To err is human. The management and emotional implications of teacher error

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Research into errors in mathematics classrooms often centres on student error. Whilst investigating teacher emotional expressions, using data from experienced teachers and affective pathways (Goldin, 2000), I encountered examples of teacher mathematical error occurring in association with expressed emotions. Similarly, I have observed instances of new teachers making errors and hence have begun exploring the implications of teacher error management. In this paper, after describing illustrative examples, I suggest a model based on a continuum of affectively driven strategies that are likely to be familiar to secondary mathematics teachers. Each affectively driven strategy has implications for teacher student relationships and for the learning of mathematics. I discuss some of these implications in terms of longer term affective impact on classroom climate and for students. I offer the model for further discussion in relation to developing growth mindsets.

Keywords: Error handling, emotions, classroom, expertise.

Introduction

There is no doubt that we all make errors and human instinct is to avoid errors as unpleasant experiences. Yet brain analysis research suggests error, however unpleasant, is essential for effective learning; for creating neural connections. Moser et al. (2011) through studying the neural mechanisms during numerical mistake making shows that this activity fires synapses. There seem to be two synaptic responses. Firstly, there is an increase in electrical activity when the brain experiences conflict. This happens without awareness. Secondly, brain signals act to draw conscious attention to the error. Emotions are also triggered by conflict (such as recognising an error), which means making a mistake triggers an observable emotional response. The emotions may be exaggerated as error provides not only a trigger for emotions, but also requires the person experiencing the error to engage in some form of minimising or regulation. Such a positive view of errors is supported by Boaler (2015) and others who suggest we should go further than just avoiding error; that errors should be attended to as part of addressing misconceptions and hence are necessary for learning. In mathematics teaching errors can take many forms, often numerical. Boaler suggests creating a culture where students are comfortable with handling error is beneficial for learning mathematics. Such a culture depends not only on how a teacher addresses student error, but also on how they model addressing their own errors. There seem to be international and cultural differences that merit discussion in terms of how errors are seen and addressed by teachers, from commonly using error as a teaching tool through to avoiding errors and associated discussion as damaging to self-esteem (Santagata, 2005).

Researchers investigating error focus on teacher responses to student error, and a few explore how students respond to teacher error (e.g. Heinze, 2005; Ingram, 2014b; Santagata, 2005; Steuer et al., 2013; Tainio & Laine, 2015). There is less research on how teacher error management occurs in the classrooms of experienced teachers or on the role of error. If error triggers an emotional response, this has implications for classroom relationships and for students who may not notice the error. This is particularly important in mathematics as there are perhaps more opportunities for error.

The definition of 'error' used here, interchangeable with 'mistake', is that error is a mismatch. A mistake demarcates the distinction between norms (such as usual behaviours) and a deviation, (the unexpected or different) thereby defining what is false and what is correct (Heinze, 2005). Using the classic constructivist definition of emotion as a response evoked by recognition of a disparity (Mandler, 1989), it seems error cannot occur without an emotional association. Implications include that patterns of individual emotions in mistake situations can be used as a measure of classroom culture. For this reason, Steuer et al. (2013) asked students about their teacher's handling of mistakes. In addition to identifying 'mistakes friendly' or 'mistakes unfriendly' environments, they found that perceived mistakes friendly environment resulted in increased effort. Yet as recently as 2014, research suggests that UK teachers still predominantly give the message that errors are to be avoided, often through a variety of teaching strategies that rarely indicate an incorrect solution. "These strategies all give the interactional message that errors are to be avoided, or that errors are undesirable even when the teacher does not explicitly say this, or in fact explicitly states the opposite" (Ingram et al., 2014, p.40). In terms of beliefs, a teacher's stance on error may be revealed by their response to incorrect answers, but more indicative is their response to public revealing of their own errors. Such responses model expected emotional responses to error for that class. Tanio and Laine (2015) consider this in relation to emotional contagion where "Emotional contagion means that in interactions, emotions are usually shared by participants after one participant has offered public forms of emotion for others to attend to" (p.84). Further, students will mimic or synchronise (Hatfield, 1994) with their teacher's publically expressed affective pathway. According to Goldin (2000), people experience a series of emotions as they pass through the process of problem solving in mathematics. The result is an error climate. Steuer et al. (2013) see what I refer to as affective pathways as a predominantly positive (adaptive reaction) or negative (maladaptive) patterning which, if public, means displaying certain emotions enhances learning (Tainio and Laine, 2015).

> Primarily, an adaptive reaction pattern is distinguished from a maladaptive pattern: An adaptive reaction pattern following errors and failure maintains learning motivation and functional affects such as joy; a maladaptive pattern decreases learning motivation and increases feelings of shame and hopelessness. (Steuer et al., 2013, p.197)

Examples of transcript and identified affective pathways (Table 1 & 2) from the classrooms of experienced teachers (> 10 years) illustrate how teachers encounter and manage error. I examine the data from the lens of *affective pathways* (Goldin, 2000). Affective pathways are a potentially useful model to examine the illustrative examples. A pathway structures the interpreted emotional journey by labelling emotions from identifying a problem through to either resolution or abandonment. Examining teacher modelling of how to deal with error in conjunction with how a teacher emotionally manages error may assist in interpreting the affective impression given to students. Mandler (1989) suggests that using and modelling emotional responses to error inculcates a tolerance for error that benefits learning mathematics. The means by which a teacher frames the handling and recovery from error can shape student experiences, and indicated preferred attitudes to error management (Santagata, 2005).

From the above, it seems we need errors to learn, whilst teachers can support learning and affect classroom environments by modelling positive responses to error. The question addressed here is whether examining how experienced teachers model error is useful in developing a model of error management. To address this question, the data presented below is from a larger study on teacher expressions of emotion in the classroom. Both extracts are drawn from episodes of emotional expression, deemed as such through observation, measurement of galvanic skin response (GSR), (used to roughly indicate internal emotions) and confirmed in post observation discussions. They represent how experienced teachers might manage error. Other strategies, such as used by novice teachers, are drawn from the literature, collaborated by my own experience of working with teachers.

Modelling dealing with mathematical error (Adam and Bertha)

In these examples, both Adam and Bertha successfully address a numerical error. Both express emotions (the dominant emotion is determined by the observer, using standard emotion classifications (Scherer, 2005)), yet differ in pathway from recognising discrepancy to resolution, showing the teachers' disparate ways of modelling error management.

In the first example (Table 1), Adam accidently writes 2 for the difference between 4.5 and 3.5 when demonstrating upper and lower bounds for 5 – 4. As he reads the four possible answers aloud, '2,0,2,1', he slows, quietens his voice and movements, pausing with pen poised, whilst his head moves from side to side scanning. He then steps back and just looks for several seconds, appearing absorbed. Once he has identified the error, he utters the sound 'uhh', interpreted as 'never mind'. Adam then engages in a repeated exchange of silly noises with one student, corrects the error, rewards a student who is quick to align, and continues in the same faster pace as at the start of the episode, quickly moving on from the error.

T	You can either do for 5..., 4.5 or 5.5, they're your two options, because that's the lower and the upper bound. So what I have written out on the board is all four different combinations of what can happen.	Confident
	Ok… [pause]	Uneasy
	I'm going to work out all of them. So I am going to get 2, 0, 2, 1. [GSR PEAK]	ERROR
S1	Blastoff…	
S2	It should be 1.5	
	Right, think about this. [pauses]	Confused
	The question was saying upper bound, the upper bound for 5 minus 4. That number is going to be as big as possible. [emphasis and shift in pace into regular time beat 1-and-2- and-3- and-4-] as | big | as | Pos-si-ble	Re-establishing certainty Interested
	Hm. [Pause with pen ready, his head moves as scans writing and then steps back] Looks like 2. [Pause] … Which 2 is it going to be? Well here... [pauses again, this is in a quieter voice]	Doubt Uncertainty Thoughtful

	Oh that's right, I've done that wrong, that should be 1, uhh, [faster pace resumed]	Satisfaction
	Who picked up on that? [HANDS UP] Chris [S3]? Gold star[smiling]	Pleased
S2	How about me? Oh. Uh	
	Uh	Humorous
S2	Uh I said one though sir	
	Sorry, that's a 1. The biggest number is 2. How did I get 2? I took the biggest number possible here for 5, but the smallest number possible for 4. That made the difference-as-big-as-possible. 2. [firmly stated] Upper bound.	Confident

Table 1: Affective Pathway from Adam's lesson, where he makes an error

Bertha uses a well-known mathematics website to produce questions on the area of a circle (Table 2). Following the students finding the area for a given radius, Bertha enters a volunteered answer, but the website rejects this answer. As Bertha has already calculated the answer herself, agreeing with the student, the website rejection brings an unforeseen problem for Bertha; she thinks she has made an error but has not. The discrepancy is between using π or 3.14, so it relates to the degree of accuracy.

S1	254.46 [student is providing answer to question on the board]	
T	.46	Neutral
S2	I've got .34 [Different answer which legitimises other students who also have different answer and they start calling out as well]	
T	Ok. Whoa, whoa, whoa, whoa, whoa.	Uneasy
	Does anybody disagree with the 254 bit?	Neutral
Many	No, yes, [some hands up]	
T	NO? Right. Can anybody think of a reason...	Neutral
	...oh I don't think if we can... yeah, we have. [GSR PEAK]	Uncertain
	Can anybody think of a reason why you might have different, very slightly different answers? [Terry among others raises his hand] Terry...	Confident
Terry	Is it because like one of us...um...were like... we weren't... um.... I don't know if it's right or....	
T	[Frowning]Well just, Terry, just say it, have more confidence in yourself sweetheart...	Hopeful
Terry	...some people pressed the... the pi button and some people didn't.	
T	Absolutely brilliant, well done you.	Pleased
	That's exactly right.	Satisfied
	When you press the pi button on your calculator, it uses a really accurate version of Pi. If you just put in um... 3.14, [writing something on wall behind teacher desk] then that's not so accurate...	Neutral
	...and that's the only reason.	Satisfied
	But anyway, it's coming up and telling us we're wrong.	Uneasy
	So it says use the area of the square, we've got the area of the square as 9x9,	Neutral

	and then multiply it by 3.14... [Does this on a calculator]	
S2	It's 254.34	
S4	Error	
T	... 3.14 .... (yeah) 254.34	Satisfied
Many	Yes!	
S4	Error	
T	...2...5...4....point... oh I see, point 3 4. Let's try it again [enters answer which is shown on the projector] Yeah!	Confused to satisfied
ALL	Yeah!	
T	OK	Satisfaction

Table 2: Affective Pathway from Bertha's lesson, where she makes an error

A proposed model of teacher error

One intention of drawing attention to teacher error is to inform discussions about how such error should and could be managed. The management is not the same as when a student makes an error. Firstly, that there are emotional implications of the choices made by a teacher, including the degree of emotional labour required. Secondly, that the choices are indicative of how a teacher perceives error, both for themselves and for their students. And thirdly, that repeated over time, modelling by the teacher of error management sets the climate for students in terms of their own error management. If it is desirable to challenge behaviourist views of learning mathematics (Boaler, 2015), then discussion of error management provides an accessible route to address teacher beliefs. In order to support such discussions, the following continuum of error management strategies is proposed. This is derived from both the literature on error and the above data. The continuum moves from negative (associated with a mistakes unfriendly environment and maladaptive error patterns) through to positive, and similarly from strategies with perceived reduced benefits, through to those which may have longer term positive impact for learning (mistakes friendly environment and adaptive patterns).

To compare and contrast with the examples above, I draw from research on and observations of trainee teachers. In this cohort, I observed embarrassment at making an error, ignoring the error, even when noticed, and once an error on the whiteboard left uncorrected. I also observed surreptitious correcting when the students were engaged in another task. There is ample anecdotal and observable evidence that teachers hide numerical errors. They may later notice and either leave it, or notice and amend privately. The communicated message is that errors are dispreferred (Ingram et al., 2014), and should be hidden. Similarly, public error can evoke teacher embarrassment or be correctly rapidly, where the teacher 'steps out of' rather than 'stepping into' learning through addressing the error. 'Stepping out' attaches a negative emotional association to error making. A teacher may respond to revealed error by faking, as in "I meant to do that" and publically amend. Although positive in avoiding misunderstanding resulting from the error, this choice can be negative emotionally, in that frequent repetition erodes trust in the teacher. A further response is to associate self with the error through self-depreciation. A teacher might say something like, 'What a silly error!' The effect may be that students view all error as silly, and to be laughed at. This may be positive or negative as context specific, but students may reduce contributions if they feel they may be laughed at.

There are suggestions in the literature on error that using deliberate error as a teaching strategy can be effective. This assumes a constructivist view, that the place of error is a learning opportunity, rather than a culturally located behaviourist view, that errors should be avoided (Santagata, 2005). In constructivist terms, viewing error as a learning opportunity is an ideal, yet how a mathematics teacher might cultivate such an ethos needs further research. Research from Ingram et al. (2014) found examples aimed at this ethos, but that in most cases the errors are still managed as something to be avoided. They identify a role for further strategies when positioning error in this way. They suggest either distancing self from the error since the purpose is for students not to make the same errors themselves, or apologising for an error. A more positive management might dismiss the error, but go on to associate with an emotionally positive outcome, such as thanking the student for pointing out the error. The emotional message is that criticism will not follow from error identification. However, taking the error handling strategy further, the identification may be made into an event through provoking a discussion, or may be acted out. There are many possible options, such as expecting error due to rapid engagement in doing mathematics or that error is just to be expected. The event could show that corrections are fine, that corrections are neither good or bad, and are just a learning opportunity. The attribution of value to the error communicates a message in itself.

In the examples from Adam and Bertha there is a mixture of the above that tend to the emotionally positive end of the continuum. What was not apparent either in the examples of data collection was a view that 'I never make mistakes'. Although both examples are public, Adam notices his own error as part of the next step, whilst Bertha's attention is claimed by rejection of her answer by an online website. What may be significant is the emotion work in both cases to turn the event to a positive learning experience. As for similar examples from Tainio & Laine (2015), the teachers take affective stances that display affiliation and humour (p.73). They also evoke emotionally positive responses for the students. Both show happiness in resolution of error, and give praise albeit located differently.

Bertha tells in a later interview of a formal observation that went wrong because the questions on the website changed. A repeat experience, when again being observed, albeit for research purposes, is likely to re-evoke emotions associated with insecurity, and a need to check solutions with a form of authority, in this case the website answer. Modelling a need for accuracy, for rechecking, reinforces a product orientated 'feel' in the example, where correctness takes precedence. There is also modelling of internal thought processes. In Bertha's case public thinking out-loud for self, "[muttering quietly] ...2...5...4...point...oh. I see, point 34. Let's try it again." Possibly this indicates Bertha seeking mathematical correctness. This corresponds with what she says in interview,

> I don't see myself as a mathematician. I see myself as someone who is good at maths and you can teach me anything in maths and eventually get it, which does again sounds obnoxious but that's...you know... it might take me a lot longer with some of the things. (Bertha)

Seeking confirmation of correctness perhaps indicates a belief that ‘real’ mathematicians do not make errors. This example shows an intention to model what she thinks a teacher should be doing, indicating a disparity between real and aim more commensurate with trainee teachers. In contrast, Adam models shifting ownership of error by repositioning from ‘we’ to ‘I’, modelling that gives an impression that it is ok to err. He positively manages the error, moving sequentially from a point of uncertainty into exhibiting positive emotions using humour via exchanging noises and giving praise, which acts to restore lesson balance. His modelling of how to deal with error includes distraction of attention and shifting attention via assigning a social reward for correction of error. In the episode, the error becomes an object unassigned, before it is quickly shifted into a positive outcome. As an observer, it felt as if he was pinning the error somewhere distant from self. However, he included students in his happiness at resolving the error, and hence was rewarded. Either interpretation is a modelling that downplays error. As he says afterwards,

> Oh, yeah, did I put a mistake on the board to start off with? (Yeah) Yeah...I’m not fussed with that. It happens quite a lot. I always say to the students... I’ll make mistakes, and they’ll make mistakes...and there it goes...(Adam)

Both teachers seemed to experience cognitive conflict, observable in the lesson as uncertainty, and resolve the error for themselves. They both resolve positively for their students, stepping into the error again as part of positive modelling. The data confirms that it is not the error itself but how it is managed that has implications. Public teacher error has more impact, whereas perhaps students are expected to make errors. Underlying the difference between the examples and trainee teachers lie the issues of confidence and risk with the subsequent implications to learning climate of handling error after and during public exposure. We assume that expert teachers have confidence, but the examples show that the use of emotions is part of the restorative process, as a distraction. This seems to warrant further investigation, as does the disparity between the expert (who makes no mistakes) and Adam’s declared and enacted position on error. Mandler (1989) suggests emotions activate other mental contents to deal with situations perceived as being a mismatch between what is intended and what occurs.

Conclusion and implications

In the above I have used two short episodes to illustrate teacher error management, since the research suggests that modelling of error responses plays an important role in construction of positive emotional climates in a mathematics classroom. Based on this initially small sample, the use of affective pathways seems to support exploration of the adaptive/maladaptive reaction patterns. There may be potential in exploring adaptive patterns with teachers as part of professional development. It may also be useful, in conjunction with ideas such as positive mindsets (Boaler, 2014), to consider how students might participate in error management to a greater degree. The different responses of the teachers, although both successfully resolved in that student reward is given as restorative praise in both cases, have different longer term impressions. Adam says ‘gold star’ for a student and quickly moves on, whilst Bertha draws attention to the correct answer, and to rewarding the student. The impact on students of repeated modelling of ‘not my error, let’s move on’ (process interruption only) compared to ‘we must get this right’ (product orientation) may be significant. Shifting attention acts to distance the teacher from the ownership of error, modelling addressing error as positive. This distancing compares to a negative impact that models dealing with errors as an annoying problem, one owned by both teacher and students. There is inevitably a degree of uncertainty in relation to error management. These examples represent extremes of a management continuum from valuing error as a learning experience (modelling an expectation of error into learning), to a belief that errors are obstacles to avoid. One risk to a teacher may be in not using positive emotions to manage error.

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