Supporting affective communication in the classroom with the Subtle Stone

Madeline Alsmeyer née Balaam*

Interact Lab
School of Informatics
University of Sussex, UK
E-mail: madela@sussex.ac.uk
*Corresponding author

Rosemary Luckin

London Knowledge Lab
Institute of Education
University of London, UK
E-mail: r.luckin@ioe.ac.uk

Judith Good

IDEAs Lab
School of Informatics
University of Sussex, UK
E-mail: J.Good@sussex.ac.uk

Eric Harris

Interact Lab
School of Informatics
University of Sussex, UK
E-mail: erich@sussex.ac.uk

Abstract: This paper highlights the difficulties intrinsic to gauging a student's affective state. We argue that there is a need to further support the emotional experiences of students within settings such as the classroom. Findings from our first study illustrate the inherent difficulties of understanding the emotional experiences of students within the classroom context. For example, we identify low correlations between physical expressions of emotion and the emotions reported by the students.

Findings from the first study were used to define a set of design requirements for the Subtle Stone, a device which bridges the emotional communication gap between teachers and their students. A second study saw eight high school students use a set of Subtle Stones throughout their learning. The qualitative analysis presented here focuses on the Subtle Stone as a flexible new tool for capturing self-reports of emotional experience in real time throughout learning experiences. The analysis indicates that the Subtle Stone engenders a sense of private communication between student and teacher, as well as suggesting that the Subtle Stone may raise a student's awareness about her own emotional experiences.

Keywords: affect; emotional experience; education; classroom contexts; Subtle Stone; measuring emotion; emotional communication; learning technologies.

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Biographical notes: Madeline Alsmeyer née Balaam is a Research Fellow in the Interact Lab at the University of Sussex, UK. Her research interests are interdisciplinary, spanning HCI, psychology and education, and focusing in particular on how technology can be appropriately designed to support the subtle undercurrents of face-to-face interactions. She has recently completed her PhD at the University of Sussex. This work explored how the emotional experiences of students in the classroom might be linked to the context constructed around the learning task. As part of this work she developed a tangible technology, the Subtle Stone, which allows students to privately communicate their emotional experiences with their teacher throughout their learning experiences.

Rosemary Luckin is a Professor of Learner Centred Design at the London Knowledge Lab, a Visiting Professor in Informatics at the University of Sussex, UK and an EPSRC Advanced Research Fellow. Her research explores how to effectively scaffold learning across multiple technologies, locations, subjects and times. This work is interdisciplinary and encompasses education, psychology, artificial intelligence and HCI. It investigates the relationship between people, the concepts they are trying to learn and teach, the environments with which they interact and the resources at their disposal. Professor Luckin is also a non-executive Director of Becta (the UK government agency leading the national drive to ensure the effective and innovative use of technology throughout learning) and she chairs their Research Advisory Group.

Judith Good is a Senior Lecturer in the Informatics Department, University of Sussex, UK. Good is also Director of the IDEAs Lab, which is part of the Human Centred Technology Group (along with the Interact Lab). Prior to this, Good was an Assistant Professor in the Organizational Learning and Instructional Technology (OLIT) programme at the University of New Mexico and, before that, worked as a Research Fellow at the University of Edinburgh (where she did a PhD in Artificial Intelligence). Good is interested in any uses of technology that incite people to engage with learning, and do so in meaningful ways. Specifically, Good focuses on the use of immersive virtual environments for learning, educational simulations, constructivist and constructionist learning environments, the design of visual programming languages for fostering understanding, and the use of game creation environments to foster children's skills in programming, media creation and narrative.

Eric Harris is both a Research Fellow in the Interact Lab as well as Technology Facilitator working within InQbate. Harris designs and builds devices and installations, which support new forms of human computer interaction and is particularly interested in bringing his ubiquitous computing expertise into the In-Qbate space. Harris comes from an industrial background of robotics and machine vision where he filled both Technical and Operations Director positions within a blue chip packaging company. Most recently his work at the University of Sussex, sponsored through the EPSRC funded Equator project, has been the investigation of both hardware and software toolkits, used to enable experience builders to create their own arrangements of both existing

and emerging technologies. He is also interested in the deployment and use of wireless pervasive devices to see how they might embellish user experience within augmented realities.

1 Introduction

Emotions are considered essential to students' and teachers' effective participation in instructional interactions (Meyer and Turner, 2006; Pekrun *et al.*, 2002). There is a wealth of research developing tutoring systems and educational aids that embody not only cognitive intelligence, but also emotional intelligence (Conati *et al.*, 2003; Del Soldato and du Boulay, 1995; Graesser *et al.*, 2007; Kaliouby and Robinson, 2005; Kort *et al.*, 2001; Porayska-Pomsta and Pain, 2004; Rebolledo-Mendez *et al.*, 2005; Zhang *et al.*, 2004). In general these systems have been designed to support a one (computer tutor) to one (student) tutoring interaction. The prevalence of this approach is not surprising given that one of the real advantages offered by these types of tutoring systems is their ability to provide *individualised* learning experiences based on a student's cognitive abilities, and now a student's emotional state.

Yet, most education (particularly formal, standardised education) is not conducted on a one (tutor) to one (student) basis, but often in the format of one (teacher) to many (students). Nevertheless, the development of technologies to support emotions within this category of tutoring interaction and learning context has been largely ignored. This lack of research is perhaps due to the assumption that humans are already good at understanding and supporting the emotional experiences of others (Goleman, 1996; Picard, 1997). It therefore follows that any technology designed to do this job will be superfluous in a learning context where there are many other humans (both students and teachers) available to support the emotional experiences of students within the context.

The work described in this article explores the issues surrounding measuring and communicating emotions within the classroom context, discussing whether there is indeed a need for technology which supports emotions within these learning contexts and what shape this technology might take.

This paper will start by outlining the implications of conducting research within the classroom, and examines the current methodologies for interpreting emotional experiences and affect in terms of their hypothetical application within this setting. Following this we will describe a study conducted in autumn 2006 which applied a number of emotion detection/recognition techniques within the classroom. The results of this study illustrate why learning contexts could benefit from technologies that support the recognition of emotions within the classroom. We will then go on to describe the Subtle Stone, a piece of technology designed specifically for use within learning contexts such as the classroom, which aims to support both emotional recognition and communication between the students and their teacher. Additionally the tool can act as a device for researchers interested in exploring the emotional landscape of the classroom.

In the last section of this paper we will describe a study which evaluated the use of the Subtle Stone technology in the classroom, we focus in particular on its practicalities as both an educational tool supporting teachers and students in their endeavours

and additionally, as a research tool supporting researchers as they attempt to further investigate the links between emotion and learning, in particular, within formal educational settings.

2 Researching emotions within the classroom

To situate the discussion of available methodologies for interpreting the emotional experiences of students within the classroom it is vital to understand the constraints of the classroom as a research context. Most high school classrooms are busy, noisy, messy, complicated environments, normally accommodating between 20 and 30 students per class. The students are not isolated in their learning experiences, in fact they each play a part in determining the dynamics of the classroom, and furthermore each others' cognitive and emotional experiences.

Whilst working within the classroom provides an ecologically valid, live learning environment within which to explore the various aspects of the relationship between emotion and learning, it also constrains the way research can and should be conducted.

A primary issue of working within the classroom is the need to fit whatever studies one wishes to complete into the existing timetable of the school. This often constrains the amount of time available for briefing students and setting up studies as well as the time available for post study interviews and debriefing. Furthermore, anything done within the classroom that is outside of the planned activities devised to support the students' curricular needs should distract the students within the classroom as little as possible.

Integrating technology within the classroom can be a challenge. Not only does one need to ensure that its implementation does not distract students from their learning, but also, its implementation needs to be practical. There is generally not a great deal of time available for setting up technology, and furthermore little sympathy or support for technology which does not work quickly and reliably.

Working with younger students also places some restrictions on investigating emotions in the classroom, namely the language used in any tool enquiring into emotional experience needs to be produced in a manner that will be meaningful to those participating. Of course, within this particular focus of research, questions will also be raised regarding how capable certain age groups are, particularly the under 14s, at both recognising emotional states in themselves, and understanding what this emotional state means in terms of their learning and overall educational experience.

3 Tools for collecting affective data

In current educational research three main methods have been employed for collecting information about a student's emotional state. These are:

1 biometrics

2 analysis of the student behaviour

3 student self reports of emotional experience.

3.1 Physiological biometric data

There are currently a number of projects investigating the use of biometric data (for example heart rate, galvanic skin response, body temperature) as a method for predicting the emotional state of a student (Conati *et al.*, 2003; Kort *et al.*, 2001; Oehme *et al.*, 2007). These techniques have shown themselves to be relatively reliable within laboratory settings (often generating accuracy rates level with an average human's emotional detection ability (Picard, 1997)), however it is yet to be seen whether these measuring devices will remain reliable when taken out of the laboratory and into classroom-type environments.

The issue with applying this method within the classroom is essentially related to the messiness of this type of learning context. Whilst it is possible to correlate changes in biometric data with changes in emotional states throughout an experience within a laboratory setting where variables can be comparatively easily controlled, the same recorded changes within a classroom context cannot be so easily related to an emotional change. Instead they could also be a result of something else changing within the context, for example, who the student is sitting next to, what the room temperature is, or whether they had a class in physical education prior to the session.

Furthermore, whilst these methods might be reliable and non-intrusive with respect to the learning experience of the student (*i.e.*, the student does not need to continually evaluate their emotional state), they could, in some circumstances, be considered personally intrusive.

3.2 Behavioural data

The analysis of a student's behaviour can also be used to detect the emotional state of a student (for example, Del Soldato and du Boulay, 1995; Kaliouby and Robinson, 2005; Litman and Forbes-Riley, 2004; Rebolledo-Mendez *et al.*, 2005; Zhang *et al.*, 2004). Behaviours analysed include interpreting the amount of help the student has requested, the level of task they have chosen to complete, and, analysing the conversation or body language of a student.

Observations can be either made in real time, in which case the observations can create an observer effect (however recent methodologies claim to reduce these effects through the use of peripheral observations (Baker *et al.*, 2004)), or made retrospectively commonly using video data as a stimulus.

These methods of predicting the affective state of a student are relatively non intrusive to the flow of the learning, yet the same issue arises as to whether the results obtained within experimental learning contexts (predominantly one to one computer tutoring) can be generalised up and out of this particular learning context and into learning contexts more like the classroom.

Specifically, if emotions are considered to be socially constructed (Schutz *et al.*, 2006), it is possible to imagine situations (for example a classroom context), where some cultures prefer not to display, either through conversation, body language or facial expression, certain emotions (for example, anger, and in some circumstances enthusiasm or interest).

Research also suggests that humans interact with fewer inhibitions when working with computers than they do when working in face to face situations (Bordia, 1997), and are less likely to conform to social norms. This may mean that the ways in which humans

feel comfortable expressing emotions when working with computers could be very different from the types of behaviours used by humans when expressing felt emotions whilst working with other humans.

3.3 Self reports of emotional experience

Both physiological biometric data and observational behavioural data tell the story of emotional experience from an objective perspective, where the student's own subjective meaning-making beliefs about their own emotions are sidelined. Self report methodologies in contrast are subjective and place their focus on the student's beliefs about their emotions and their own meaning making systems. Self report as a methodology is traditionally the most common emotional data collection method to be used within classroom educational settings (for example Ainley, 2006; Meyer and Turner, 2006; Pekrun *et al.*, 2002).

There are a number of widely acknowledged issues relating to collecting self reports of emotional states during a learning experience. For example, by asking a student to consider and reflect on their own emotional state, a researcher may inadvertently cause the student to change their emotional state. In addition the most commonly used methods for eliciting a self report during the experience (questionnaires) are likely to interfere with the learning of the student when administered in real time.

Retrospective reports of emotional experience although less intrusive to the learning experience, may have reduced accuracy as students' memories of their experiences become less clear. Or indeed a student may have further reflected on her experiences resulting in the student arising at a new vision of what her experiences were.

As demonstrated in this short review of common research techniques, there is as yet no single method through which researchers interested in supporting emotions 'in the wild' may elicit the emotional experience of a student reliably, non-intrusively and practically. However, it may be possible to obtain a clearer picture of students' emotional experience in the classroom by combining a number of these research techniques.

The next section will describe a study that examined the reliability and feasibility of triangulating research methodologies (using two types of observational data and one type of self report data) to investigate emotional experiences within the classroom.

4 Getting under the skin of foreign language students in the classroom: a first study

This study began the examination of the research methodologies, probes and types of language that are appropriate for use with a teenage audience (13–17 years olds) when discussing or collecting data regarding the students' emotional experiences of foreign language learning.

Foreign language classes are the focus of this study since foreign language learning is a subject that is likely to evoke emotional experiences, as unlike many other subjects, the learning of a language is an inherently social process. This all but makes certain that mistakes will be made and made in a fashion that can be easily observed by others within the learning context. Furthermore, the process of learning a language requires an

individual to embrace and identify with another culture. Whilst for some students this process of developing another persona and learning and identifying with another group is positive and inherently exciting, for others it can be deeply threatening (Oxford, 1999).

4.1 Participants

The study was carried out in a British school, with 3 separate German language classes in 2 separate school years, year 9 (13–14 year olds) and year 12 (16–17 year olds). A total of 20 students in 10 pairs took part. Six pairs of students were selected from the year 9 classes, whilst 4 pairs of students took part from the year 12 class. The 6 pairs of students who participated in the study from the year 9 classes were selected at random at the start of each lesson, whereas the selection process for the year 12 class was exhaustive: there were only 8 students taking the class.

4.2 Procedure

The study took place over the space of a month in the autumn/winter term of 2006. The study investigated the changes in experience based on an adapted set of the learning emotions identified by Pekrun *et al.* (2002). These were: motivation, relief, enjoyment, hope, pride, anger, anxiety, confidence, hopelessness, embarrassment and boredom. The terms confidence, motivation and embarrassment were added to Pekrun *et al.*'s original set since the researchers felt that confidence and embarrassment may be particularly relevant to foreign language learning instructions. The addition of motivation enabled the exploration of the relationship between emotional and motivational processes.

4.3 During class

Two students were video recorded per classroom session. Each member of the pair was required to complete a verbal scale-based questionnaire (from 'not at all X' to 'extremely X') to report how they were feeling at the outset of the classroom session. This questionnaire was created in order to elicit a self report of a student's emotional experience as quickly and as simply as possible so as not to interfere with their learning experience. For more information about the construction of this questionnaire please see Alsmeyer *et al.* (2007).

Two pieces of footage were recorded for each student; each recording constitutes what will be referred to in this article as a learning interaction. One recorded learning interaction focussed on a student as they participated in a verbal activity (generally with the teacher) in front of the whole class. The second recorded learning interaction focussed on the pair of students as they participated in a pair-based verbal activity (and not under the observation of the rest of the class). Each of these learning interactions lasted between one and a half and two and a half minutes.

4.4 After class – student participants

The students completed a stimulated recall interview individually within one week of the classroom activity. During this interview the students were shown the recorded learning interactions. Each video clip was paused once every 30 sec, at which point the student was asked to recall how they remembered feeling by reporting for each emotion whether

they recalled feeling more of the emotion, less of the emotion, or the same level of the emotion in comparison with how they reported feeling at the beginning of the lesson. A semi-structured interview was also conducted to capture thoughts, feelings and suggested changes with respect to the use of the tool and methodology.

4.5 After class – observers

At a later date two observers viewed the video data in order to give a third person interpretation of the students' emotional experiences. Observer 1 is a trained and experienced tutor in higher education and she viewed the entire data set. Observer 2 was the teacher of both the classes that took part in the study. Due to constraints on his time he viewed 10% of the data set.

The interpretations in emotional experience were collected using the same method as the students' own recollections of experience. Each learning interaction viewed by an observer was paused every 30 sec at which point the observer was asked to give his or her impression for each emotion of whether he or she thought the student felt more of the emotion, less of the emotion or the same level of the emotion in comparison with how the student had reported feeling at the outset of the lesson.

4.6 After class – behavioural data analysis

Throughout the study video data was collected, recording the facial expressions, body language and vocalisations of the students. After the study, the video data was coded by a researcher along fixed categories within four dimensions of possible physical manifestations of emotional experience. These were:

1 changes in facial expression (frowning, smiling, sneering, raising the eyebrows and furrowing the eyebrows)

2 changes in body language/posture (touching the face or hair, turning away, folding arms)

3 changes in vocalisations (fast speech, slow speech, use of fillers and long pauses)

4 eye gaze direction (whether the student was looking towards or away from their conversational partner).

The coding was conducted using Anvil which allowed the researcher to record which behaviours were exhibited by a student during a learning interaction, when the student began exhibiting a particular behaviour and when the student ceased to exhibit the behaviour.

4.7 Results

The results from each of the three different data sources collected throughout the study will be presented in turn. First, data collected through observations and interviews with the students will be presented, second, we will draw comparisons between the observer reports and student self reports of emotional experience, and finally a comparison of the student self reports of emotional change and the behaviourally coded video data will be described.

Although the learning interactions varied in length, all were at least one and a half minutes. Therefore only the first one and a half minutes of each learning interaction have been coded to allow for the use of absolute frequencies.

4.8 Incidental observations and interviews

Self reporting methodologies and research tools must be understood by every student if they are to provide useful information to the teacher or Intelligent Learning Environment. However the results generated through observations as the study was conducted, along with the interview data, suggest that some students between the ages of 13 and 17 found the fairly abstract emotional terms used in the self report tool such as motivation and anxiety difficult to understand. In fact throughout the study 25% of the students asked for clarification of at least one of the emotional terms. Interestingly, there were also emotional terms used within the tool (for example anger), which most students reported never experiencing at school.

4.9 The relationship between the students' self reports of emotional experience and the observers' beliefs

Cohen's Kappa Coefficient was used to calculate the inter-rater reliability between the students' self reports of emotional experience and the interpretations of emotional experience provided by Observer 1 and 2.

Table 1 The Cohen's Kappa Coefficient values calculated between the students' self reports of emotional experience and Observer 1's interpretations of emotional experience

Motivation	*Relief*	*Enjoyment*	*Pride*	*Hope*	*Confidence*	*Anger*	*Anxiety*	*Embarrassment*	*Hopelessness*	*Boredom*
–0.14	0.11	0.10	0.02	0.17	0.08	0.05	0.08	0.06	0.03	0.11

First, a Cohen's Kappa value was calculated for all pairings of the students' self reports of emotional experience and Observer 1's interpretations of the students' emotional experiences. The Cohen's Kappa values for each of these calculations was found to be low indicating that there is little agreement between what the student reported as their emotional experience over a learning interaction and what Observer 1 believed the student to be experiencing throughout the same learning episode.

In order to investigate whether this low agreement between Observer 1 and student was due to Observer 1 not having implicit knowledge of the subtle cues that a student might use to convey their emotional experiences within the classroom, the teacher (Observer 2) was asked to give his interpretations over 10% of the video data. Again, the Cohen Kappa coefficient was used to calculate the level of agreement between Observer 2's interpretations of a student's emotional experience and the student's self-reports of emotional experience. Again, the Cohen's Kappa coefficient comparing the reports for each emotion were found to be low, with the exception of confidence ($k = 0.34$) and hope ($k = 0.21$) which Observer 2 was found to be slightly more reliable at interpreting.

Table 2 Cohen's Kappa Coefficient values indicating the level of agreement between the teacher's belief about the emotional experience of the student in contrast with the students' beliefs about their emotional experience

Motivation	*Relief*	*Enjoyment*	*Pride*	*Hope*	*Confidence*	*Anger*	*Anxiety*	*Embarrassment*	*Hopelessness*	*Boredom*
–0.09	0.12	–0.18	0.10	0.21	0.34	0.07	0.06	–0.16	0.06	–0.07

Finally Cohen's Kappa coefficient values were computed for the pairings of Observer 1 and Observer 2's beliefs about the students' emotional experiences. The results in Table 3 show that there is a stronger agreement between what Observer 1 and Observer 2 perceive the emotional experience of the students to be. In particular Observer 2 and Observer 1 show a moderate level of agreement with regards to the students' boredom throughout a learning experience (K = 0.44). Observer 1 and Observer 2 also show moderate agreement in their interpretations of student enjoyment (K = 0.29) and student hope (K = 0.23).

Table 3 Cohen Kappa Coefficient values indicating the level of agreement between the teacher's belief about the emotional experience of the student in contrast with the independent observer's belief about the student's emotional experience

Motivation	*Relief*	*Enjoyment*	*Pride*	*Hope*	*Confidence*	*Anger*	*Anxiety*	*Embarrassment*	*Hopelessness*	*Boredom*
0.17	0.19	0.29	0.16	0.23	0.03	0.00	0.06	0.15	0.18	0.44

4.10 Correlations between the students' self reports of emotional experience and the coding of changes in body language, facial expressions and vocalisations

The average number of instances of each coded behaviour exhibited within a learning interaction by the total set of 20 students in 40 learning interactions within the classroom is detailed in Table 4. This data indicates that these students produced relatively few physical expressions of emotion within the formal classroom setting.

The non-parametric Spearman's Rank-Correlation test was applied to the data to explore the strength of any correlations found between the emotional experience as reported by each individual student and the volume and type of physical manifestations of emotion expressed by a student.

Table 4 The average number of occurrences of each coded physical manifestation of emotion within a learning interaction

Slow speech	*Fast speech*	*Filler*	*Long pause*	*Arms folded*	*Turning away*	*Touching face or hair*	
1.93	0.00	2.25	0.98	0.73	0.48	1.78	
Smile	*Frown*	*Eyebrows raised*	*Eyebrows furrowed*	*Open mouth*	*Sneer*	*Looking away from partner*	*Looking at partner*
2.15	0.40	0.95	0.25	0.23	0.40	9.55	8.35

The mode report for each of the reported emotions given by a student within the learning interactions (*e.g.*, did the student generally report feeling more, the same, or less motivated throughout the learning interactions?) gives the trend in emotional experience. This value was correlated with the total number of each of the coded physical behaviours exhibited during that learning experience.

In total five statistically significant correlations were found between possible physical manifestation of emotional experience and trends in emotional experience as reported by the students, each related to movements of the eyebrow.

The raising of the eyebrows shows three statistically significant correlations with trends in emotional experience. Enjoyment was found to be positively correlated with raising the eyebrows ($r_s = .497$, $N = 20$, $p = .026$), embarrassment was found to be negatively correlated with the raising of the eyebrows ($r_s = -.528$, $N = 20$, $p = .017$), and finally anger was negatively correlated with raising the eyebrows ($r_s = -.460$, $N = 20$, $p = .041$).

The furrowing of the eyebrows was found to be statistically significantly correlated with two trends in emotional experience. Enjoyment is positively correlated with the furrowing of the eyebrows ($r_s = .465$, $N = 20$, $p = .039$), and boredom was negatively correlated with furrowing the eyebrows ($r_s = -.548$, $N = 20$, $p = .012$). The entire correlation matrix can be found in Table 5.

4.11 Discussion of findings

A quarter of students asked for clarification over at least one of the terms used within the questionnaire tool which indicates that an initial pilot study may have been useful in ensuring all the emotional terms used in this study were appropriate for these students learning within this particular school context. This in turn suggests that tools used for emotional research purposes within education must be flexible if they are to be appropriate for each individual group of students.

Table 5 The correlation matrix detailing the general trend in emotional experience against the total number of physical manifestations of emotion coded within the learning experience

Emotion	*Slow speech*	*Filler*	*Long pauses*	*Arms folded*	*Turning away*	*Touching face or hair*	*Smile*	*Frown*	*Eyebrows raised*	*Eyebrows furrowed*	*Open mouth*	*Sneer*	*Looking away partner*	*Looking at partner*
Motivation	0.207	–0.112	–0.01	–0.079	0.091	–0.237	–0.397	–0.103	–0.211	0.016	0.053	0.303	0.25	–0.144
Sig (2-tailed)	0.38	0.639	0.965	0.739	0.703	0.313	0.083	0.664	0.371	0.946	0.824	0.194	0.287	0.543
Relief	–0.32	–0.404	–0.059	–0.007	–0.347	–0.281	0.082	0.337	0.243	0.117	–0.026	–0.094	0.177	0.347
Sig (2-tailed)	0.169	0.077	0.805	0.978	0.133	0.23	0.73	0.146	0.301	0.624	0.914	0.694	0.456	0.134
Enjoyment	0.105	0.036	0.43	0.089	–0.176	0.078	0.141	–0.231	0.497*	0.465*	0.261	–0.168	–0.157	0.004
Sig (2-tailed)	0.658	0.879	0.059	0.709	0.459	0.744	0.553	0.326	0.026	0.039	0.266	0.479	0.509	0.988
Pride	0.161	–0.185	–0.075	0.262	–0.031	0.048	–0.006	–0.197	0.206	0.085	0.326	0.024	–0.201	–0.058
Sig (2-tailed)	0.499	0.435	0.752	0.265	0.896	0.841	0.98	0.406	0.384	0.722	0.161	0.919	0.396	0.807
Hope	0.187	–0.031	0.346	–0.038	0.178	–0.19	–0.252	–0.044	–0.13	–0.215	0.161	0.377	–0.145	–0.11
Sig (2-tailed)	0.429	0.897	0.135	0.873	0.454	0.423	0.284	0.855	0.585	0.362	0.497	0.101	0.543	0.644
Confidence	0.281	–0.04	0.238	0.001	–0.084	0.094	–0.009	–0.216	0.146	0.024	0.024	0.178	–0.004	0.16
Sig (2-tailed)	0.229	0.865	0.313	0.995	0.725	0.694	0.97	0.361	0.539	0.919	0.919	0.452	0.987	0.499
Anger	–0.186	–0.015	0.005	–0.098	0.027	–0.277	–0.34	0.074	–0.460*	–0.137	–0.137	0.078	0.059	0.246
Sig (2-tailed)	0.431	0.948	0.984	0.682	0.911	0.237	0.142	0.756	0.041	0.564	0.564	0.743	0.806	0.297
Anxiety	0.023	0.274	0.045	–0.033	0.037	–0.175	–0.014	–0.02	–0.415	–0.18	–0.051	–0.281	0.087	–0.125
Sig (2-tailed)	0.922	0.242	0.85	0.889	0.876	0.461	0.952	0.932	0.069	0.447	0.831	0.23	0.716	0.6
Embarrassment	–0.196	–0.085	–0.318	0.105	–0.046	–0.125	–0.418	0.056	–0.528*	–0.222	–0.297	–0.063	–0.076	–0.038
Sig (2-tailed)	0.408	0.721	0.172	0.66	0.846	0.599	0.066	0.816	0.017	0.348	0.204	0.793	0.75	0.874
Hopelessness	–0.143	0.294	0.037	–0.19	0.175	0.038	0.1	0	–0.171	0.094	–0.178	–0.169	0.246	0.135
Sig (2-tailed)	0.547	0.208	0.876	0.423	0.462	0.873	0.675	1	0.471	0.693	0.452	0.477	0.296	0.57
Boredom	0.091	0.132	–0.349	–0.115	0.101	–0.09	–0.243	0.054	–0.407	–0.548*	–0.268	0.148	0.227	0.031
Sig (2-tailed)	0.704	0.578	0.131	0.63	0.671	0.706	0.302	0.822	0.075	0.012	0.254	0.533	0.336	0.896

Note: The correlation is significant at the 0.5 level (two-tailed) if marked with a *.

The findings from this study go some way towards illustrating the challenge entailed in interpreting a student's emotional experience within learning contexts such as the classroom. Whilst each of the students in this study reported experiencing emotions and changes in emotions during a learning episode, these emotional experiences were not often strongly correlated with easily observable changes in body language, facial expressions, vocalisations or direction of eye gaze. Those correlations found to be significant were often single and subtle behaviours (each of the five significant correlations were related to movements of the eyebrow) that may be difficult to track within busy learning environments, particularly for teachers already focussed on the process of teaching and managing the classroom.

Rather than using coding schemes where observers are trained to identify emotional experiences based on specific and agreed changes in facial or bodily expression (such as Ekman and Friesen's (1978) Facial Action Coding System), we instead used two observers who utilised their own natural, and individual understanding and recognition of emotion to code the emotional experiences of the students. As a result we are able to begin to explore the perception of students' emotional experiences from the viewpoint of the teacher, rather than the highly trained researcher.

The analysis presented earlier calculating the similarities between the judgements made by the students themselves, Observer 1 (a trained higher education tutor) and Observer 2 (the students' teacher) undermine the assumption commonly made that humans (and particularly human tutors) are good at interpreting the emotional experiences of others. Our results showed that neither Observer 1 with little face to face experience of working with the students, nor Observer 2, the teacher with up to three years experience of teaching the students, could reliably interpret the students' emotional experiences.

A common criticism of self report methodologies for collecting data about emotional experiences is the notion that we as humans are not always able to understand our own emotional experiences, let alone describe them accurately. Confounding this further is the lesser practise and ability in younger people to fully understand and articulate their emotions (Zeman *et al.*, 2007). It is therefore possible that the low levels of agreement found between each of the observer's interpretations and the students' interpretations of their own emotional experiences is due to the students misinterpreting or misreporting their experiences. (A position that could be strengthened given the proportion of students who lacked comprehension of at least one emotional term.) However, if this were the case one might expect to see that the comparisons made between Observer 1 and Observer 2's interpretations of the students' emotional experience agree with greater regularity and strength. Whilst it is the case that the observers' interpretations of emotional experience showed stronger agreements in their interpretation of 9 out of the 11 emotions, the strength of the agreement between the two observers can only be considered moderate for boredom.

What is important to stress here however is that this difficulty in interpretation could stem from the unwillingness of the students (perhaps because they feel uncomfortable) to express how they are feeling in the classroom. This hypothesis is supported by the low counts of coded observational data found in our study, and research which highlights the significance of the context upon the way in which emotion is expressed (Boekaerts, 1993; Schutz *et al.*, 2006).

Emotion is considered to be essential to the learning process, where encouraging and supporting the 'right' emotional experiences can lead to greater learning gains. For example, Craig *et al.* (2004) found that states of confusion and flow are likely to lead to greater learning gains and boredom linked to lesser learning gains, whilst Dreisbach and Goschke (2004) found that positive affect in general leads to greater amounts of flexibility but also distractibility and reduced perseverance. Efforts are being made to incorporate emotional intelligence in artificially intelligent educational systems, however this same effort is not being applied within classrooms, perhaps because it is believed that human teachers already understand the emotions of their students and how to support and positively influence these experiences. What our results suggest however is that it can be difficult and time consuming for a teacher to correctly interpret the emotional experiences of their students. Therefore supporting the emotional experiences of students when one does not fully understand that experience provides a great challenge to teachers in the field.

5 Supporting emotional communication in the classroom

The results presented so far have highlighted the difficulties prevalent for teachers and researchers within traditional learning contexts in understanding the emotional experiences of students. In response our work has evolved towards developing an educational tool capable of supporting emotional understanding and communication by helping to bridge the gap between what a student feels able to publicly express in terms of their emotion within a classroom and what a student feels able to privately divulge. The tool can be used as a means of collecting self reports of emotional experiences in real time from a student embedded in a learning context, and also enlighten teachers as to the emotional experiences of their students.

The requirements for such a tool are as follows:

- *Privacy* – We hypothesise that the classroom context limits the extent to which students feel comfortable expressing their emotional experiences publicly. In response, the tool must enable a student to overcome these social pressures by supporting a private means of communication.
- *Real time information* – The tool should be capable of providing real time information to the teacher in order that they are capable of responding appropriately to their students' emotional experiences.
- *Easy to use and interpret* – Since the tool is designed for use in the classroom, the tool should be both easy to understand and intuitive to use. It should not distract the students' or teacher's attention away from the task at hand.
- *Emotional accessibility* – The tool should make the abstract concept of emotion more tangible for the young student.
- *Encouragement of use* – If students are to use a tool of this kind independently without prompting, the tool itself needs to be both fun and engaging to use and perceived as useful.

6.1 The Subtle Stone

The Subtle Stone is a squeezable handheld and tangible device that allows for the communication of emotion from student to teacher through colour. It has been designed to meet the requirements described in the previous section.

Colour is increasingly being used within Human Computer Interaction projects (Lindstrom *et al.*, 2006; Stahl *et al.*, 2005; Wang *et al.*, 2004) as a method for expressing the emotion of a user. However, in this case colour was chosen as a potential and appropriate metaphor for emotion in the classroom since colour has been used to make the discussion of emotions more accessible and even more enjoyable for younger people (as seen in Seuss, 1998). Furthermore as discovered through the first study, the emotional terms typically used by researchers can be ill defined and difficult for young students to understand and relate to. The hope is that colour will allow younger students to better engage with the concept of emotion.

The use of colour in the tool we have developed is not intended to be used in a predictive sense, *i.e.*, we do not assume that if a student chooses red they are feeling angry. Instead we are using colour as the syntax of an emotional language for the classroom that individual students within that classroom are able to define for themselves, *i.e.*, the student defines which colour maps onto which emotional term.

To engender privacy each student develops their own colour:emotion language whereby they define which colour represents a particular emotion. When a student wishes to share a particular emotional experience with their teacher they squeeze their Subtle Stone until it displays the colour representing that particular emotion. As a student changes the colour of their Subtle Stone, the student's corresponding representation on the teacher interface changes colour also. In order that the teacher does not have to remember and recall each of the student's colour:emotion languages, the colour transmitted by the Subtle Stone to the teacher interface is translated to the colour:emotion language as defined by the teacher.

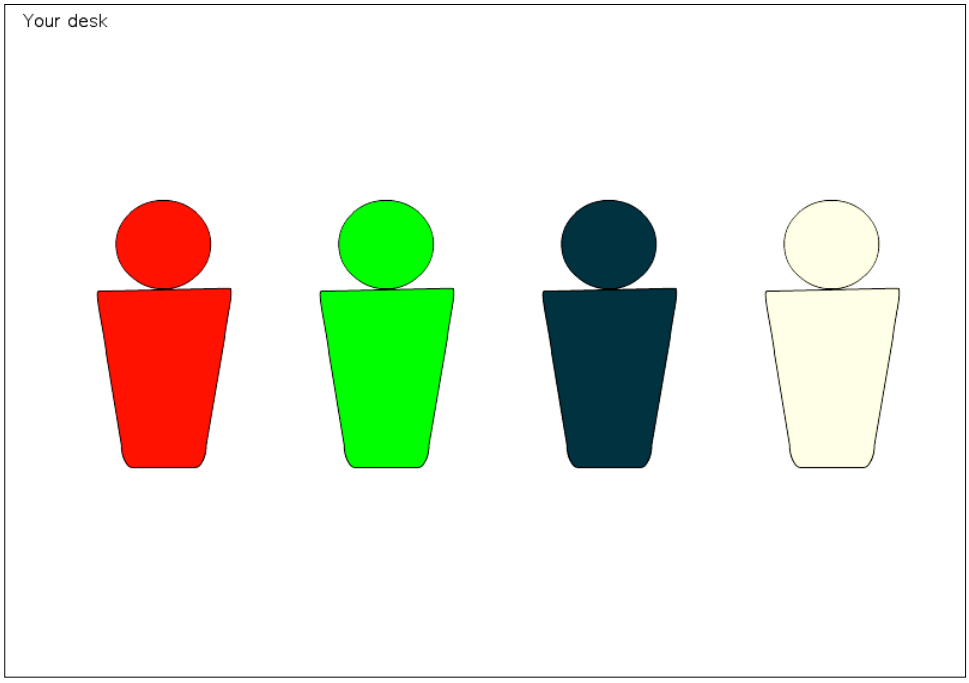
We developed a prototype of the Subtle Stone by adapting a commercially available juggling ball. (A close up of the Subtle Stone is included in Figure 1.) The juggling ball was capable of displaying seven separate colours, with a squeeze of the ball resulting in a colour change. The adaptations we made to the juggling ball enabled us to capture when the ball had been squeezed and additionally to check that the colour displayed by the ball matched the colour the interface inferred as being displayed. Since the available juggling ball displayed seven colours the resulting initial prototype was also capable of displaying only seven colours and therefore communicating seven separate emotions.

Each Subtle Stone was connected via an EZIO board to the teacher interface. As it currently stands the teacher interface is an abstraction of the classroom layout with a separate person shaped object representing each of the students. Each icon is placed within the interface as they are within the classroom, from the reference point of the teacher's desk (see Figure 2).

Figure 1 Subtle Stones in action in the classroom (see online version for colours)

Note: Top right insert: close up of a Subtle Stone.

Figure 2 A screenshot of the teacher interface (see online version for colours)



7 Taking the subtle stone to the classroom: a second study

The Subtle Stone technology was taken into a classroom to investigate how well it met the requirements for a tool supporting emotional communication in the classroom as defined earlier.

7.1 The participants

The study took place over the space of one month within a summer term at a British high school in the South East of England. The study incorporated 16 students, 8 of which were in a fast track year 7 German language class (11–12 year olds, 4 boys and 4 girls). These students were considered to have a talent for languages, and intended to complete their GCSE German (a British qualification taken by students in secondary school normally at the age of 16) at the end of year 9, 2 years earlier than average. The other 8 students were members of a year 9 German language class (13–14 year olds, 4 boys and 4 girls), they were students of average ability, who had all chosen German as one of their GCSE options, aiming to take the German GCSE exam at the end of year 11, in 2 years time.

The age range of students used in this study is younger than those who took part in the first study. This difference in student age range was partly due to the older group of students being absent from school at the time of the study and partly because we (both researchers and teacher) felt that the younger students might benefit more from an intervention of this kind, particularly since it was in general the younger students in the first study who had difficulty understanding and engaging with a number of the emotional terms used.

In total four Subtle Stones were developed for use in this study, as such, four students were selected from each year group to use a Subtle Stone throughout their German classes for the period of one month, and four students from each year group were asked to keep a diary, recording in any manner that they might wish accounts of their emotional experiences of learning German. The study covered ten hours of German language lessons for those in year 7, and six hours of German language lessons for those in year 9.

7.2 Pre study set-up

At the beginning of the study the year seven student group were asked to pick 7 emotions which they, as a group, considered relevant to their learning experiences out of the 11 emotions used in the study presented earlier. The students chose: Motivation, Pride, Confidence, Boredom, Frustration (we deliberately lowered the intensity of the word Anger to Frustration, based on experience from the previous study), Relief, and Enjoyment. (Although it would have been possible to come to the study with seven pre-defined emotions based on results from the first study it was felt that the students might be more engaged with the study and the Subtle Stone or diary if they were given some control over which emotions were considered relevant to their learning.)

7.3 The diary users

The four students in each group using the diaries were given their diaries and asked to write down whenever they could and however they wanted their emotional experiences of learning German. They were asked to, if possible, make an entry in their diary for each lesson.

7.4 The Subtle Stone users

The Subtle Stone users were introduced to the technology and its purpose and given a demonstration of how the Subtle Stones worked. Each student was then asked to independently define their colour:emotion language by selecting which colour displayed by the Subtle Stone would convey which of the seven chosen emotional terms. The Subtle Stone users were told to use their Subtle Stones whenever they wanted to communicate an emotion to their teacher during lessons.

7.5 Procedure

At the beginning of each class each student was asked to indicate on a bar graph their current emotional state for each of the seven emotional terms being used in the study. Two video cameras were set up to capture audio, facial expressions and the upper body movements of the eight students throughout the hour long lesson.

Since the prototype Subtle Stones were a wired solution the students using the Subtle Stones were asked to sit together on the front two desks in order to minimise the amount of wires trailing across the classroom. Similarly the students using the diaries throughout the month long study were also asked to sit together and towards the front of the class in order to be able to capture the four students using only one video camera.

Throughout each class the Subtle Stone users had access to crib sheets detailing their colour:emotion language. Log files were generated for each student using a Subtle Stone during each lesson. The log files contain the colour selected by the student, what emotional term that colour related to, and lastly a time stamp for when the colour had been selected.

Twice throughout the study each student completed a stimulated recall interview using 5 min of footage from a recent lesson in much the same way as the students of the previous study, *i.e.*, the students were asked to recall once every minute whether they remembered feeling more, the same, or less of each emotion based on what they had reported feeling at the beginning of the lesson.

At the end of the study an interview was conducted with each student (including the teacher) to gauge their impressions and experiences of using the technology within the classroom. A semi-structured interview was utilised to create a focussed two-way conversation between the researcher and student. The interviews lasted between 10 and 20 min and were conducted either after school or during the students' lunch breaks. The interviews were conducted on a one-on-one basis between a student and the primary researcher on this project with whom the students had become acquainted over the course of the study.

7.6 Results

The remainder of this article will present data that relates to the user experience of working with the Subtle Stone in a live learning environment. The data presented here is mainly based upon the semi-structured interviews that were conducted with both the class teacher, Mr. Simpson, the Subtle Stone users and the diary keepers.

A theme-based analysis was applied to the interview data in order to identify the elements of the interview responses that addressed one of four themes. These were:

1 privacy

2 ease of use and interpretation

3 emotional accessibility

4 encouragement of use.

These four themes were selected since they represent the foundations upon which the Subtle Stone was designed. As such, a primary interest is whether these crucial elements of the design have been satisfied by the Subtle Stone and therefore provide evidence for whether the Subtle Stone has value both as an educational tool and as a research tool.

7.7 Privacy of emotional communication

Based on *in-situ* examination of use, the requirement for privacy seemed to be of more importance to the year nine students than it was for the year seven (*i.e.*, younger) students. For example, the students in year nine were much more prone to hide their Subtle Stones during class, whereas the students in year seven often kept their Subtle Stones on display during the class and the Subtle Stones even seemed to prompt discussion between the Subtle Stone users about the way they were feeling.

Whilst the semi structured interviews did not contain a question which directly enquired about privacy, 3 of the 16 students raised privacy as crucial to emotional communication within the classroom and additionally one of these three students clearly felt the Subtle Stone offered a sense of privacy which could not be maintained through verbal means of communication.

> *Interviewer*: [Referring to an earlier section of the interview where the interviewee commented that she didn't like it when Mr Simpson said to the class how she had reported feeling.] You didn't like it when Mr Simpson said that you felt frustrated.
>
> *Vicki*: I didn't mind it, I didn't mind it when he didn't say it to the class, but when he said it to the class because it was a bit embarrassing, and I didn't like people looking at my [Subtle Stone].
>
> *Interviewer*: So you preferred to keep [your Subtle Stone] quite private?
>
> *Vicki*: Yeah.

Whilst the importance of privacy was not raised by the year seven Subtle Stone users during the interview sessions, a year seven diary keeper alluded to the importance of privacy in expressing emotions during class.

> *Interviewer*: How comfortable are you expressing how you're feeling during class, either saying or using body language to let your teachers know how you're feeling?
>
> *Harry*: Well, if we were just doing it normally I wouldn't be, but if I'm writing it in a book I would be…
>
> *Interviewer*: So normally you wouldn't feel that comfortable, but when you've got a private way of doing it, it makes you feel more comfortable?
>
> *Harry*: Yep.

The students were asked whether they would prefer a tool such as the Subtle Stone in future versions to continue being based on colour, or something else, such as words. Sarah, a particularly shy girl from the year nine group was explicit in her reasons for preferring colour.

> *Interviewer*: Did you like using colours or would you have preferred using the words?
>
> *Sarah*: I preferred using the colours 'cause everybody had different meanings for them, so they didn't know what you had chosen.
>
> *Interviewer*: And why is it important for you that they didn't know what you had chosen?
>
> *Sarah*: Because then they wouldn't know what I'm feeling.
>
> *Interviewer*: And you'd prefer if no one else knows how you're feeling?
>
> *Sarah*: Yeah.

7.8 Ease of use and interpretation

Technologies within the classroom should be easy to use to ensure that they do not detract from the learning goals of a lesson. As a result this theme was approached throughout the semi-structured interviews via two questions: "How distracting did you find using the Subtle Stones in class?" and "Were the Subtle Stones easy to use?" All eight of the Subtle Stone users reported that they were easy to use. Five of the Subtle Stone users reported that the Subtle Stones were not at all distracting, whilst a further three (two from year seven and one from year nine) answered that the Subtle Stones were initially distracting, but that the level of distraction lessened as the study continued. Additionally, there were no occasions throughout the study where any of the Subtle Stone users asked for clarification about how the Subtle Stones worked or what their purpose in the classroom was. Mr. Simpson (the class teacher) also agreed that the Subtle Stones were not a great distraction in the classroom.

> *Interviewer*: What did you think about the Subtle Stones in general being in the class?
>
> *Mr. Simpson*: […] Umm, themselves I thought they would probably be more of a distraction but they weren't necessarily, which is probably quite good, although it's more of a distraction for the other kids.
>
> *Interviewer*: Yes, they [the other kids] were quite curious about them.
>
> *Mr. Simpson*: Yeah, but certainly not long term.

Whilst the interview data suggests that the Subtle Stones themselves were easy to use and were not a major distraction in the classroom, the teacher interface proved more problematic. At several points throughout the study and once during the post study interview Mr. Simpson alluded to the difficulties he had in interpreting the level and volume of information provided by the Subtle Stones.

> *Interviewer*: So what do you think was bad about [the Subtle Stones]?
>
> *Mr Simpson*: […] the range of emotions, that there was quite a lot of information to take in, and also knowing how to react to certain situations, so if some kid is feeling really motivated, does that command a response? Should I then go over to that kid and say oh god that's really good, or well done I'm really pleased that you're motivated and then question them more? Umm, or if they're feeling proud or if they're feeling, whatever else it might be, I tended to just very much ended up using it really more that if somebody was having a problem, they were frustrated, and that kind of thing, I wonder, if therefore I'm necessarily using it as best as I could be.

In the excerpt above Mr. Simpson highlights the difficulties he had parsing the volume of data being presented to him through the teacher interface. But, Mr. Simpson also raises another pertinent issue which is once the emotional data has been provided what does one, whether a teacher or a tutoring system usefully do with it?

7.9 Emotional accessibility

Emotional accessibility is a difficult concept for the younger student to relate to. As such, the issue of emotional accessibility was pursued through questions relating to the use of colour within the tool. During the interviews the students were asked whether they liked the use of colour within the tool, or would they have preferred to use a word based tool. Six out of the seven students asked preferred the use of colours instead of emotion terms, with the seventh student being neutral to the choice. In three cases the students were unable to elucidate what made them prefer colours instead of words as a method for communicating emotions. In the cases of the other four students, one student preferred to use colour because it offered more privacy and another student felt the colour somehow reflected something about a particular emotional experience. Lastly, two students reported that they felt colour was easier to use than words to communicate emotion.

> *Interviewer*: So how about using the colours and linking them to emotions rather than using the words themselves?
>
> *Matthew*: Umm, the colour coding is easier to understand, so yeah.
>
> *Interviewer*: How did you feel about using colours to talk about emotions rather than words?
>
> *Jonathan*: It would be easier than using words because you've only got a certain amount of choice.

The theme-based analysis of the semi-structured interviews is to some extent able to build a case for the Subtle Stone making the concept of emotion more accessible to the young student. However, what was particularly evident through watching the videos of the class sessions from both the diary keeper perspective and the Subtle Stone user perspective is the difference in the number of times these sets of students discuss emotions in general or discuss how they are feeling. The analysis presented here is in its

early stages. The initial analysis has been conducted by selecting classroom sessions at random and viewing both the footage centred on the Subtle Stone users and that centred on the diary keepers. A count is made for every time a student mentions their emotional state or whenever the group discusses emotions in general. Two year seven sessions have so far been treated in this manner.

In the first of these randomly selected sessions (which in this case is three sessions into the study) the Subtle Stone users mentioned emotions 14 times, whilst the diary keepers made no mention of emotions. During the second session (midway through the study) the Subtle Stone users mentioned their emotions on nine separate occasions, whereas the diary keepers only mentioned emotions once during the hour long session.

7.10 Encouragement of use

A tool which requires independent and unprompted use by students already engaged in the process of learning must encourage use, otherwise there is a danger that the technology could sit unused on the students' desks providing no extra information to the teacher or the researcher. There are a number of qualities in learning technologies which can help to encourage its use, for example the learning technology should be easy to use, it should also be fun to use and the technology should be perceived as useful. The issue of ease of use was addressed earlier so this section will focus on whether the Subtle Stones were perceived as useful within the classroom context.

Each of the eight Subtle Stone users were asked whether they felt the Subtle Stones were a useful tool and why or why not. All eight of the Subtle Stone users responded that they found the Subtle Stones a useful tool to have in the classroom. Six of the eight Subtle Stone users reported that the tool was useful because it allowed them to express how they were feeling to Mr. Simpson. Two of the year nine Subtle Stone users indicated that they felt the Subtle Stones were useful because the tool encouraged them to reflect on their emotions within class. In addition the students reported that the Subtle Stones made it easier for them to think about their moods and emotions during learning. (A finding that is somewhat supported by the initial analysis reported earlier suggesting the Subtle Stones prompted greater conversation on the emotions experienced during learning.)

> *Interviewer*: Did you think that having the balls in the class was useful?
>
> *Vivki*: Yeah.
>
> *Interviewer*: Can you explain why that is?
>
> *Vicki*: You know when you write things down it makes it easier to think about, I don't know you never think of your feelings and if you use the [Subtle Stones] you sort of felt them more and knew what you were feeling and it made it a bit easier to get your feelings out.

Importantly, Mr. Simpson also believed that the Subtle Stone technology was a useful addition to his classroom. He reports that it helped him to quickly identify the students who were having trouble and in addition it helped him to identify learning activities and tasks that were underperforming.

> *Interviewer*: What did you think about the Subtle Stones in general being in the class?
>
> *Mr Simpson*: Umm, I thought they, I thought they were a very good idea in the fact that from a teaching point of view it was really nice to be able to use their information to then sort of adapt things slightly, what's going on in the lesson, or at least to be able to go over and talk to some person and say you know, what's the problem? I think that's probably how I used them most.
>
> *Interviewer*: So did you find it useful explicitly knowing how they were feeling?
>
> *Mr Simpson*: Uh, I suppose yeah. Yes definitely. It was a real eye opener for me. In the fact that there were certain activities that I tend to plan more often, and yet it was quite clear that some of the kids just didn't get anything out of it at all.

This excerpt from the transcribed interview with Mr. Simpson suggests that not only did the Subtle Stones provide him with useful information about the emotional experiences of his students, but also that the use of the Subtle Stones in class actually helped Mr. Simpson to identify learning tasks and activities which were not performing as well as he had previously thought, and therefore enabled Mr. Simpson to make his teaching more effective (and possibly more affective).

But Mr. Simpson also reported finding the wealth of information provided by the tool at times overwhelming. He seems to have been particularly surprised at the difficulty he experienced in knowing what the appropriate reaction to certain emotional reports should be.

> "[…]
>
> And I certainly hadn't thought about it beforehand that it would be such an issue for me as to what to do with that information.
>
> […]
>
> But I suppose it goes back to that thing we were talking about a second ago, well you know how do I use this information as far as I can see that this particular person is feeling that emotion? But I suppose, if someone is struggling, or they're frustrated or bored you can do something about it, but if they're feeling really good, then why change something, if it's not broken. But surely that demands a reaction, of whatever reaction that might be.
>
> […]
>
> So yes I do think that it has a lot of worth, but it's knowing how to use it."

These sections of transcribed interview with Mr. Simpson illustrate both some of the advantages of using a tool such as the Subtle Stone within classrooms, and also some of the disadvantages from the teacher's perspective. Whilst Mr. Simpson clearly found explicitly knowing about the emotional experiences of his students useful, and was able to use this information to reflect on his teaching methodologies, he did sometimes find the level of information provided by the tool overwhelming. Mr. Simpson also raises what should be an important issue within emotional research, which is, what should we do with this information now that we have it? Finally, if the teacher finds dealing with the self report data from four students per class difficult, then scaling up the system as it

currently stands to work with a classroom full of students (circa 30 students) would make the task seemingly impossible for Mr. Simpson. A discussion of how we intend to counter this overload of emotional information is developed in the final section of this article.

8 Discussion and future work

The aim of the Subtle Stone technology is to provide a means of supporting emotional communication in the classroom as well as a method by which self reports of emotional experience may be collected in real time within real and busy learning contexts.

There are a number of self report methodologies which have been designed in order to facilitate the collection of self reports in real time within learning contexts. The Between The Lines method (Ainley *et al.*, 2002) is a non-linguistic tool where students choose a cartoon face that most represents the emotion they are currently feeling. Typically, the student is asked at intervals determined by the researcher to self report their emotional experiences. Ainley (2007) claims the Between the Lines methodology takes a student around 30 sec to complete, with minimal intrusion to the task. The Experience Sampling Form method (Hektner) is a short questionnaire designed to capture details of experience, whilst the Experience Sampling Form is used to collect data relating to all facets of experience, it has been specifically adapted to collect data relating to a student's emotional experience (Collins and O'Tolle, 2006).

These short questionnaires or emoticon methods provide a means by which the researcher can collect data relating to the emotional experience of students in real time, but the Subtle Stone methodology offers advantages over these. Whilst most methods used to collect emotional information dictate to the student when an emotional report is collected, the Subtle Stone methodology puts the student in control of when they choose to send emotional reports. This allows the user to choose for themselves when they want to reflect on their emotional experiences and convey information, limiting the interference that the methodology plays on the learning of the student. This 'push' rather than 'pull' methodology also means that emotional data or relevant emotional transitions are not lost because the student has not been asked to self report during that space of time. (Although it is possible that other emotional experience data is lost because the student is not aware of a change, or chooses not to communicate it through the Subtle Stone.)

Key to the Subtle Stone is its support for private communication. The interview analysis presented in the results of the second study provide support for the notion that some students prefer to keep their emotional experiences private. They do not want everybody in the learning context to know how they are feeling. Methodologies such as Between The Lines or the Experience Sampling Form may be perceived by the student as easily overseen and understood by members of the classroom context, in contrast the Subtle Stone methodology, whilst visible is less easy to translate without the user's willingness to share their secret language. The design of the Subtle Stone highlights the privacy engendered in it making it possible to reassure the shy user and overcome contextual hurdles to encourage honest use.

Lastly, the physicality of the tool offers the user an experience that maps partially onto the reality of the emotional experience, *i.e.*, emotions are a physical and cognitive phenomenon. Dourish (2001) uses the term embodied interaction to emphasise the importance of designing interactions which harmonise with our everyday practices and bodily experiences. The emotional experience involves both the physical and the cognitive. If the principles of embodied interaction are followed by the creation of tools to express and communicate emotion then this leads the designer towards creating physical tools that involve the body in their use and interaction. So whilst the student in the classroom may feel restricted in so far as what they can outwardly express about their emotional experiences through their body, by providing the student with a Subtle Stone where subtle physical interaction is central to its operation, we are able to begin putting the body back into students' emotional experiences in the classroom.

So far we have discussed the advantages of the Subtle Stone over more traditional methods of collecting real time self reports, yet the tool also aims to offer something more to the classroom and those who work within it. Early observations of the Subtle Stone users in contrast to the diary users saw that those students interacting with the Subtle Stones reflected on and discussed emotions and their own emotional experiences more often than those who were recording their emotional experiences in a diary. Whilst this finding requires further formal analysis it does suggest that the Subtle Stone may be capable of helping students to become more aware of their emotions whilst they are learning, which in turn could lead students towards more effective management of their emotions.

Additionally, the Subtle Stone, unlike any other classroom based emotional data collection methodologies, provides teachers with access to real time information about the emotional experiences of their students through the eyes of those students. Results from the first study raised questions about how much a teacher really does understand about the emotional experiences of students in the classroom. The Subtle Stone is able to provide teachers with further information to inform their lesson planning and behaviour management strategies.

A number of questions remain with regards to emotion and its relation to learning. Given the advantages offered by the Subtle Stone, its use within the classroom could potentially allow for research within the classroom to be strengthened and our understanding of the relationship between learning and emotions to be increased. In particular, the Subtle Stone could be used to further explore which emotions have a positive effect on the learning experience of students, which emotional transitions are common in different types of students and how elements such as the task or learning context influence the emotions or emotional transitions made by students. Additionally, results from these studies will enable researchers to offer support to teachers in their efforts to provide effective learning experiences.

With the addition of biometrics placed within the packaging of the Subtle Stone it would be possible to conduct research investigating how metrics such as galvanic skin resistance, heart rate, blood pressure and behavioural actions such as the pressure of a squeeze or the manipulation of the Subtle Stone map onto self reports of emotional experience given in real learning contexts.

The interview analysis presented earlier highlighted issues with the teacher interface. In general, the interface provided too much information to the teacher and too often the teacher was unsure of how to make the most of this new supportive data. These less positive aspects of the teacher experience provide a motivation for how the technology might be developed further.

One aspect that we will be exploring is how we can usefully filter and represent the information provided to the classroom teacher, so that they feel more in control of the information presented to them. It is possible that the most useful information for a teacher to know in real time is when a student is transitioning from a negative emotion to a positive emotion or vice versa, or when a student has been experiencing a negative emotion for a long period. To explore whether this is the case a new interface is being designed which will filter the information so that the teacher is only made explicitly aware of these instances of students' emotional experiences. The teacher can find out more about the emotional experiences of students by rolling over the student icons, but this more detailed information is only presented if requested.

Additionally, a reflective interface may be developed which works to present numerous streams of data to the teacher or trainee teachers to encourage reflection on how teaching practise and the learning context affect students' emotional experiences. At present it is thought that the interface will be made up of the emotional experience data collected via the Subtle Stones, the teacher's lesson plan and snapshots of the classroom at regular intervals via a tool such as the SenseCam (Harper *et al.*, 2007). Through the use of a reflective interface, discussion and exploration may turn towards collaboratively developing frameworks for responding effectively to, or supporting students' emotional experiences.

This article has highlighted the inherent difficulties for teachers and researchers in understanding or responding to a student's emotions within the formal learning context of the classroom. We have presented the concept of the Subtle Stone and argued that it has potential to provide an avenue through which self reports of emotional experience might be collected during lessons both for the benefit of the teacher and the benefit of the researcher.

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