Chapter 2
Understanding Engagement in Science Education: The Psychological and the Social

Stacy Olitsky and Catherine Milne

It is a prevalent understanding among teachers, curriculum writers and education researchers that students need to be engaged in order to learn science. Empirical studies in education indicate the importance of student engagement for effective teaching and learning (e.g. Ainley et al. 2002). Many teacher education programmes advocate a focus on engagement when they promote pedagogical strategies based on constructivist views of education. Such programmes encourage teachers to provide opportunities for students to build their own meanings in science through direct experience, rather than the more traditional transmission models of teaching (e.g. Duckworth 1987). Pedagogy based on a constructivist approach implies student engagement in that the students need to be active, making sense of their world through integrating their new experiences with their prior experiences, beliefs and knowledge (Driver et al. 1994). One example of an approach to science teaching developed in accordance with constructivist thought is the 5E instructional model, which consists of the following phases: Engagement, Exploration, Explanation, Elaboration and Evaluation (Bybee 1997). According to this model, the first phase, student engagement, can be fulfilled through some type of short experience that is designed to access prior knowledge and stimulate curiosity. Similarly, in many teacher education programmes, teachers are encouraged to engage students by designing lessons with some kind of a 'hook' that is supposed to gain students' attention and pull them into the subject matter.

Constructivist perspectives, both personal and social, primarily focus on the cognitive aspects of engagement, in that the emphasis is on cognitive tasks such as questioning prior beliefs or building on prior knowledge. However, in order to

S. Olitsky (✉)
Department for Teaching and Learning, The Academy for Advanced and Creative Learning, 816 E. Kiowa Street, Colorado Springs, CO 80903, USA
e-mail: solitsky@gmail.com

C. Milne
New York University, New York, NY, USA
e-mail: cem4@nyu.edu

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implement pedagogical strategies based on constructivism, engagement on an emotional level is crucial. For example, students need to be excited by the 'hook', or have positive emotional tone associated with the process of questioning their ideas in order for such strategies to be effective. Paul Pintrich, Ronald Marx and Robert Boyle (1993) were critical of models for student learning that focused only on 'cold' cognition, ignoring the role of student engagement in classroom activities. Further, empirical research has also affirmed the importance of engaging students on an emotional level (Alsop and Watts 2003). Mike Watts and Steve Alsop (1997) argued that theories, such as conceptual change, need to take into account the emotions behind actions if learning in science is the final goal of developing such theories. If we assume an active learner, an agent, then it makes sense to acknowledge the role of emotions in engagement. However, in order to do that, we need to develop a richer understanding of the nature and role of engagement in classroom contexts.

Such clarification is important, because the everyday use of the term 'engagement' among teachers emphasises the slipperiness of this idea as it currently emerges in discussions about pedagogy. For some teachers, engagement is an individual construct evidenced when they talk of a student who is 'disengaged'. This places an attribute, and perhaps responsibility, on that student. Sometimes teachers describe how they did not sufficiently 'engage the students', which then places the focus and the responsibility on the individual teacher. For others, engagement is collective, with teachers describing how students and teacher become so caught up in a lesson that they are surprised when the end of class is signalled.

In this chapter, we examine new research in which engagement is posited as emerging from collectively generated emotions, which then has implications for both cognition and behaviour. This social and emotional view of engagement does not mean that individuals' actions are thought to be irrelevant. Rather, attention to the collective aspects of engagement means that an individual's actions are not understood as a product of some kind of inclination or personality trait (e.g. this child is disengaged or shy). Instead, we follow the sociologist Randall Collins in viewing individuals as products of social situations, and argue for a dialectical relationship between the social and the individual.

We develop, illustrate and support our view of engagement by describing outcomes of our research that illustrate how collectively generated emotions led to changes in both behaviour and cognition within two science classrooms in Philadelphia. Similar findings about the results of engagement from two very different schools support the primacy of the social and emotional aspects of engagement in influencing other dimensions of engagement, and have implications for paths that teachers can take in order to implement positive classroom changes.

Conceptions of Engagement

Much of the research that informs current understanding of engagement in science education comes from behavioural or cognitive studies. Jennifer Fredricks, Phyllis Blumenfeld and Alison Paris (2004) proposed a multifaceted model that consisted

of behavioural, emotional and cognitive engagement. They identified *behavioural engagement* as engagement associated with a range of actions from students' classroom behaviours, including on-task behaviour and participation in extracurricular activities. *Emotional engagement* is associated with students' attitudes, interests and values as identified in a student's reactions to peers, teachers, the curriculum content and school. *Cognitive engagement* is associated with motivational and self-regulated learning. Cognitive engagement could be identified from students' willingness to 'exert the effort' that was required to understand 'complex ideas and master difficult skills' (Fredricks et al. 2004, p. 60). The authors argued for the importance of thinking of engagement as a mega-construct that was composed of interrelated aspects of behaviour, emotion and cognition and for understanding engagement in each construct as existing on a continuum. They acknowledged the limitations of single variables for characterising the responses of children to specific tasks or activities and argued for the fusion of behaviour, emotion and cognition under the concept of engagement. Further, they identified engagement as a malleable construct that was open to changes in the context. While their review was helpful because it synthesised extant research on engagement, we do not think that the model of three separate continua is the most accurate perspective, because it begs the question of the complex relationship *between* cognition, emotion and behaviour. However, as we argue later in the chapter, social theory provides strategies for understanding this relationship.

If we look at research on engagement conducted over the past 20 years, we find that many studies adopt a focus on individual engagement. For example, in science education, consistent with the prevailing learning theories, early studies of engagement focused on individual students and measures such as 'time on task' as indicators of engagement (e.g. Tobin and Capie 1982). Even now, while researchers investigating engagement might acknowledge the importance of the social, they still rely on research methods such as interviews and surveys that seek individual measures of engagement. For example, acknowledging the limitations of a purely behaviourist approach to understanding engagement, Daniel Hickey and Steven Zuiker (2005) adopt a different approach using situated cognition to define engagement as *engaged participation*. They postulate engagement as a dialectic between participation and non-participation with students involved in negotiating their identity based on the extent to which they become involved in meaningful practices within specific knowledge communities. They argue that, rather than a focus on individuals, their unit of analysis is 'domain knowledge practices' associated with the curriculum. However, typical of previous studies, Hickey and Zuiker used individual sources of data such as student assessments to develop their model of engaged participation.

Two other studies of note inform our understanding of engagement as social. Leslie Herrenkhol and Maria Guerra (1998) used a design to try to move science education away from a transmission model of teaching and learning. They argued that: 'Transforming constructivist models into viable classroom practices has proven to be a significant challenge' (p. 467). They defined engagement as 'discourse practices that extend beyond the behaviour of individual students and involve social and cognitive activity' (p. 439). Working with 4th graders, they compared a classroom

where students were assigned intellectual roles and a classroom where students were assigned both intellectual and audience roles. The results of their study indicated that both audience and activity was necessary for engagement. However, they did not speculate about why this might be so and their study was conducted not in a 'typical' class, but in two classes that were specifically set up for the study. In later sections of this chapter, we argue that sociology of emotions provides a framework for making sense of their findings.

Randi Engle and Faith Conant (2002) also used a situated cognition model to frame engagement as disciplinary, based on creating learning environments that support (1) problematising subject matter, (2) student agency to address these issues, (3) accountability for appropriate norms of behaviour, and (4) availability of resources. Engle and Conant identified observable connections between the discipline's discourse, in this case science, and students' actions and argued that if students make intellectual progress, this engagement is productive. They called their measure *productive disciplinary engagement*, a concept also promoted in the National Research Council's (2007) publication, *Taking Science to School*. Engle and Conant recognised the role of emotion and used observations from videotape data to identify some of the behaviours that we also associated with engagement. We agree with them that greater engagement can be inferred both from the level of substantive contributions that students make when a topic is under discussion and the ways in which students attend to each other. We argue that the sociology of emotions provides a framework for this analysis.

Moving from the Individual to the Collective: Emotional Engagement as Social and Temporal

Historically, emotional engagement has been measured using survey or self-report instruments and has been mainly associated with interest. For example, Connell et al. (1995) used self-reports to identify self-perceptions of perceived competence, autonomy and relatedness that were hypothesised to affect student engagement. While these measures can serve to identify aspects of individual student engagement, it could be hard to draw implications that could guide changes in teacher practices for several reasons. One issue is that these types of measures address aspects of a student's engagement at the particular point in time when the survey was administered, rather than averaging out the fluctuation in emotional engagement through sequences of events in the classroom. Therefore, it is difficult to pinpoint causes of either engagement or lack of engagement.

In addition, by focusing on individual students' self-perceptions, the relationship between collective engagement to individual levels of engagement is not sufficiently addressed. On a practical level, efforts to improve individuals' levels of engagement without accounting for the group interactions can be counterproductive. One example of this phenomenon comes from our own research in an urban school, City Magnet. The students described how, when the teacher tried to promote a sense of

competence by assigning tasks that were easily accomplished, students would become embarrassed because everyone knew which questions were easy (Olitsky 2005). Just surveying the students' emotional engagement at a single point in time would be misleading, because the same student might report low emotional engagement after being given an easy question, yet high emotional engagement after successfully explaining a new concept to a peer. Self-reports could therefore be faulty measures because any student's sense of competence, autonomy or relatedness is deeply embedded in the day-to-day context of classroom interactions and their implications for emotions. An alternative approach to surveys would be to attempt to understand the contextual variables that inform fluctuations over time in the levels of engagement of both the individual and collective.

A recent study did address the temporal nature of engagement, investigating how emotional engagement varied with activity structure (Uekawa et al. 2007). Study methods included classroom observations, focus groups and the Experience Sampling Method (ESM), based on Mihaly Csikszentmihalyi's (1990) *flow* theory of engagement, to measure engagement in real time as students were asked to record their cognitive and affective responses at specific times. We find this work resonated with our view, because it acknowledges that levels of engagement change depending on context.

We have worked to develop research methods that can help us to investigate the role of classroom interactions in providing the context that informs student engagement. Following Erving Goffman (1959), we understand an interaction to be an act between members of a social group. A focus on interactions allowed us to identify segments of lesson sequences when engagement was a more obvious feature of the classroom. In addition, we situated classroom interactions within events over a longer timescale. In this chapter, we draw on examples from studies that we conducted to illustrate the importance of examining the social aspects of engagement over time, with an understanding of the ethnographic context. Both of the class contexts that we describe in this chapter are unusual in that students were more engaged than had been observed previously as demonstrated by changes in student participation, including their use of canonical science language.

An example of a change in student action that could only be recognised because of prolonged involvement of the researchers with the classroom context involved Sherez, an African American student. She was a significant player in the presentation of a series of science demonstrations designed to show that air was made of molecules that had volume even though these molecules could not be directly observed (Milne and Otieno 2007). In the first instance, when Sherez came to the front of the room to carry out a demonstration, she took 6.5 seconds to reach the front of the room where the demonstration was to be performed. In the demonstration, Sherez inverted a cup containing a scrunched-up piece of paper at its bottom under water and the paper stayed dry.

Sherez's actions were significant, not just for her, but also for the other students in the class. From previous observations of class interactions, we knew that, up to that point, Sherez had not been able to identify much chemistry that was of interest to her. At first, her participation in the first inverted cup demonstration was almost a

risk-taking behaviour because she had to weigh any possible loss of social capital with other students against participation in the demonstration. Thus, her initial movement was measured, as demonstrated by her slow movement, providing a space for her to assess how other members of the class interpreted her involvement. Equally, her decision to participate became a resource for other class participants. Although we did not realise it at the time, these actions contributed to the emerging collective positive emotional energy of the class. The second time when there was a need for someone to conduct a modified version of the demonstration, following a rich discussion about the observations that could be made from the first demonstration, Sherez volunteered with alacrity and took less than a second to move to the front of the room to perform the new demonstration.

If Sharez had taken a self-report survey of emotional engagement at some point during the class session, the results would be misleading, and the important role of collective emotional engagement could be missed. If taken towards the beginning of the period, her answers might indicate that she was disengaged and, if taken towards the end of the period, her answers might indicate engagement. However, the answer to such questions would not tell us how engagement-related behaviours, such as the speed at which she came to the front and her verbal participation, changed over time depending on the overall levels of engagement of the class or how these actions became a resource for other students. Through observing interactions, it became apparent that, as students became emotionally absorbed in an activity, like the demonstration and the ensuing discussion, Sharez's behaviour changed. Without a focus on collective engagement, the significance of these separate observations would not be recognised.

Another example for the need for long-term study of classroom interactions involves Carla, a student at City Magnet school, who usually did not volunteer to participate in whole-class discussions and describes herself as not being good at science. However, when watching her peers at the board complete problems involving the balancing of chemical equations, she frequently offered helpful comments to them. Like other students in the classroom, she described the activity of balancing equations as 'fun'. This student might score as disengaged on a general self-report survey but, based on her behaviour and on interviews, her levels of engagement in the classroom varied with the activity and changed throughout the year.

In closely analysing both transcripts and videotapes, it became apparent that her participation changed in response to the collective mood of the class. There was a general pattern in which, following a series of interactions when students supported each other's work and there was a sense of solidarity and common rhythm, she was more likely to participate, sometimes using canonical science language. Following a series of interactions when students were not collectively engaged, or when students made negative comments about each other's attempts at participation, she was often either silent or made off-task comments. In studying this classroom over the course of a year, it became clear that her engagement was contingent on her level of confidence which, in turn, emerged from collective emotional experience. Without long-term observation of participation in the classroom, it would be difficult to discern these types of patterns.

As these two examples illustrate, it is crucial to focus on how engagement evolves over time within the social setting of the classroom in order to understand individual students' engagement-related behaviour, affect and cognition. In this chapter, we discuss how studying social interaction can tell us why and how student levels of engagement change. We argue that a social perspective is important in order to plan for positive changes that will result in the engagement of more students in science classrooms.

The Primacy of Emotional Engagement: Theoretical Perspectives

In this section, we delve more into social theory and recent studies in order to understand the relationship between collective and individual engagement. We attempt to formulate a perspective that can account for changes in engagement over time, address the dialectical relationship between the individual and the collective, and elucidate the interrelationship between different dimensions of engagement. We argue that emotional energy (Collins 2004) is a necessary ingredient for engagement, and that its presence within classroom interactions supports student learning and participation.

Some recent studies aimed at understanding inequalities in schools emphasise the importance of a social perspective on emotional engagement, and the impact of emotions on student behaviours. For example, Rowhea Elmesky (2001) and Gale Seiler (2002) found that when students' cultural capital is not valued in science classrooms, students perceive strong boundaries between their own knowledge, values and dispositions and the cultural enactment of school science. Negative emotions ensue when this occurs, and this interferes with learning. They recommend that science curricula be changed in order to be more relevant to the interests of students in low-income urban areas. In other words, rather than focusing on why an individual student is disengaged, efforts should be made to engage the class as a whole using knowledge of students' culture in order to increase curricular relevance and encourage expression of cultural dispositions. In doing so, students begin to feel more positively about their participation in science, with the implication that positive emotions lead to greater cognitive and behavioural engagement. In another study, Elmesky and Seiler (2007) found that interest in science among urban African American students increased due to collectively generated emotions resulting from science activities that facilitated students' enacting their cultural dispositions towards movement expressiveness.

In the sociology literature, the term 'engagement' is less common than in the education research literature, but there are other concepts that have a close correspondence. Mihaly Csikszentmihalyi's (1990) concept of 'flow' is used to explain when students are caught up in an activity, absorbed and engaged. He writes that students experience flow when there is a match-up of the level of skill and the type of task, so that students are challenged enough to find the task interesting, but not so

challenged that the task seems impossible and they become frustrated. Engagement is relevant here, as one of the crucial aspects of flow is the emotions that students experience during a particular task (e.g. whether they are frustrated or confident). Flow, however, as it has commonly been applied, retains an individual focus in science education research studies even though we are of the opinion that flow can also be experienced collectively. In the classrooms in which we worked, we found that students were more willing to engage with a difficult task if they were involved in a collective experience that generated positive emotions, and less likely to engage with an appropriate task if the collective emotional engagement was absent.

We also find that the concept of flow offers only a partial approach to understanding when and how students become engaged, because there are many activities that offer a particular student a level of challenge that is appropriate to his/her skill. Appropriate challenge can be a precondition for engagement, but a theory of engagement also needs to account for why a student would become absorbed in one appropriately designed activity rather than another. Based on our research, we have come to see the role that collective emotional engagement plays in influencing students' becoming cognitively engaged in particular science-related topics or tasks.

In working to understand collective engagement, we draw on the concept of *emotional energy* (EE) and interaction ritual (IR). Collins (2004) explains that EE is the basis of why people engage in particular activities, join particular groups or develop particular identities. He argues that people are EE seekers, choosing courses of action based on their anticipation of the emotional pay-off from participation in solidarity-building interaction rituals. Collins' work emerged from Émile Durkheim's (1965) writings regarding how interaction rituals solidify group ties. He describes ritual as 'a mechanism of mutually focused emotion and attention, producing a momentarily shared reality, which thereby generates solidarity and symbols of group membership' (2004, p. 7). IRs are characterised by bodily co-presence, a build-up of mutual focus, the development of a common mood, an 'entrainment', or coordination, of body movements and speech, shared experience between participants on both an emotional and cognitive level, and boundaries to outsiders.

Apart from feelings of solidarity and an increase in positive feelings associated with the group, successful IRs also support focus on the symbols that circulated in the interaction. Symbols that are both exchanged and created become invested with emotional energy, and can be used later to generate successful IRs with others who find these symbols similarly charged. For example, after a rousing political speech, when attendees get caught up in coordinated cheering, the participants can become energised, be more likely to display signs in favour of the candidate, and be more likely to participate in the campaign. Another way to put this is that they become engaged in the political process.

Like symbols, concepts and knowledge can become invested with EE through being invoked in successful IRs. These include the ideas, concepts and language that circulate in science classrooms. The implication is that, if classroom interactions are characterised by solidarity, emotional energy will become invested in the science-related symbols and participants will be drawn to talking about science with teachers and peers. In other words, whether students choose to come to the front of

the board to do a problem or carry out a demonstration depends on their anticipation of emotional pay-off for doing these things – whether they believe that the interactions will result in high levels of EE. Kenneth Tobin (2005) argued that head nodding, humour, eye contact, body orientation, overlapping speech and the completion of each other's sentences are behaviours associated with synchrony that support the emergence of emotional engagement. While acknowledging the cultural nature of some of these behaviours, our classroom experience indicated the veracity of Tobin's general argument. From this stance, emotional engagement is primary, and informs the behavioural and cognitive aspects of engagement, rather than three separate continua.

We have been critical of methods of data-gathering that rely primarily on self-reports. Collins' theoretical work suggests that engagement is to be understood as a social occurrence embedded within interactions. Taking this view, a person's engagement in an activity needs to be understood as the culmination of both short-term and long-term previous interactions with the symbols and groups that are relevant to that activity, illustrating the limitations of time-static measures, such as self-reports which do not address how individuals are the outcomes of situations.

The Role of Collective Emotional Engagement in the Emotional, Behavioural and Cognitive Engagement of Individuals

Collins (2004) describes how EE is not only invested in symbols, but also resides in individuals who have different levels of EE that they bring to interactions. These levels of EE are expressed as pride, confidence, shame, shyness or other characteristics related to how a person approaches others. Yet these characteristics are not 'personality traits' that are static, but instead they fluctuate from situation to situation based on each person's prior experiences with IRs in particular contexts. Collins explains: 'Pride is the emotion attached to a self energized by the group; shame is the emotion of a self depleted by exclusion … nonverbal and paralinguistic measures of pride and shame can be useful as measures of high and low EE' (p. 120).

An implication of this perspective on the transferability of EE from IRs to individuals is that socially shared emotion influences individual engagement. After successful IRs that result in participants leaving with high levels of EE, these participants are likely to approach similar situations in the future with greater levels of confidence. Confidence can be seen as an indirect measure of individual emotional engagement, as it is similar to the 'perceived competence' that is used in self-report measures in other studies of engagement. This emotional engagement in turn affects behavioural and cognitive engagement in that people who are confident in a specific situation are more likely to participate actively (behavioural engagement) and engage with the content (cognitive engagement).

Collins (2004) provides an example that can illustrate the relationship between the three dimensions of engagement in his discussion of why people sometimes choose not to speak in public forums. He describes how sometimes, in academic lectures, there is a long pause before the audience offers any questions:

> The subjective experience of members in the audience at that moment is that they can think of nothing to say. Yet if the pause is broken – usually by the highest-status member of the audience asking a question – multiple hands go up. This shows that the audience was not lacking in symbolic capital, in things to talk about, but in emotional energy, the confidence to think and speak about these ideas … not that they had nothing to say, but that they could not think of it until the group attention shifted to the audience. (p. 72)

This 'group attention' changes the focus of the IR, so that the audience becomes more central, which raises participants' EE levels and therefore their confidence to speak.

In Collins' example, as well as in our own observations of science classrooms, a multidimensional model of engagement with three separate continua is not sufficient for understanding how people become engaged. Instead, we believe that collective emotional experience is primary. Our studies show that high levels of EE lead to confidence and other expressions of emotional engagement such as pride, which then support students' active participation through activities such as volunteering to help with a demonstration or using canonical science language in developing an explanation.

In applying these ideas to science classrooms, a student's demonstration of science knowledge might not be a result of students' personality traits, general interest in science, or knowledge of the material. We argue that instead, the participation is an outcome of collective emotion generated in IRs. One relevant factor, similar to Collins' example of the academic lecture, is whether the focus of group attention is on the teacher or on the 'audience' – the students. Referring to the earlier example of Carla who participated more frequently during the unit in balancing equations, her increased participation was not because, in some abstract way, she believed that she was better at balancing equations than she was at other tasks in science. Instead, it was because, during interaction rituals associated with balancing equations, there was a shift in attention from the teacher to the students when the students solved problems at the board with the support of their peers (Olitsky 2007). The collective emotional experience generated when students helped each other during balancing equations IRs contributed to increases in levels of confidence for many students, and therefore their willingness to engage with the material on a cognitive level.

An important feature of this situation is that the teacher's efforts to help her students learn the material were effective because she provided a structure with the goal of establishing a positive emotional starting point, an essential ingredient for student success. According to Collins (2004), part of this emotional experience involves the establishment of a context that is well bounded and has a mutual focus that effectively secures the group's attention. Balancing chemistry equations, science demonstrations or any shared experience can provide such a starting point. The initial question that can frame planning for such an IR is not a cognitive one (e.g. 'What is the prior knowledge that students bring to a learning context and how can

I access this knowledge when teaching this material?'), but an emotional one ('How can I try to optimise the initial emotional experience for students when introducing this material?').

Certainly Ms Loman's providing students with an effective method for approaching problems involving balancing equations was essential for the IR to take place, as it would not have occurred if the students had no idea how to approach such problems. We are not arguing that these skills are unnecessary, and that it is only the emotional component that matters. Instead, we are arguing for the complementarity of emotion and skills in order for the instruction to be effective. In teacher education programmes, attention is often given to assessing student knowledge and drawing on this knowledge in order to design instruction. Our research suggests that, in the beginning of a school year or a unit in which new material is introduced, it is also vital to provide initial emotionally engaging experiences that establish boundaries around the class as a group.

In Tracey's classroom, the shared observational experience of students in the class as they participated in the science demonstrations about the gas laws allowed them to feel confident that each of them had access to the same experiences and therefore could make equally valid observations. Even if a specific student was not one of those to propose an explanation of the observed phenomenon using molecules and atoms, he/she felt more confident about his/her ability to make connections between the explanations and these shared observations (Milne and Otieno 2007). Science demonstrations are focused whole-class interactions that are constitutive of a fluid type of ritual that exists on a continuum between social situations and formal rituals. They are structured by some ritual elements, such as mutual focus, group assembly, barriers to outsiders and shared mood, but the application of these elements depends very much on the context and on the actions of agents including students and the teacher. Through use, demonstrations became ritualised as IRs and help to build student expectations that something interesting or contradictory was going to happen and contribute further to positive emotions in the classroom.

We have described IRs that are solidarity producing. However, other rituals, such as the 'order giving' rituals of some typical classrooms, can support a gain in EE for the order giver and a loss for the order taker, without actually increasing feelings of group membership (Collins 2004). One example would be a lecture or reprimand by a supervisor. After experiencing such a loss of EE and, therefore, shame, individuals might shy away from these groups and the use of symbols invoked during those interactions. A student who experiences science classrooms as order-giving rituals, in that teachers or other students do not accept her/his contributions as worthwhile, can carry low levels of EE into future interactions involving science. An apparent lack of confidence or interest can present as an 'individual' characteristic, but it is a product of the situation (i.e. an outcome of low levels of EE generated in previous interactions). Another route to an individual's loss of confidence is feeling excluded from an IR in which most of the participants experience solidarity and raised levels of EE. Participation in a dynamic conversation in which one does not know anything about the topic could result in this type of EE loss, thus highlighting the

importance of science demonstrations as a shared experience in Milne and Otieno's (2007) study.

From the teacher's perspective, the confident student who is charged with EE appears to be more engaged. That student will freely inject his/her contributions with the expectation of solidarity, which Collins (2004) describes as 'smooth flowing rhythmic coordination in the micro rhythms of the conversational interaction; it gives the feeling of confidence that what one is doing, the rewarding experience that one's freely expressed impulses are being followed, are resonated and amplified by the other people present' (2004). Similarly, if the whole class, or even most of the class, is feeling high levels of EE and is confident in that setting, then it would seem to a teacher that the class is collectively engaged. When teachers describe a 'good discussion', in which most of the students provide contributions, take risks with their comments, ask questions and develop explanations, it is likely that most of the students anticipate high levels of EE in these interactions and so are more willing to speak. Other contexts in which we have observed this happening include students giving each other high-fives when they successfully complete a complex task, such as working out the chemical formula for a compound or completing a half-life problem (Milne and Ma 2008). The primacy of collective emotional experience and the power of confidence can be used to help in understanding the differences in engagement that were observed by the researchers conducting these studies.

An assumption that underlies some of the previous research on engagement is that past experiences of success at an activity will lead to a person's confidence in his or her abilities. The implication is that confidence emerging from success will contribute to the student being willing to verbally participate in class discussions, come to the front of the class to use the chalkboard or demonstration, use science language, or exert effort on a test. Yet our research has shown that prior success might not be sufficient for the emergence of either collective or individual engagement. Rather, the accompanying emotions are more predictive of engagement. Positive emotions can accompany actual success, but not always. For example, in City Magnet during the balancing equations, it was the harder problems at which students were initially *unsuccessful* that elicited student cooperation and positive emotions, rather than the easier problems that students solved successfully (Olitsky 2007).

Interaction Rituals and Engagement: Implications

Our studies have shown how collective emotions generated through successful IRs have transferred to individuals' increased confidence and pride, and have led to changes in different dimensions of student engagement within two science classrooms in Philadelphia. An implication of this research is that collective emotions can have a powerful impact on collective engagement and on individual identity, class participation and learning. Conversely, when individuals develop increased pride and confidence related to science participation, IRs in class have a greater chance of success. The similar findings about engagement from two very different

schools, one selective and the other an urban neighbourhood school, support the primacy of the social and emotional aspects of engagement in influencing what has typically been described in previous research as cognitive engagement.

For teachers wishing to foster positive classroom changes, these studies suggest the need to provide a shared experience that is available to all within a context that has clear boundaries and excludes outsiders. Establishing this type of situation allows the development of group co-presence that supports students in monitoring each other's emotional states. From this structure, it is possible to build an intensity of group emotion evidenced by synchronous shared observations and explanations, students completing each other's sentences, overlapping or latched speech between participants and shared excitement. In a classroom, positive emotional energy builds from successful interactions into interaction ritual chains that support cognitive and behavioural aspects of engagement. This energy is available to everyone in the class who becomes caught up in the collective emotional experience.

Evidence of student engagement can include actions such as eye gaze, overlapping speech, entrainment in conversation and shared action. Cognitive aspects of interactions indicative of engagement can include participation in the use of language associated with science knowledge, an interest in asking questions, a willingness to focus on observation as well as explanation, and a desire to work together to construct science understanding. Emotions are experienced internally and exhibited so that they are available to others. We have argued that establishing collective engagement requires specific classroom structures. However, the agents of teacher and students are central to the establishment of interaction ritual chains and emotional energy that are essential for the expression of collective and individual student engagement.

Going back to Herrenkhol and Guerra's (1998) study, their definition of engagement was based primarily on cognitive types of actions that involve 'monitoring one's own comprehension of another's ideas, coordinating theories with existing evidence, and challenging the claims put forth by others' (p. 441). Participation in these types of tasks requires risk-taking in that students need to be willing to share their own conceptions and ideas. They, therefore, require some level of confidence in engaging in science discourse. We argue that it is the collective emotional experience that leads to individual student confidence, thereby making cognitive engagement possible. The link between confidence and these higher-level cognitive tasks further lends support to our argument that emotional energy provides the basis for cognition and should be the initial focus of educational practice.

Additionally, the view of engagement as stemming from collective emotions can add an important piece to perspectives of engagement that portray it as integrally tied to an individuals' participation within collective, goal-oriented activity, such as Engle and Conant's (2002) *productive disciplinary engagement.* An individual's participation within a discipline, which is a similar conception to the 'community of practice' that Jean Lave and Etienne Wenger (1991) describe, requires not only skill, but also the desire to be part of the group and manipulate its symbols, the confidence that one can participate in this group, and an identity associated with this group. All of these are outcomes of high levels of EE. An individual, therefore,

needs to have participated in previous solidarity-producing interactions in order to be imbued with the EE that is a necessary precondition for productive disciplinary engagement. Similarly, Palincsar, Anderson and David (1993) describe the importance of flexibly adapting intellectual roles so that students do not apply science knowledge in a rote manner. Rather, students need to appropriate the science-related symbols and tools for their own use and develop fluency with them. This deep level of participation necessitates positive emotions, as high levels of confidence are necessary in order to take the risk of manipulating symbols in creative ways.

Overall, we argue that collectively generated emotions are a precondition to the different dimensions of engagement required for effective science teaching and learning. These emotions affect individual levels of EE, which have implications for student confidence and, therefore, learning. Conversely, when individuals emerge from IRs with high levels of EE, they can help initiate or participate in future solidarity-building IRs related to science. Assumptions that sometimes permeate some academic and non-academic discourse include views of individual students as either 'engaged' or 'disengaged', and views of subject matter as either interesting/relevant or uninteresting/irrelevant. In contrast, our research supports a focus on interactional situations and how EE transfers between the individual and the collective.

We argue that attention to emotion-related outcomes needs to inform all aspects of instruction. Individuals who emerge from series of solidarity-producing classroom interaction rituals will develop the confidence, desire and energy to expend the effort in order to engage with science content and to participate in communities centred on science.

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