Enhancing Mathematics (STEM) Teacher Education in Regional Australia: Pedagogical Interactions and Affect

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This article reports on initial findings, including the mathematics components, of a multi-institutional Science, Technology, Engineering, and Mathematics (STEM) project, *It's part of my life: Engaging university and community to enhance science and mathematics education*. This project is focussed on improving the scientific and mathematical thinking of pre-service teachers (PSTs) by aligning their pedagogy with the scientific and mathematical thinking that occurs in authentic, real-world contexts. This article discusses emotional literacy and emotional regulation as aspects of self-reflective professional development and how these measures are conceptually related to improving competence and confidence for pre-service STEM teachers. This report details how emotional feedback was used in trials of a pilot program to enable PSTs to analyse, understand, and make use of emotional information to improve their teaching confidence, particularly in mathematics.

Introduction

This paper reports on the initial stages of an Office of Learning and Teaching (OLT) funded Science, Technology, Engineering, and Mathematics (STEM) project, *It's part of my life: Engaging university and community to enhance science and mathematics education*, that seeks to address a lack of confidence and competence in science and mathematics teaching in regional and rural Australian schools. The project addresses these issues through the development of interventions that focus on how mathematicians and scientists think and solve problems and how this may be linked to the ways that people solve problems in everyday life (Woolcott, 2015). In particular, this report focuses on the development and application of some of the affect measures used by the project to provide feedback in relation to pre-service teachers (PSTs) pedagogical self-reflections on their lesson preparation and lesson delivery in mathematics. Affect, as a measure of emotional experience and understanding, is viewed as fundamental to the professional development of confidence and competence in teacher training (Tobin & Ritchie, 2012), and the project's use of affective feedback thus represents an important aspect of achieving the larger project goals of improving these aspects of pre-service training. With this in mind, a brief framework to contextualise and position the project is presented, followed by a description of the affect-related measures being reported along with some key results of their use in initial project trials. Improvements to the measures; in particular, how to use these to better connect emotional literacy to appropriate research goals, are then recommended as a focus for ongoing research.

Background

Context and Theoretical Framework

There has been a steady reduction in the number of Australian students who are studying mathematics and science at both the secondary (high school) and tertiary levels of education (Lyons & Quinn, 2010). There is also a shortage of appropriately qualified mathematics and science teachers available to teach at the secondary school level,

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particularly in rural schools (e.g., Ainley, Kos, & Nicholas, 2008). For example, Thomson (2009), in a report based on data from the 2007 Trends in International Mathematics and Science Study (TIMSS), identified that many Year 4 teachers reported having little specific training or specialised education upon which to base their teaching of the TIMSS assessment topics. Similarly, Australia's Chief Scientist, Professor Ian Chubb and colleagues have repeatedly expressed concern in relation to the state of Australian STEM education (Chubb, Findlay, Du, Burmester, & Kusa, 2012). Importantly, an Australian Association of Mathematics Teachers' (AAMT, (2014) report on quantitative skills has proposed that one key step in developing mathematics literacy in schools was by "helping schools to teach STEM as it is practiced, in ways that engage students, encourage curiosity and reflection, and link classroom topics to the 'real world' ".

This project seeks to address such issues by clarifying links between content knowledge and confidence as related to contextualised or situated learning in Australian classrooms. In initial trials of the project, this was enacted by having PSTs work in groups to develop pedagogical contexts and scenarios, guided by expert mathematicians, scientists, and pedagogy mentors, to construct and optimise inter-dependent and collaborative scenario-based lessons that utilised local community contexts to increase the meaning of the lessons (e.g., Woolcott, 2015).

Sources of Feedback to Encourage Competence and Confidence

In terms of tracking the influences associated with STEM teaching, various sources of feedback were provided to encourage PSTs to analyse and reflect on their learning and teaching in a way that connected what they were teaching, and what their school students were learning, to the contextualised content of the lessons. It is important to note that these sources of feedback were incorporated into a series of iterated enhancement and feedback/reflection modules during initial trials of the project (Woolcott, 2015). Enhancement modules involved interactions between the PSTs and world-class science and mathematics researchers, and between PSTs and experienced educators who specialise in the area of classroom pedagogy. The feedback modules involved collaborative groups of PSTs analysing their teaching and how they had made use of the expert advice, as well as including input and guidance from their pedagogical mentors. As the PSTs developed experience across the modules, they then began mentoring less-experienced colleagues, providing yet another source of feedback for the project.

The Role of Affect in Teacher Confidence and Competence

An important part of the reflective processes for the project involved *affect* feedback, including emotion ratings, video recordings, and voice parameter analysis (Yeigh & Woolcott, 2014). Research by Tobin and Ritchie (2012) suggests that *emotional arousal* (positive or negative) is related to teaching competence and confidence in PSTs, and because of this the particular focus of this paper concerns how the project utilised some of these sources of feedback, determined as key sources, to assess and analyse PST affect in relation to the scenario-based lessons they developed in conjunction with the expert mathematicians, scientists, and pedagogy mentors. Emotional arousal was operationally defined as affect for the project because affect represents the external expression of emotion as attached to ideas or mental representations. Measures used, therefore, were concerned with how the PSTs were analysing and interpreting their emotions in relation to their teaching, and what impact this was having on their confidence and sense of

competence about the teaching. In this respect, the project sought to measure the degree to which affect, and the corresponding ability to regulate emotions, moderated confidence in the PSTs, and how this may have influenced their competence.

Affect as a Basis for Critical-moment Reflection

Affect was measured from a variety of perspectives and using several different strategies, with an overall goal of measuring affect to have the PSTs learn how to identify and analyse their teaching-related affective states. This was done in order for the PSTs to assess their own emotions and motivations, and to ensure that the emotional and motivational climate of the classroom was optimally supportive for the learning of their students (Tobin & Ritchie, 2012). A discussion of the critical moments and the related emotion diaries follows. Other affect measures are reported elsewhere (e.g., Donnelly, Pfieffer, Woolcott, Yeigh, & Snow, 2014; Yeigh & Woolcott, 2014).

Methodology

Trial Structure

The methodology of the initial trials was developed around collaborative team discussions in order to produce a plan for a teaching lesson. The lesson was followed by self-reflection and a collaborative feedback/reflection session. In line with theory on the value of iteration in learning processes for PSTs (e.g., Davis & Dargusch, 2015), this sequence was repeated as iterations of the sequence: Enhancement Module; Teaching Lesson; and Feedback/Reflection Module (see Figure 1).

ENHANCEMENT - *to facilitate interactions with research scientists and mathematicians and university educators to improve competence in pedagogy and subject knowledge.*	TEACHING LESSON - *a topic nominated by the target school prior to Enhancement*	FEEDBACK/ REFLECTION *- to utilise self-evaluation to examine links between competence and confidence.*

Group A (PSTs) 3 iterations of enhancement/ feedback cycle	Group B (PSTs) Waiting list (no enhacement or feedback/reflection) – each PST teaches one lesson
Group A Control (no enhacement or feedback/reflection) – each PST teaches one lesson	Group B 3 iterations of enhancement/ feedback cycle

Figure 1. The iterated sequence of Enhancement Module, Teaching Lesson and Feedback/Reflection Module. The lower diagram shows the grouping of PSTs within these initial trials.

Each Module was here treated effectively as a discussion-based learning intervention for the PSTs. Each trial was preceded by a training session that explained the process to be undertaken and the rationale behind each Module. The initial mathematics trials were

based around this process, with groups of 3-6 volunteer PSTs in each trial, with teaching done in schools local to the university.

Critical Moments

All teaching lessons included full audio/visual (video) recordings, and PSTs then used these to analyse and reflect on their teaching. In particular, they identified six *critical teaching moments* for each lesson, where each *moment* represented an important (positive or negative) emotional feeling or experience associated with the pedagogical process of instruction, that they felt influenced their competence and/or confidence in relation to the lesson. Instructions for providing this aspect of the affect data were for PSTs to record the start and finish times for six segments of the video identified as representing a critical moment for each lesson, and seeking to identify two segments from the first third of the lesson, two segments from the middle third of the lesson, and two from the final third of the lesson.

Critical moment data was also recorded in the same manner by observing PTSs, allowing comparisons to be made between experienced and observed affect for each teaching PST. These comparisons assisted in identifying affect-related issues for the PSTs, as well as highlighting affective trends in the overall iterations that took place during these trials.

Emotion Diary

PSTs were also asked to complete an emotion diary for the critical moment segments identified in relation to their teaching (see Figure 2). The emotion diaries used well-established affect icons and their meanings to represent the various emotional states PSTs might experience during teaching (or observe in another PST's teaching). To complete these diaries, PSTs were trained to recognise emotions in terms of observing changes in voice volume, pitch, tone, or other sound qualities when observing one another, and when analysing their own video recordings. They were also trained to notice how overall body language during teaching (e.g., facial expressions, breathing rate, sweating, vasodilation [blushing], posture, increased muscle tension, etc.) might indicate a particular feeling or bodily sensation.

Using this training to direct their diary recordings, both teaching and observing PSTs were instructed to complete an emotion diary for each critical moment segment identified in the video recording by the teaching PST. The diary was completed by selecting appropriate affect icons to represent the teaching PST's emotions during teaching, and then selecting from the scale a number that represented the intensity of the emotion next to the icon. As shown in Figure 2, the emotion diary also provided space to write open-ended comments about the selected emotions, and PSTs were encouraged to use this space to elaborate and explain their affective identifications in terms of what the teaching PST was doing at the time, what else might be going on in the classroom, and at whom the emotion seemed to be directed.

Emotion	Please describe briefly what you were doing, what was happening and at whom the emotion was directed.
 Excitement/Enthusiasm	
 Happiness	
 Enjoyment	
 Pride	
 Anxiety/Worry	
 Frustration	
 Disgust/Contempt	
 Annoyed/Irritated	
 Disappointment	
Embarrassed	
Interested	
Confident	

1	2	3	4	5
Not at all	A little	Moderately	Quite a bit	Extremely

Figure 2. The emotion diary used to identify affect during teaching sessions and in relation to reflective lesson analysis (used with permission Tobin & Ritchie, courtesy of Henderson)

Results and Discussion

Early findings from these initial trials, which included both science and mathematics teaching, support the use of affective data to examine the thinking and behaviours that led to emotional states in pre-service teachers (PSTs). It was also felt that a need existed to report on the current findings promptly, as the purpose of these analyses was to assist PSTs improve their ongoing competence and confidence in STEM-related teaching, including the teaching of mathematics. These outcomes appear to support the efficacy of having PSTs learn how to identify and analyse their teaching-related affective states in order to assess their own emotions and motivations, and to ensure that they understand the relationship between emotional literacy and effective pedagogy.

Critical Moment Analysis and Emotion Diaries

Critical moment analysis involved both the teaching and observing PSTs using the video recordings to analyse and reflect on the affective states of the teaching PTSs during lesson delivery. For each lesson, the teaching PST initially identified and analysed six critical moments from the video, representing important points at which some form of affect had influenced their pedagogy. The non-teaching PSTs then also analysed the video according to the identified time signature for each moment, and provided feedback on the affect they observed in relation to each identified moment.

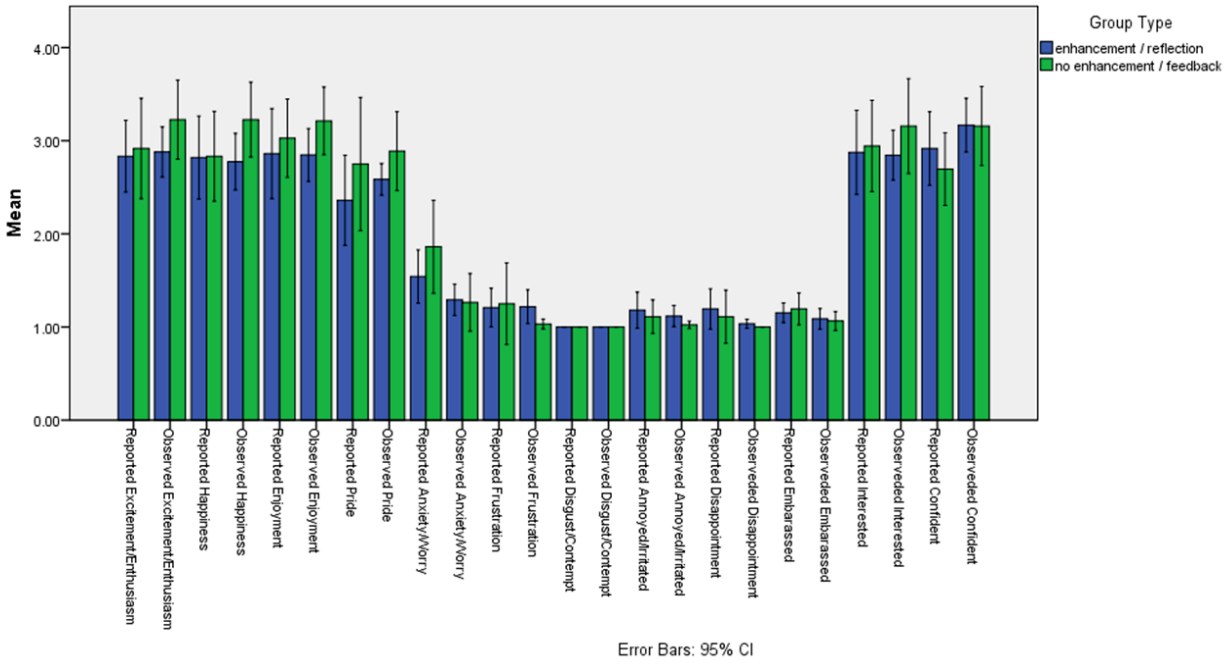

Figure 3. Critical moment data by group type (see also Donnelly et al., 2014)

Figure 3 shows a mean comparative overview of how these critical moments were analysed in terms of reported affect versus observed affect–for PSTs who had received enhancement for the lessons they delivered and for PSTs who had not received enhancement for the lessons they delivered. There were three significant differences in relation to these critical moment analyses, involving differences between reported and observed *anxiety/worry* ($t_{[17]}$= 2.62, $p<0.02$), between reported and observed *confidence* ($t_{[17]}$= -2.20, $p<0.05$), and between reported and observed *embarrassment* ($t_{[17]}$= 2.21, $p<0.05$). It should also to be noted that on average the *no enhancement* group tended to experience and report higher levels of positive emotion, and lower levels of negative emotion, than did the *enhancement* group.

With regard to the analysis of critical teaching moments, it is of interest that the *no enhancement* group tended to experience and report higher levels of positive emotion, and lower levels of negative emotion, than did the *enhancement* group. This was especially true for emotions relating to *Excitement/Enthusiasm*, *Happiness*, *Enjoyment*, *Pride*, and *Interested*, which all represent positive forms of affect. Note also, however, that the no enhancement group self-reported much greater *Anxiety/Worry* than the enhancement group, even though this was observed as lower than the enhancement group by others. Perhaps what was occurring here was that a greater sense of *pressure* took place for PSTs undergoing enhancement–a type of performance pressure–while a sense of *missing out* took place for PSTs when they were not receiving enhancement. In either case, the question again arises as to whether an intentional or unconscious emotion-regulation strategy may be occurring to control emotional display and, if so, how this might be operating.

A project survey was undertaken along with the affect analysis (Whannell, Woolcott, & Whannell, 2015) and, although it covers far wider ground than just the affective domains of the project, several findings from the factor analysis performed on the survey

do appear relevant to the current paper, including the existence of a Teacher Reflection Scale (TRS) as a valid project construct (Cronbach's alpha 0.854). There is, in fact, a significant positive relationship between the TRS and mathematical thinking, being able to support school students, and pedagogical confidence. In addition, it is of particular interest that the correlation between the TRS and the number of mathematical curriculum units completed at university is negative. This suggests that the amount of experience that the respondents had in terms of formalised mathematical learning was inversely associated with their reflections on teaching practice or on the respondents' understanding of the impact of emotions on teaching. Considering that the identification of strategies to enhance PST confidence and competence through reflection is one of the primary aims of the project, these overall findings indicate that opportunity exists for the project to make a genuine contribution to the training of pre-service teachers of mathematics.

One of the clearest outcomes from this early analysis of the project affect data is that some sort of emotion-regulation strategy seems to be occurring in relation to emotional display. In this respect ongoing research will need to investigate the degree to which PSTs are aware of such strategies, why certain emotions seem to be controlled in a more strategic manner than others, and how emotional regulation takes place. Perhaps the use of a dedicated debriefing session, aimed at exploring these specific aspects of the reflective process, could be used to further train PSTs in this direction. Additionally, incorporating specific reflective prompts into the critical moment analysis strategy could also be used to elicit this sort of information. In both cases, the aim of improving PST emotional awareness, in terms of connecting the experience of distinct emotions to individual behavioural responses, would be further clarified.

Implications of Findings and Future Research Directions

It's part of my life is a multi-institution STEM project, designed to increase the competence and confidence of training mathematics and science teachers. This report has focused on initial analyses of how the project used affective measures as part of the iterative processes by which pre-service teachers (PSTs) explored and analysed the pedagogy connected to their teacher training. The findings in this paper reflect those found by Woolcott, Yeigh and colleagues (e.g., Donnelly et al., 2014; Yeigh & Woolcott, 2014) that the PSTs have exhibited a positive emotional bias overall, and also displayed greater changes in their negative versus positive emotions. These findings also suggest that when receiving enhancement for their lesson development (expert science or mathematics input, plus pedagogical guidance), the PSTs may feel pressure to perform, whereas when not receiving enhancement (developing their lesson in collaboration with other PSTs only) they may feel as though they are missing out on important information.

The analysis completed so far, however, (e.g., Donnelly et al., 2014; Woolcott, 2015; Whannell et al., 2015; Yeigh & Woolcott, 2014) supports the project's emphasis on reflective affect analysis to increase pedagogical confidence, and thus links this training strategy to the larger project goal of increasing competence through increasing pedagogical confidence. Importantly, differences between experienced (self-reported) affect and observed affect highlight the need to elaborate the reflective process in terms of consciously identifying the relationship between specific emotions and their behavioural correlates. Overall, these findings indicate that the project's use of affect analysis is appropriate as a means of addressing the lack of confidence and competence in science and mathematics teachers in Australian schools. Indeed, in this most essential criterion the project seems to be hitting the targets it has set for itself quite well. The findings also

provide clear avenues for improvement with respect to some aspects of the reflective process, suggesting the need to forge clearer conscious correspondences between affect and behaviour on the part of training STEM teachers. In this respect the project will need to modify certain elements within the reflective process, and this is viewed as an important way forward for the ongoing project program. The effect of these modifications will be to better connect emotional literacy to the project research goals, in order to improve the overall project goal of developing quality teaching practices that are directed at the enhancement of science and mathematics teaching in Australia.

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