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Engineering students' self-confidence in mathematics mapped onto Bandura's self-efficacy

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Abstract

In the UK since the early 1990s, there has been widespread concern and extensive reporting about the difficulties encountered by engineering students with the mathematical elements of their university courses. Students' lack of previously expected mathematical skills is of particular concern and has prompted the provision of mathematics support in many UK institutions. A related problem is students' lack of self-confidence (or self-efficacy) in their mathematical capability, and this paper seeks to explore how this has arisen and how it affects students' learning, and proposes suggestions for improvement.

Interviews were conducted with final year engineering students at Harper Adams University College in 2009. These explored students' experiences of and self-confidence in learning and using mathematics before and during university and what they anticipate in the future. The seven students interviewed exhibited a range of self-confidence and achievement and their responses about self-confidence and mathematics support were analysed. Despite their wide ranging backgrounds, all of the students achieved well in their first year university engineering mathematics modules, which naturally increased their self-confidence. Several students described how using the mathematics support provision had helped them with mathematics and improved their confidence.

In addition to analysing the interview scripts thematically, Bandura's model of self-efficacy (Bandura, 1997) was used as a conceptual framework with which the students' accounts were cross-matched. Bandura's model proposes four sources of self-efficacy (past achievement; comparison with others; what others tell you; feelings or physical states) and four mediating processes (cognitive; motivational; affective; selective processes). Additional sources of self-confidence outside of Bandura's model were also described by the students, in particular working with peers, appropriate speed of teaching and small group sizes.

The most important source of self-efficacy was found to be students' past experience of success or failure, and all four of Bandura's mediating processes were referred to by the students. There was no mention, however, of verbal persuasion, and it is argued that lecturers and support tutors might do more to develop students' confidence through this means. Most importantly, students' opportunities for success should be maximised, including careful provision of challenging tasks at the right level, in order to build students' self-confidence in mathematics.

Introduction

Since the early 1990s, there has been widespread reporting of national concern regarding UK students' competency in mathematics. This phenomenon became known as the *mathematics problem*. In 1995 the report *Tackling the mathematics problem* expressed 'the profound concerns of those in higher education about the mathematical background of students applying for courses in mathematics, science and engineering' (London Mathematical Society, 1995, p1). Sutherland and Pozzi noted that 'Students are now accepted on engineering degree courses with relatively low mathematics qualification in comparison with ten years ago' (1995, p5).

The consequence of students being less well prepared in mathematics was that many then had difficulties with the mathematical elements of their courses, resulting in failure or withdrawal. In their *Subject overview report of electrical and electronic engineering* the Qualifications and Assessment Agency

expressed concern at relatively high failure rates in the first and second year of undergraduate degree courses (up to 60% non-completion rate) and that student failure was mainly due to problems with students acquiring necessary skills in mathematics (QAA, 1998).

The declining mathematics competency of the student intake at several universities in successive years was reported by Hawkes and Savage in their report *Measuring the mathematics problem* (2000). The PROGRESS 1 conference reported a survey of 42 HEIs which found that the subject of mathematics overwhelmingly dominated the list of problematic subject areas for both first and second year engineering students in 67% of circumstances (Cutler and Pulko, 2001). These difficulties also threatened the supply of suitably trained graduates essential to science, industry and the wider economy (Roberts, 2002). So great was the national concern that a government inquiry into post-14 mathematics education was conducted which 'found it deeply concerning that so many important stakeholders believe there to be a crisis in the teaching and learning of mathematics in England' (Smith, 2004, page v).

Many UK HEIs now provide mathematics support provision. Reported examples include Perkin and Croft (2004), Parsons (2005), Bamforth, Robinson, Croft and Crawford (2007) and Croft, Harrison and Robinson (2009).

Whilst students' lack of mathematical skills was clearly a problem, another related issue was students' lack of self-confidence (or self-efficacy) in their mathematical capability (Kent and Noss, 2003). It is this lack of self-confidence which this paper seeks to explore: how it has arisen and how it affects students' learning.

At Harper Adams University College in England, student achievement and retention was improved after the engineering mathematics modules were restructured in 2001 and a mathematics support tutor was appointed (Parsons, 2005). Engineering courses were available at four award levels (MEng, BEng, BSc and HND/Foundation Degree (FdSc)), with opportunities for movement between awards. Entrants to BEng and MEng engineering degree programmes were required to have mathematics to at least AS level (the first part of the English 16-18 mathematics qualification comprising both AS and A2 levels), although some students had Advanced level equivalent qualifications such as National Diplomas instead. Entrants to BSc and FdSc courses were students with less strong mathematics backgrounds. In classroom-sized groups (BEng students with MEng students, separately from BSc and FdSc students), students were taught mathematics by several lecturers in two hour sessions which included students working on problems. Mathematics support provision in the form of regular, optional *Extra Maths* classes and individual appointments was also available (Parsons, 2005).

In June 2009, semi-structured interviews were conducted with seven final year engineering students who represented a range of experiences, abilities, self-confidence, courses and levels of achievement. The students were questioned about their experiences of learning mathematics before and during university and their anticipated use of mathematics post-graduation and were asked to reflect on their years at university and how their abilities and self-confidence had progressed. This particular research was part of a larger project examining students' learning of mathematics and statistics for which other interviews and questionnaire surveys were conducted but are not described in this paper.

This paper presents the theoretical framework of Albert Bandura's four principal sources of self-efficacy beliefs and four mediating processes by which the effects of self-efficacy are produced (Bandura, 1997). His model is consistent with the work of other researchers, as we shall show. The methodology for the student interviews is described, followed by a selection of findings relating to self-confidence and mathematics support. The findings related to self-confidence are cross-referenced with Bandura's sources and processes and it is concluded that the theory provided a useful explanatory framework. Finally, some suggestions to increase students' mathematical self-confidence are given.

Self-confidence in mathematics

Self-confidence is a belief (Fishbein and Ajzen, 1975). The Oxford Dictionary defines *confidence* as 'self-assurance resulting from a belief in one's own ability to achieve things' (2007, p201). Professor Albert Bandura, a renowned award winning American psychologist and past president of the

American Psychological Association (Pajares, 2004), defined perceived self-efficacy as 'not a measure of the skills one has, but a belief about what one can do under different sets of conditions with whatever skills one possesses' (Bandura, 1997, p37). As can be seen, *self-confidence* and *self-efficacy* are broadly similar. Bandura considered each person to have sets of different self-efficacy beliefs, each relating to different skills and distinguishing between sub-skills and overall skills which he termed *operative capability*. For example, he deemed driving competently in varied conditions to be a non-trivial *operative capability* (Bandura, 1997, p38).

Parsons et al. (2009) model self-confidence in three confidence domains: '*overall confidence in mathematics*' (for example, a person lacking this confidence might say 'I don't have a mathematical brain'); '*topic level confidence*' (specific to a particular topic and level of difficulty); and '*application confidence*' (for example the confidence to apply mathematics in a workplace environment with less predictable mathematical requirements). All three domains would be termed *self-efficacy* by Bandura (1997), whose *operative efficacy* is equivalent to '*overall confidence in mathematics*', and whose *sub-skill efficacy* relates to the '*topic level confidence*', with '*application confidence*' being a self-efficacy under different conditions.

Pajares and Miller (1994) also wrote about *self-efficacy* in mathematics, but distinguish between self-efficacy and mathematics *self-concept*, stating that:

> *Self-concept differs from self-efficacy in that self-efficacy is a context-specific assessment of competence to perform a specific task* […] *Self-concept is not measured at that level of specificity and includes beliefs of self-worth associated with one's perceived competence.*

Pajares and Miller's *self-efficacy* is similar to '*topic level confidence*' and *self-concept* is equivalent to '*overall confidence in mathematics*'. Whilst Parsons et al., Bandura, and Pajares and Miller use different terms for these *self-confidences*, there is a common distinction between the *self-confidence* to perform a specific task and an overall *confidence* in mathematics. The '*overall confidence in mathematics*' is of particular

interest because it relates to students' perceived capability in mathematics in general, which Parsons et al. (2009) have shown has a statistically significant relationship with students' achievement in engineering mathematics at university.

Bandura's self-efficacy theory (1997) is used in this paper because it provides a detailed framework for the sources and effects of self-efficacy which has been widely recognised and referenced by other researchers. One such example is a study of computing students which investigated the source of students' self-efficacy beliefs and their engagement with learning (Warwick, 2008). Both Bandura and Warwick emphasise the helpfulness of considering *ability* to be an acquirable skill rather than an inherent quality; this encourages positive cycles of effort, achievement and confidence or positive feelings about mathematics (Warwick, 2008; Ernest, 2000; Bandura, 1997).

A description of Bandura's model for self-efficacy is provided here in preparation for later presentation of the results of cross-matching the students' experiences to the model. Bandura proposes four principal sources of self-efficacy beliefs: '*enactive mastery experiences*', '*vicarious experiences*', '*verbal persuasion*' and '*physiological and affective states*' (1997, p79). *Enactive mastery experiences* are past experiences of endeavours, both successful and unsuccessful. Past successes enhance self-efficacy whilst failures undermine it, especially failures in early experiences of the activity. Persevering to complete difficult problems is recognised as contributing to producing a strong self-efficacy. *Vicarious experiences* are comparisons with peers or similar persons and circumstances; perceived superiority enhances self-efficacy whereas perceived inferiority lowers self-efficacy, depending on the capabilities of those with whom comparisons are drawn. *Verbal persuasion* occurs when others say whether they consider that we can succeed. Other people expressing faith in one's capabilities helps to sustain self-efficacy, but this must be realistic and has the greatest effect when people already have reasons to believe they can succeed. *Physiological and affective states* provide further information about people's capabilities. For example, an accelerated heart rate may be interpreted as a sign of distress and inability to cope well. Affective states

relate to moods, feelings and attitudes. Mood states can affect memory; a negative mood tends to activate thoughts of past failings, thus diminishing self-efficacy, and the reverse for positive moods (Bandura, 1997).

The above sources pertain to the formation of self-efficacy beliefs, whilst the mediating processes describe the various areas affected by the outworking of a person's self-efficacy beliefs. In Bandura's model there are four types of mediating processes: '*cognitive*', '*motivational*', '*affective'* and '*selective'* (1997, p116). In *cognitive* processes a person's self-efficacy affects whether he or she will view a task or situation as being achievable or not. *Motivational* processes are those which influence a person's reasons for and willingness to do certain actions. These can be grouped into three categories: what past successes or failures were attributed to; what certain behaviours are expected to achieve and how that outcome is valued; and goal characteristics of specificity, proximity and challenge. *Affective* processes can be affected by efficacy beliefs worked out in the person's thoughts, actions and emotions. For example, a person may feel anxiety if they lack the self-efficacy for a task. *Selective* processes choose (or reject) particular endeavours. 'People of high efficacy not only prefer normative difficult activities, but also display high staying power in those pursuits' (Bandura, 1997, p160). This not only affects endeavours and areas of study chosen and pursued but also those which are avoided or ruled out. If these choices are made at a formative stage it may impact the rest of the person's life.

Whilst Bandura's model of four sources and four mediating processes provides a recognised framework, it can be seen that there is some similarity between an affective state and an affective process. Thus 'affect' can be either (or possibly both) a source and/or a consequence of a person's self-efficacy. This overlap does produce some uncertainty as to how to interpret the students' feelings in the analysis. One might also question why Bandura grouped physiological and affective states together as one source, rather than treating these as two separate sources, although it could also be argued that the two are inter-related and would therefore be difficult to separate.

The interview process is described in the next section and findings from these interviews in the following two sections. Cross-referencing of

the findings with Bandura's framework is then detailed in the results and analysis section (cross-matching with Bandura's self-efficacy model).

Methodology

In mid-2009, requests were made for final year students to volunteer to be interviewed for research about learning mathematics. The requests were made in engineering mechanics lectures and through emails and posters. Of the seven male engineering student interviewees who volunteered, five were previously known to the interviewer and none had been asked individually. All were rewarded with a £10 voucher. The students are referred to anonymously as Students A to G.

The courses taken by the seven volunteers are listed in Table 1 below. The BEng and MEng students were taught together for mathematics and mechanics, whilst the BSc and FdSc students were taught different versions appropriate to students with less mathematical backgrounds. Five of the students had transferred to more mathematically demanding courses and were working at a higher level of mathematics than their entry qualifications indicated.

Recorded interviews were 35-55 minutes long. Qualitative data analysis was performed on the transcripts. As semi-structured interviews, there were pre-prepared questions and further questions were also asked in order to

Table 1. Interviewees' courses and mathematics qualifications

Student	Course	Had A2 Mathematics
A	MEng Off Road Vehicle Design	Yes
B	BEng Off Road Vehicle Design	Yes
C	BEng Agricultural Engineering	Yes
D	BEng Agricultural Engineering	No
E	BEng Agricultural Engineering	No
F	BSc Agricultural Engineering	No
G	BSc Off Road Vehicle Design	No

pursue topics of interest. The pre-set interview questions related to pre-university, the various years and stages of their courses and their anticipated future work after graduation.

The interviews were analysed thematically using three different approaches: deductively (by considering the students' responses to the set questions), inductively (by looking for other themes which arose in their responses) and by cross-matching the responses with Bandura's theoretical framework. This qualitative analysis was an iterative process, with the scripts being repeatedly revisited. Sources of self-efficacy which were outside of Bandura's model were also identified. The topics focused on in this paper are the students' self-confidence in mathematics at university and how it was affected by their use of mathematics support.

Results and analysis: pre-set question responses and self-confidence

In this section the responses to pre-set questions about self-confidence and other *ad lib* responses about self-confidence are described and analysed. The cross-matching with Bandura's model will be presented in a later section.

The first substantive interview question asked students how confident they were at learning and doing mathematics (i.e. at that particular moment during their end of final year examinations). Student A was very confident in mathematics and Students B, C and G were quite confident. Student A said '*I was always in top sets and got good marks*' '*I can get 80-90 percent in a maths exam, it's not difficult*' and Student C said '*If I know what I am doing, I can do it*.'

Student D and Student F both reported that they had begun their courses lacking in confidence but that it had increased and, at the time of interview, were confident that they could do mathematics. However, both attributed their improvement to hard work rather than ability. Student D could not do the mathematics at the beginning but could after four years of hard work.

Really a lot of things for me are a real long slog, but the main thing is that I'm prepared to spend the hours doing it and put the effort in [...] *That's what got me up to this level I think* [...] *My*

mathematical confidence has gained over the whole four years but that's mainly through doing it, and repeating it, and doing it again (Student D).

I was never very confident when I started and then I've found that if I do a lot of practising I can still do it now, but I wouldn't say I'm particularly confident with it. It's just practise that keeps me going. I'm no genius with maths. [...] *I often do well in maths, but it's only because I practise a lot* (Student F).

Bandura described a study of children learning mathematics who were given set feedback independent of their actual performance. Some were given feedback that they had improved through effort, which enhanced their perceived self-efficacy; others had feedback that they had a natural ability for the activity and their self-efficacy increased more (Bandura, 1997). Those findings would suggest that Student D and F's gain in confidence could have been greater if they had believed more in their natural ability and not just their efforts.

Student G was confident that he was good at mathematics, but his experiences overall were affected by his dyslexia. Student E, however, was very negative about his ability to do the mathematics in the final year and had a lot to say about his difficulties, although he had been very confident in his first year when he was on the less mathematically demanding FdSc and BSc courses.

The most self-confident at mathematics of the seven students interviewed was Student A. He was a MEng student who had taken A2 mathematics at school; he was always in the highest ability group and did very well. At university he always completed all of the exercises, initially with a friend and then again alone. He made sure that he always learnt the process and understood it; he revised thoroughly and was confident in his exams. He was so confident about learning new mathematics that he derived a suitable formula, combining several others, from a book on his work placement. He was confident he would be able to do all of the mathematics he would need in the future. The highlight of his course had been the mechanics lectures and he was full of praise for the lecturers and enjoyed the mathematics being applied. Of the seven interviewed, this student was consistently

the most confident and high achieving in mathematics.

By contrast, Student E was the least confident of those interviewed. He described himself as 'not very' confident at mathematics and had a lot to say about his difficulties, for example, '*no, even now, I don't understand it, I still struggle*'. He attributed his difficulties to not having studied A level mathematics: '*Fair enough I've been to your support sessions, but that's not two years of learning* […] *at A level*.' He explained that he had been confident on the less mathematically demanding FdSc and BSc courses and his recall of those lectures was positive, but he had found the BEng mathematics very difficult and his reflections on his final year mechanics lectures and examination were very negative.

> *You learn everything for a question and … understand how to do it, and understand the maths behind it, get in the exam and it is written in a different way and then it is just "how do I do that?"* (Student E).

Contrary to this student's pessimistic outlook (throughout his course) and lack of confidence, he actually achieved well. He had started on the HND/FdSc course (partly because he hadn't studied A level mathematics), and had been so successful (especially in mathematics) that he was offered the chance to transfer *twice*, initially to BSc then onto a BEng course (with higher entry requirements) and ultimately obtained a high class of BEng degree. The interviewer considered that his verbal responses were probably affected by his mood (he had found some of his recent examinations difficult), this being an example of a negative mood reducing self-efficacy (Bandura, 1997).

The greatest problem created by Student E's lack of confidence and lack of fluency in mathematics was that it reduced his effort. There were procedures which he didn't even try to do or learn because he assumed that he wouldn't be able to do them in an examination. This is discussed later in conjunction with Bandura's selective mediating processes.

The students all agreed that mathematics was useful and several students were enthusiastic about its importance, particularly students A and F. This was consistent with Warwick's findings (2008), where his students believed

that mathematics was useful for computer science.

All of the interviewees expected that they would need some mathematics in the future and were fairly confident they would be able to do what was required of them. The most confident student was consistently so ('I'll be fine and that's what I do everyday'). Others considered that they might need to revise or refresh their memory when required and having a book to which they could refer would be helpful. Even the least confident student felt he would be rusty but would manage. The results described in this section are cross-matched with Bandura's self-efficacy model later in this paper.

Results and analysis: mathematics support

Students were asked whether they had used the mathematics support, at what point in their studies and in which years of study they thought this help should be available.

There was a range of usage of the mathematics support amongst the students (Table 2). Five of these students had used it and only the MEng and one BEng student (Students A and B) had not used some mathematics support. Also shown in Table 2 are the students' responses when asked when they thought the support should be provided (which obviously bears some relation to when they themselves used it or felt they had needed it).

Where the students had referred to mathematics support, whilst answering other questions, this was noted. A selection of the students' references to mathematics support as part of their answers to other questions is given below.

> *I spent a lot of time practising and doing extra maths for you, and all the extra maths sessions with you, so it wasn't easy but I built it up, and I can do it now* (Student F).

> *We obviously came to see you for help* […] *I've been to your support sessions* […] *This year we probably could have done with coming once a week* (Student E).

> *First year was really helpful, just, you went right back to sort of, GCSE level and worked back up again* […] *then got*

a lot of help from you, to get me through the first year maths, and I think, from then on it sort of built my confidence up […] *I think you always know you've got a bit, like, someone here to help you behind the scenes* […] *when you get stuck* […] *Later in the week, go away, do a bit and then come and see you if you got stuck so, yeah, I think that probably helps, builds more confidence* (Student C).

Student C had used the mathematics support and spoke about how it had helped him to pass engineering mathematics and increased his confidence. At school there was no extra help and he later '*gave up*' because it was '*really quite hard*'. This was an example of a goal being too challenging which was in turn de-motivating. However, at university he succeeded '*whereas here,* […] *you're always here to help and I think that's what sort of got us through*' (Student C).

As has been shown, there were positive references to the helpfulness of the mathematics support and the quotations from the student responses provide evidence for some of the benefits to these students from the support they received.

Results and analysis: cross-matching with Bandura's self-efficacy model

Three of Bandura's four sources of self-efficacy were referred to by the students. Many of them referred to doing well in mathematics (*enactive mastery experiences*), some at school, while all referred to doing well at university (especially in the first year) which had built up their confidence. A few examples are listed: Student A did well at school and university; Student F had got 90% in the first year mathematics module ('*I had never got 90% in exams before, so I was quite proud of that*'); Student G could do the maths at secondary school and at university.

Student D spoke of the importance of difficult work. The work getting harder had made him increase his efforts, which in turn increased his confidence. Student A spoke of a confidence boost experienced from completing a difficult exam question after initially being stuck. These experiences are consistent with Bandura (1997) in that persevering to succeed with more difficult work is important to establishing a robust self-efficacy. When a person solves a mathematics problem which he or she considers difficult this prompts a reappraisal of their self-efficacy. However, for a problem considered already within his or her capability no reappraisal is required.

Positive examples of *vicarious experiences* include Student C, whose confidence was boosted by being around students without A level mathematics, which he felt gave him the advantage. A different student who was Scottish considered that he knew more mathematics than the English and Welsh students on entry. Student B referred to very bright classmates at school influencing his A level choices; this is described further under *selective processes*.

Table 2. Use of mathematics support and recommended provision

Student	Award	When/if used	When help should be provided
A	MEng	Never	1st Year for BSc and HND
B	BEng	Had thought about it	1st year
C	BEng	Used it in 1st and 2nd year	1st year
D	BEng	Used it in 1st and 2nd year	Throughout
E	BEng	Used it in 2nd year	Throughout
F	BSc	Used it every week in the 1st year	First year and possibly 4th year
G	BSc	Used a bit and for revision	Good for 1st years

There was, however, no *verbal persuasion* described by the students at all. Perhaps, had they been asked specifically, they may have recalled some instances, but in their answers to the general questions posed no such examples arose. This could be improved by university staff being made much more aware of the importance of developing a dialogue with their students within which opportunities are taken to actively encourage them and, where appropriate, provide positive feedback regarding their successes.

Affective states were described by some students. Student A enjoyed the mechanics lectures, which were the overall highlight of his course. Student C was sad when he finished some mathematics work with an enthusiastic colleague on work placement because he had enjoyed it. Student D described the satisfaction of being able to complete a complicated example and feeling very pleased about it. Student E, however, was in a negative mood at the time of interview (due to finding some of his recent examinations hard) and the interviewer considers that this could have made him recall more negative experiences than if he had been in a positive mood.

Apart from the sources of self-efficacy above, other features that students referred to as conducive to increasing confidence were smaller group sizes, working with friends and the lecturer not going too fast. These were suggested as helpful lecture features but are more feasible, and occurred the most, in the mathematics support situation.

The four types of *mediating processes* through which a person's self-efficacy might take effect were all referred to by the students in their interviews. There were various examples of *cognitive processes*. Student A (the most confident) sought the highest goals: to do everything and understand everything, did problems first with a friend and again alone and checked full solutions if necessary. He deliberately set high goals and persevered to achieve them. Student E (the least confident) had persevered in order to achieve BEng but was selective in some of his endeavours, deliberately omitting some of the longest and hardest topics.

Motivational processes were evident in several students' transcripts. Students D and

F considered that they succeeded through effort. This view of achievement and confidence through effort provided a strong source of motivation. Students D and E were both put off revising and practising some longer and harder questions (Student E thought he could not do them, whereas student D thought he could but that it would have taken too long). In both cases their motivation and effort was reduced by their lack of confidence. Their expectancy of success was low and the value of the outcome was also low because the students could choose alternative questions in the examination instead. Students A, D, E and F show examples of cycles of confidence, effort and achievement (Ernest, 2000; Warwick, 2008; Bandura, 1997).

Student C had given up on some earlier school work when he found it hard and had no-one to help (which was de-motivating), whereas knowing there was mathematics support available at university had helped him to maintain his motivation (and confidence).

Several students talked about their aspirations (particularly to obtain a degree and pass examinations) which were distal (i.e. distant) goals. Whilst important, these goals were not such powerful motivators as more urgent tasks (proximal goals) such as completing assignments before submission deadlines (which were understandably given more priority).

Several students described feelings and attitudes towards mathematics (*affective processes*) and some have already been described in the *affective states* source of self-efficacy above. Positive (or negative) feelings were associated with high (or low) self-confidence and these feelings could be considered as both a cause of and effect on students' self-confidence.

Selective processes have already been described, as when Students D and E chose to omit some harder questions from their revision. Student B ruled out the possibility of A level studies due to lacking confidence from vicarious experiences, something which will probably affect the rest of his life. Five of the students interviewed had performed well and transferred to a more mathematical award; they spoke of their self-confidence being built up in the earlier mathematics which then contributed to them opting for the course transfer offered.

Conclusions

All of the interviewees had been confident or had gained in confidence in mathematics during their first year and felt sufficiently confident in their future use of mathematics. However, in most other respects, the students described a full range of experiences regarding learning mathematics and related subjects both before and during university. Some students had gained ability and confidence by working really hard.

Most of the students had used the mathematics support (generally in their first and second years) and described how it had helped them improve their ability and self-confidence. Positive feedback was obtained, despite there being limited questions asked specifically about the support.

The definition of self-efficacy, forming and mediating processes defined by Bandura (1997) provided a helpful framework to interpret the students' experiences, although there was some lack of clarity over whether feelings were a source or a mediating process or both. Examples were found for all of Bandura's four mediating processes (*cognitive, motivational, affective and selective*). Interviewees mentioned three of the four sources of self-efficacy: *enactive mastery experiences, vicarious experiences* and *affective states*, but not *verbal persuasion* – this could be improved on. Lecturers and support tutors might consider doing more to create an environment in which students are encouraged that they *can* do mathematics.

Lecturers can also give positive messages to students regarding the concept of ability: considering ability not as a fixed inherent quality but as an acquirable skill instils hope and encourages student effort.

Mathematics teaching and support staff should seek to provide opportunities for all of Bandura's four sources of self-efficacy (Bandura, 1997), through course design, delivery, feedback and mathematics support, in order to improve students' self-confidence as well as their skills in mathematics. However the most important source of self-efficacy (both theoretically and empirically) was found to be students' past experiences of success, so it is most important that opportunities for active participation and success are maximised. Whilst care should be taken to provide achievable tasks so that success is possible, it is also important to include some more difficult or challenging problems as it is overcoming these which prompts a person to reappraise and raise their self-confidence. At Harper Adams the small classroom setting provided many opportunities for practise and success; however the mathematics support environment provided a more personal setting for practise and encouragement. Students' increased self-confidence is not only beneficial in its own right but also promotes positive cycles of further effort and achievement. ∎

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