers>." His tone and the way in which he starts the conversation with *now* differs from the voting discussions that started with phrases like *all right the big vote huh*, and *well, like last week*.

Extract 3 Initiating a discussion about *educational implications* of debates

Alberto	no::w putting this back <into the context> of you as <science teachers> and you as teaching the concepts of science technology society throu:gh argumentation. <remember> that debating is a structured form of argumentation↑ there are other ways to do it. can you sta:rt

already seeing some (.) practical issues coming through rela:ting to: perhaps the use of debate or more generally argumentation in a science classroom (.)? what practical things might you look for if you were going to structure an activity (0.5) around those ideas↓ (1.7) how would you conduct it (0.9) what would you do after seeing toda::y's::: (1.6) presen [↓tation.

The frequency and speech rate of Alberto's voice during discussions of educational implications were lower than the values during voting discussions. The differences in prosodic characteristics could indicate low levels of emotional arousal (e.g., anxiety). However, Klaus Scherer (1989) notes that the characterization of specific emotions is not possible due to the low reliability of measures of acoustic parameters for low intensity emotions such as anxiety.

What was also different during these discussions from the voting discussions was the number and length of pauses in Alberto's opening utterance. Toward the end of his utterance there were multiple pauses. When the first pause of 1.7 seconds was not met with a response, Alberto continues with another statement followed by a 0.9 second pause and then another long pause of 1.6 seconds when finally a student responded. Some brief and substantive discussion was then generated in subsequent turns; however, only one student was involved. Therefore the discussions about educational implications formed structures like those of univocal interactions where one speaker dominated the interaction. This led to a concomitant decrease in the participant's perceptions of EC and neither mutual focus between participants nor collective emotional arousal was observed within the class.

The utterance in extract 3 could have signaled a shift to the students from a natural ritual during the voting to a formal ritual on educational implications due to the decrease in Alberto's frequency and speech rate and an increase in the number of pauses. This formal ritual produced low emotional energy during the discussion as indicated by the few cases of laughter and lack of mutual focus all of which signal a failing ritual (Collins 2004). We suspect the prosodic features of Alberto's

voice set the *tone* of the ensuing discussions. Whereas a casual tone was set in the voting discussions, the prosodic features observed during the educational implications discussion set a *formal tone*. One way in which his tone could influence the class's perceptions of EC is through emotional contagion (Collins 2004). The emotional contagion metaphor refers to the way in which emotions are transferred between individuals or groups of people so that people become "infected" with the emotional states (e.g., happiness) of other individuals. Although Alberto's tone did not convey any intense emotion it could have communicated neutrality to the students (consistent with the decrease to an EC rating close to 3). Another highly speculative possibility was that Alberto's tone was indicating a low intensity negative emotion such as anxiety. This explanation could also account for decreased EC ratings through emotional contagion as the class became infected with this emotional state. Other conversational features such as differences in the length of the opening utterances (short in the voting, long in the educational implications) and use of educational terminology for the discussions about educational implications support our claim that these were formal rituals.

Through video analysis we observed that the students' levels of engagement with the discussions about educational implications had deteriorated from the levels maintained prior to the voting discussions. The body positions and gaze of students indicated a lack of mutual focus. Alberto was engrossed in the discussion as evidenced by his emphatic hand gestures and forward body position; however, there were only two students who focused on him during the three-minute interval (interval 17, figure 2). Therefore, discussions about educational implications produced decreases in EC and structures of failed rituals.

Synthesis of findings. Natural rituals corresponded with voting discussions, were aligned with positive EC, and were characterized by dialogic interactions, laughter, faster speech rates, and mutual focus of attention. Voting discussions during the second and third debates were events that disrupted the formal IRF structure of class interactions initiated by Alberto. Formal rituals consisted of debates and discussions about educational implications. These activities (with the exception of engaging debate presentations) aligned with decreases in EC and were characterized by interactions that were univocal, had slower speech rates, and low levels of mutual focus between participants.

One possible explanation for the differences in EC ratings during univocal debate presentations and univocal discussions about educational implications could be that the students had expectations of being positioned as recipients of information rather than being positioned as vocally active participants. Turner's (2007) sociological theory of emotions specifies 17 principles of which the first states that "[w]hen expectations for self, other, and situation are met in an encounter, individuals will experience mild positive emotional arousal…(p. 200)." In contrast, his third principle states that negative emotional arousal will result from expectations not being met. In approaching the debate presentations with the expectation for limited forms of social interaction, the audiences' perceptions of EC were positive when the presenters were engaging and negative when they were not engaging. Thus, the audience's cultural fluency with the debate ritual may have focused their EC ratings on the quality of the performance by the debaters when rating the EC because they did not expect to participate in engaging dialog during the presentations. This explanation is consistent with the observation of positive EC during engaging debate presentations and negative during flat debate presentations. In contrast, during the discussions about educational implications the class may have expected to engage in more dialogic forms of interaction (as occurred during the voting discussions). When they were met with long monologs initiated by Alberto or other students, the EC ratings decreased as students' expectations for the interactions were not met. The prosodic features of Alberto's voice – frequency, speech rate, number and length of pauses – in addition to his use of educational terminology (e.g., scientific literacy, argumentation) may have impacted on the way in which his bid to start the interaction was perceived by students as a formal ritual.

An alternative explanation is that the EC ratings depended on the different conversational resources that participants required for the voting discussion and discussions about educational implications. The voting discussion required students to cast and then defend their votes. Because the students had science backgrounds, their confidence with the topic of the discussions may have provided the discursive resources required to participate and produce dialogic interactions. In contrast, the students had only completed two education units at the time of the study. Thus, the students' exposure to educational terminology (e.g., "argumentation," turn 1, extract 4) and concepts that were essential for the discussions about educational implications, may not have been addressed prior to

Alberto's unit. In this way, few students may have had access to the necessary concepts for engaging extensively in these discussions.

A cautionary note must be made in relation to the last point because it has been argued that students actively choose whether or not to use technical terminology when responding to class discussions in science classrooms (Olitsky 2007). By conceptualizing technical terminology as a cultural resource, Stacy Olitsky (2007) provided evidence that students chose to use science terminology during interactions about science demonstrations as they enacted identities that they deemed to be valuable within the peer group. If students did not consider themselves or were not considered by others as "good science students" they curtailed their use of scientific terminology when they answered questions. In a similar way, the preservice teachers in our study may have chosen not to use educational terminology to protect identities they had formed within the peer group at some other place and time or because they do not wish to identify themselves as "good preservice science students."

Our findings suggest that student perceptions of EC may be associated with both the collective climate of the class during more interactive activities such as discussions, or they may be associated with the sum of individual emotions that result from individual expectation states being met or unmet during univocal interactions. There appears also to be interplay between students' expectation states, dominant types of rituals (formal/informal) and the interactional structures (dialog/monolog) associated with their perceptions of EC. A highly nuanced set of characteristics of EC has emerged that extends the relationships between univocal and dialogic interactions and EC shown by Tobin et al. In their study, the EC was positive when interactions were dialogic and negative during univocal interactions. Our findings show that the preservice teachers' perceptions of EC may depend not only on whether the structures of interaction are univocal or dialogic, but whether these structures are nested within larger forms of classroom activity (e.g., debates, discussion on educational implications) and whether they meet the expectation states brought to bear on the dominant activities. For example, class discussions involved both dialog, that was associated with positive EC, and univocal interactions that were associated with decreased EC. Students' expectation states may not be met during discussions if one speaker dominates the interactions or if they do not

have the requisite knowledge to participate in the discussion. This would lead to feelings of negative emotions and potentially color their perceptions of the class EC.

An unexpected result in the study was the observation that, for the majority of the time, class EC was positive. Due to this finding, the ranges of positive EC were the best way to explore connections between different rituals and events on the production of EC. That is, the valence (i.e., positive or negative) of EC was not sufficient in accounting for the observation that EC was mainly positive. However, the range of positive EC values (EC range 3.1-5.0) could be related to the types of class interactions during different rituals and class activities. For example, very high positive EC was recorded during voting discussions. Low ratings of positive EC were associated with formal discussions. We explore this observation further in the next section by extending the original conceptualization of EC presented at the start of the study by refining the construct of *intensity of EC*.

Refining the EC construct and implications for preservice science teacher education

This study illuminates the events and associated social interactions that coincided with different levels of EC in a class centered on debates about three different SSI topics. No relationships were established between the debate topics and EC. Although the overall class EC was positive during the debate lessons, specific events within the lessons were responsible for high positive EC values. Without these events the EC would have been closer to neutral for the duration of a lesson. The significance of this finding is that specific, short duration events of high emotional intensity can saturate an entire lesson with positive EC. When students later recollect their experiences of their science education course, the positive emotions experienced during specific events may resonate with their memory and affect their perceptions of EC for an entire lesson. The results demonstrate that class interaction rituals affected students' perceptions of EC. Natural and formal rituals were identified as key types of class interactions responsible for the production of EC during the lessons. Natural rituals produced positive EC whereas formal rituals led to decreases in EC (but still positively valenced). The study contributes to the theoretical development of the EC construct by refining the construct of *intensity of EC* to account for our empirical observations.

Refining the intensity of EC construct

EC was theorized as having a positive or negative valence in our theoretical framework and was

measured in terms of both valence and intensity. Valence was not sufficient to account for all of the empirical observations in this study. Given that most class interactions were associated with positive EC – with the exception of flat debate presentations – the concept of *intensity* allows us to explain that certain types of interaction led to higher ranges of positive EC (i.e., EC= 4.0-5.0) than other interactions that produced lower ranges of positive EC (i.e., 3.1-3.9).

We elaborate *intensity of EC* further through an analogy with the construct of intensity of emotions (Turner 2007). As well as being valenced, individuals experience emotions in various levels of intensity from low (e.g., Happiness=content; Fear=concern), to moderate (e.g., Happiness=cheerful; Fear=anxiety), to high (e.g., Happiness=joy; Fear=terror). For example, for the positive emotion *happiness*, the corresponding low intensity emotion is *content*. In our study, high intensity emotions such as joy or terror were not observed frequently. One case of high intensity positive emotions was observed during Kai-Ying's engaging presentation. We observed moderate intensity emotions such as happiness or cheerfulness with greater frequency during moments of group effervescence such as during the voting discussions. Thus, positive EC ratings in the range of 3.8-5.0 associated with voting may correspond to moderate intensities of emotional arousal like cheerfulness at the collective level. Low EC ratings (i.e., 3.1-3.7) that were associated with discussions about educational implications may correspond to low intensity emotions (e.g., content or gratified).

The related concepts of feeling rules (Hochschild 1979) and display rules (Ekman 2007) offer possible explanations for our findings that the intensity of EC was mainly in the range of neutral to positive EC. Feeling rules refer to socially constructed guidelines that tell us how we "want to try to feel" (Hochschild 1979, p. 564). Display rules is a concept developed by Paul Ekman (2007) to explain why emotions are not always displayed publicly. What both constructs offer is an explanation for why certain emotions at certain intensities are displayed in one situation and not another. As adult learners, the preservice teachers in our study may have been influenced to varying extents by the social rules developed through family, school and society in general that inform their emotional displays. For example, the codes of behavior and conduct learned at school typically apply punitive measures to displays of aggression (i.e., high intensity anger) towards peers and teachers. Based on these rules preservice teachers are unlikely to engage in intense emotional displays (whether positive

or negative) during class interactions. This may have the effect of creating a floor and ceiling on the possible intensities of EC that can be measured in any class. It would take a significantly profound event for individuals to display intense emotions publicly.

The concept of *intensity of EC* warrants further refinement to develop a stronger empirical base than what our single study can provide. Some support for our concept is already available from a re-interpretation of Tobin et al.'s (2013) work. In a similar way to our study, their evaluations of EC were mostly positive with only a few cases of negative EC. Therefore, the variation in class interactions across the multiple instances of positive EC in their study also cannot be accounted for by valence alone (i.e., that it was positive). An alternative possibility is that for any time interval during which EC is measured, the effect of specific positive emotions (e.g., happiness) could overshadow other emotions (e.g., anxiety) that the participants are experiencing or may have experienced. One way of ascertaining whether this is the case would be to construct measures for each specific primary emotion (e.g., joy, anxiety etc.) and to measure them on a scale of 1 to 5. Coupling such measures with micro-analysis of facial expressions and prosodic features of people's voices within a 3-minute time interval could help us to understand better why the majority of class EC is positive and whether, if any, negative emotions are evident in this time interval. Doing so would allow us to investigate the way in which all emotions contribute to EC in the moment for any event and, in a more enduring sense, to an entire lesson. Such research is significant because it could help teachers and researchers to understand better whether transient emotions experienced by students on short time-scales (i.e., seconds) have any impact on EC or not. If positive emotions dominate students' perceptions of EC and have lasting effects on their impressions of science classes, then there may not be any need for teachers to be concerned if they observe short-term displays of negative emotions. An alternative possibility is that positive emotions overshadow important negative emotions so that teachers and researchers cannot rely on EC measures as their only source of evaluation of classroom climates to inform their "reading" of a class (Hargreaves 2000).

The use of similar methods to Tobin et al. for investigating EC and the refinement of *intensity of EC* are steps towards addressing the need for unifying the methods and concepts used for investigating emotion in education as suggested by Pekrun and Schutz (2007). In this study we

assumed that the EC construct would correlate with successful and unsuccessful class interactions based on the codependence of emotional energy and social interactions as predicted by interaction ritual theory (Collins 2004). We found that positive EC coincided with natural rituals such as voting discussions. During debate presentations, natural interactions were not possible due to the structured nature of these presentations. This could explain why there was very little difference in EC ratings associated with the debate topics whereas engaging presentations corresponded with positive EC. To the extent that we identified no difference in EC with respect to the debate topics, perhaps students' experiences of debating as an engaging class activity overshadowed any emotions that students may have felt towards the SSI (e.g., climate change). Research in which different debate topics from those involved in our study could help to confirm this finding. In ongoing research we are exploring further the interrelated nature of EC and class interactions to understand better the connections between lesson topics and activities with class EC.

Implications for science teacher education research and practice

Formal rituals are an inevitable part of classrooms life; at some point direct explanations or lectures are likely to surface. Our findings that EC was neutral, and sometimes positive during formal rituals, suggests that these kinds of teaching approaches are not entirely deleterious to class EC. It may be possible to change the EC during univocal interactions for example, by using the same interactional styles as the engaging debate presenters. In addition, during formal rituals, it may be possible to structure the beginning of these interactions through content of talk and vocalizations such as those observed in the voting discussions that created an informal feeling and led to positive EC. However, we cannot say from our results what effect, if any, extended periods of lecturing or monolog would have on EC. The trends in our data show that EC decreases during monolog so it is foreseeable that it could continue to decrease into negative valence during extended monolog. At this point it would be safe to assume that monologs should be kept short with ample opportunities for dialog as this is likely to lift the EC from neutral to positive. We suggest that preservice science teacher educators would benefit from becoming aware of their class EC so as to initiate positive interactions when EC is notably low or negative. The micro-processes of interaction that we have reported including prosody, gestures and the type of discourse (univocal/dialog) can inform practitioners on how to change their

conduct in ways that are likely to boost the EC into positive and highly positive ranges during a lesson if there are signs of a decline in EC. Signs of the breakdown of interactions reported in this study included verbal and non-verbal conduct such as the teacher's tone of voice (e.g., decreased speech rate), lack of eye-contact between class members, lack of synchronized body movements, and reduced or no collective effervescence. Other educators can use these verbal and non-verbal cues to monitor their class EC and respond by redirecting the interactions towards more positive emotional interactions. This could be achieved by reproducing the structure of *voting discussions* that involved faster speech rates, colloquial terms, and dialogic interactions. This is desirable because preservice science teachers may be encouraged to reproduce activities like SSI debates in their own future classes, according to interaction ritual theory, if they perceive them to be positive emotional experiences.

In this research we theorized EC in terms of a dialectical relationship between individuals and collective. That is, the components of EC that are attributable to individuals cannot be separated from those associated with the collective. Operationally, when individuals experience EC the experience is considered holistic and irreducible to individual and collective components. The approach used in this study is grounded in contemporary work of Collins (2004) and Turner (2007) and is historically constituted in Durkheim (1912/1995). We opted to measure the EC in terms of valence and magnitude – setting aside the actual emotions produced in the time interval associated with the measurement of EC. This work expands on earlier research (Tobin et al. 2013) in that in this study all participants were involved in measuring their in-the-moment experience of EC. The insights provided by this method afford interesting analyses of EC that are constrained by the specific methodology used. Although there is much more for us to learn from analyses of the substantial data set we produced in this research, we regard actual emotions expressed in a time interval also are part of EC. Accordingly, in future research the methods used in the present study can be adapted to include the principal emotion experienced in each time interval in which EC is measured. For example, clickers could be used to obtain information associated with the following question: which of the following emotions did you experience as most salient in the last 3 min.? Participants could then record EC in terms of the most salient emotion experienced, selecting from a list such as: happy, angry, sad, fearful, disgust,

surprise, none of the above. We acknowledge that there are potential limitations to our methods for measuring EC because participants may find it difficult to focus on a class activity and on rating the class EC at the same time. Our study design sought to decrease the impact of such factors on our results by using the EC data heuristically to identify class events from video data rather than taking the EC ratings to be direct measures of "the class EC" as some external reality.

An area for further study is to explore whether changing the sequences of classroom activities has any effect on student perceptions of EC. In our study, the sequence of activities was always debates-votes-educational implications discussions. Perhaps if the discussions preceded the more engaging votes then perceptions of EC during the discussions would have been higher. Another possibility worth exploring is whether a science demonstration or game that precedes engaging debates lowers the students' perceptions of EC during debates. As far as science education is concerned, EC is a fertile area for research that has significant implications for theory production and transformation of practice. We expect to be involved in such research and are excited by the possibilities for our ongoing research and studies undertaken globally. There is no doubt that there is much to be gained from studies of EC and we anticipate different frameworks and contexts will enrich the research dialog.

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References

Beard, C., Clegg, S., & Smith, K. (2005). Acknowledging the affective in higher education. *British Educational Research Journal,* 33, 235-252. doi:10.1080/01411920701208415

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

Collins, R. (2010). The micro-sociology of religion: Religious practices, collective and individual. *Association of Religion Data Archives, Guiding Paper*.

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

Ekman, P. (2007). *Emotions Revealed*. New York: St Martin's Griffin.

Evans, I. M., Harvey, S. T., Buckley, L., Yan, E. (2009). Differentiating classroom climate concepts: academic, management, and emotional environments. *New Zealand Journal of Social Sciences Online,* 4, 131-146. doi:10.1080/1177083X.2009.9522449

Giddens, A. (1979). *Central problems in social theory: Action, structure and contradiction in social analysis*. Berkley, CA: University of California Press.

Hargreaves, A. (2000). Mixed emotions: teacher's perceptions of their interactions with student. *Teaching and Teacher education,* 16, 811-826.

Hocschild, A. R. (1979). Emotion work, feeling rules, and social structure. *American Journal of Sociology,* 85, 551-574.

Juslin, P. N., & Scherer, K. R. (2008). Vocal expression of affect. In J.A. Harrigan, R. Rosenthal, & K. S. Scherer (Eds.), The new handbook of methods in nonverbal behavior research (pp. 65-136). New York: Oxford University Press.

Mazer, J. P., & Hunt, S. K. (2008). The effects of instructor use of positive and negative slang on student motivation, affective learning, and classroom climate. *Communication Research Report,* 25, 44-55. doi:10.1080/08824090701831792

Milne, C., & Otieno, T. (2007). Understanding engagement: Science demonstrations and emotional energy. *Science Education,* 91, 523-553. doi:10.1002/sce.20203

Olitsky, S. (2007). Promoting student engagement in science: Interaction rituals and the pursuit of a community of practice. *Journal of Research in Science Teaching,* 44, 33-56. doi:10.1002/tea.20128

Pekrun, R., & Schutz, P. A., (2007). Where do we go from here? Implications and future directions

for inquiry on emotions in education. In P.A. Schutz, & R. Pekrun (Eds.) *Emotion in Education*. (pp. 313-331) Boston: Elsevier Academic Press.

Pekrun, R., Goetz, T., Frenzel, A. C., Barchfeld, P. & Perry, R. P. (2011). Measruing emotions in students' learning and performance: The Achievement Emotions Questionnaire (AEQ). *Contemporary Educational Psychology,* 36, 36-48.

Ritchie, S. M., Tobin, K., Hudson, P., Roth, W.-M., & Mergard, V. (2011). Reproducing successful rituals in bad times: Exploring emotional interactions of a new science teacher. *Science Education.* 95, 745-765. doi:10.1002/sce.20440

Ritchie, S. M., Tobin, K., Sandhu, M., Sandhu, S., Henderson, S., & Roth, W.-M. (2013). Emotional arousal of beginning physics teachers during extended experimental investigations. *Journal of Research in Science Teaching,* 50, 137-161.

Roth, W.-M., & Hsu, P.-L. (2010). *Analyzing communication: Praxis of method*. Rotterdam, The Netherlands: Sense Publishers.

Scherer, K. S. (1989). Vocal correlates of emotional arousal and affective disturbance. In H.L. Wagner, & A. S. Manstead (Eds.) *Handbook of social psychophysiology: Emotion and social behavior* (pp. 165-197). London: Wiley.

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

Sewell, W. H. Jnr. (2005). *Logics of history. Social theory and social transformation.* Chicago: The University Press of Chicago.

ten Have, P. (2007). *Doing conversation analysis* (2nd Ed.). SAGE: London.

Tobin, K., & Ritchie, S. M. (2012). Multi-method, multi-theoretic, multi-level research in the learning sciences. *The Asia-Pacific Education Researcher,* 20, 117-129.

Tobin, K., Ritchie, S. M., Oakley, J., Mergard, V., & Hudson, P. (2013). Relationships between EC and the fluency of classroom interactions. *Learning Environment Research.* doi: 10.1007/s10984-013-9125-y

Trigwell, K. (2012). Relations between teachers; emotions in teaching and their approaches to teaching in higher education. *Instructional Science,* 40, 607-621.

Trigwell, K., Ellis, R. A., Han, F. (2011). Relations between students' approaches to learning, experience emotions and learning outcomes. *Studies in Higher Education,* 1-14. doi:10.1080/03075079.2010.549220.

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

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

Wertsch, J. V., & Toma, C. (1995). Discourse and learning in the classroom: A sociocultural approach. In L. P. Steffe & J. Gale, *Constructivism in education* (pp. 159-174). Hillsdale, NJ: Lawrence Erlbaum.

Whitall, J. (1949). The development of a technique for the measurement of social-emotional climate in classrooms. *Journal of Experimental Education*, 17, 347-361.

Zeidler, D., Sadler, T. D., Applebaum, S. Callahan, B. E. (2009). Advancing reflective judgment through socioscientific issues. *Journal of Research in Science Teaching,* 46, 74-101. doi: 10.1002/tea.20281

Zeidler, D., Sadler, T. D., Simmons, M. L., & Howes, E. V. (2005). Beyond SSI: A research-based framework for socioscientific issues education. *Science Education,* 89, 357-377. doi:10.1002/sce.20048

Zembylas, M. (2005). Creating a supportive emotional tone for learning in the classroom. In Zembylas, (Ed.) *Teaching with emotion: a postmodern enactment*. 4, (pp. 65-94). Conneticut, USA: Information Age Publishing.

Appendix A- Transcript Coding Conventions Based on ten Have (2007)

[A single left bracket indicates the point of overlap onset

] A single right bracket indicates the point at which an utterance or utterance part terminates

(0.1) Indicates elapsed silence in tenths of seconds

(.) Indicates elapsed silence of less than a tenth of a second

Underline is used to denote stressed sounds

- A dash indicates a cut-off sound

? A question mark indicates rising intonation

↑ An up arrow indicates rising pitch

º The degree symbol indicates utterances or parts of utterances that are softer than surrounding conversation

<> Right/left carets are used to bracket utterances or parts of utterances that are speeding up

h *H*s indicate an outbreath

(()) Double parentheses contain the transcribers descriptions of actions pertaining to a part of the conversation.