Formative assessment that bites

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Abstract

It is now an established fact that the learning cycle is greatly enhanced by timely and effective feedback. The use of formative assessment has now become an indispensible vehicle to facilitate student engagement in the feedback process, even if they do not recognise they are receiving feedback. This paper presents a review of some formative feedback events, in which civil engineering students at The University of Salford participate. The cohorts studied cross six years (200+ students), and three programmes at FHEQ level 7. The study indicates that carefully designed feedback events can have a significant impact upon understanding of structural behaviour for students preparing for professional status.

Keywords: Formative assessment, feedback, learning style.

1 Introduction

Masters (FHEQ level 7) students at The University of Salford (UoS) taking MEng Civil Engineering, MEng Civil & Architectural Engineering or MSc Structural Engineering degrees take a module in trimester 1 called *Introduction to Structural Design with Computer Applications* (ISDCA) and a module in trimester 2 called *Bridge Engineering* (BE). This paper reports findings from a six year study of action research interventions designed to improve student understanding of structural behaviour. The study led to a separately delivered sketching course which was also made available to graduates preparing for IStructE membership examinations in the Lancashire & Cheshire Regional Group.

The initial hypothesis of this research was that learning style and formative feedback are key factors in the ability of students to absorb information and develop understanding; this sprang from earlier action research [1] which studied formative and summative assessment. The aim therefore, was to allow students to identify their learning style; and to establish a sequence of formative feedback events designed to facilitate enhanced ability in structural behaviour activities.

1.1 Learning styles

There is a long-held view that students can be categorised by the methods of learning they naturally use. The pedagogic literature is awash with arguments about whether *learning styles* are real or useful, however for the purposes of this action research they are used as a means of comparison only.

Felder and Silverman [2] provide a useful insight into learning styles which are relevant to engineers using a VLE as part of a blended learning approach. They suggest that engineering students naturally adopt an inductive learning style (general rules are formed from particular observations); however, the natural teaching style is the opposite of this (general rules are delivered first). Furthermore, they found that most engineering students identify themselves as active experimenters rather than reflective observers. So the traditional didactic lecture, where students are passive, is of little use as both active experimenter and reflective observer cannot learn effectively.

This view of learning styles is now believed to be rather simplistic and has been updated in view of more recent research. A far more complex interaction of variables are now considered to form an individual's range of learning styles. Waring & Evans [3] show a student will further develop use of a learning style if it proves to be successful. It is known that successful learners develop learning style *flexibility* and that a learner may operate several learning styles at different levels. It is therefore better that teaching approaches are tailored to the specific task, rather than the style of a particular learner or cohort of students.

1.2 The Learning Style Quantity (LSQ)

The output from a Honey & Mumford [4] learning styles questionnaire is simplistic, and divides behaviours into four types: activists, reflectors, theorists and pragmatists. All students score on all four learning styles, on a scale between zero and 20. Due to this simplicity, students can easily identify traits in their behaviour which align with the theory, and can therefore (under supervision) select appropriate learning techniques which may enhance their learning experience.

When output from the assessment is graphed on a radar plot, students discuss the meaning of different shapes and relative sizes of their quadrilateral. The area contained within each quadrilateral is used in this research as a measure of an individual's propensity to adopt a wide base of learning techniques, and is denoted LSQ. In a typical cohort the LSQ can range from 50 to 300. **Fig. 2** shows the averaged LSQ graph for six years of cohorts, which has a value of 188.

Clearly LSQ is a blunt tool as the results could easily be skewed by students who give answers which they believe are expected rather than answering honestly; so students are only informed that the results will help them improve in the future, and they are encouraged to answer quickly based on their gut instinct.

1.3 Formative assessment and feedback

Formative assessment carries no marks but serves to facilitate engagement by students in activities which will test their ability. The purpose of formative feedback is to monitor progress and correct misunderstanding such that confidence and ability is built throughout the trimester, especially during the initial weeks. Students perceive a benefit in understanding the level of their knowledge and understanding. Lecturers often perceive no benefit (for them) from formative assessment, if they do not engage in modification of learning material or processes.

Students are encouraged to become self-sufficient in feedback on sketching bending moment diagrams and deflected shapes, by creating and checking their own problems using simplistic and free, elastic analysis programmes such as LinPro.

2 The study

Masters level modules at UoS are taught in one day (seven hour), trimester blocks. The first activity for all level 7 civil engineering students is to complete an 80 question Honey & Mumford type, learning styles questionnaire. This is intended to facilitate self exploration and promote discussion about methods of learning which may best suit particular students. This takes approximately half an hour.

The second activity is to complete a paper based structures diagnostic test, which has a time limit of one hour. The test is reused every year and the questions are not available elsewhere. It covers most structural design topics encountered by undergraduates at UoS and requires knowledge of material properties, section property calculation, slenderness and deflection limits, analysis of determinate systems, plastic analysis of beams and frames, stress analysis, bending moment and deflected shape sketching, yield-line analysis of plates, strut buckling etc. There are 200 possible marks and it is unlikely anyone could complete the test within the time limit. The test has a notorious reputation but students are unaware of how, or if, to prepare. After a discussion about good or poor answers to each question, students are issued with a pictorial examiners report on *how not to answer structural behaviour questions*.

Three, ten minute, paper based, weekly structural behaviour tests follow. The first two are multiple choice, the final test requires free-hand sketching of bending moment diagrams and deflected shapes.

The teaching event in the last week of trimester 1 is devoted to preparing students for the end of module IStructE Chartered Membership (CM) style structural design examination. This involves the students in marking a specimen solution prepared by the lecturer, engaging in a critique and then peer assessing each other’s solutions to the same question. Before taking the module examination, students retake the structures diagnostic test.

Each event is accompanied by a feedback session in which students engage in critique of their own, or others, work. The cycle of formative assessment and feedback events for the ISDCA module is shown in **Fig. 1**.

In trimester 2 the Bridge Engineering module follows a similar format and examination to the ISDCA module; including an examination preparation event, in which students are taught to mark a question. The BE examination is also in the IStructE CM style but students are given half the time (three hours) to complete the assessment.

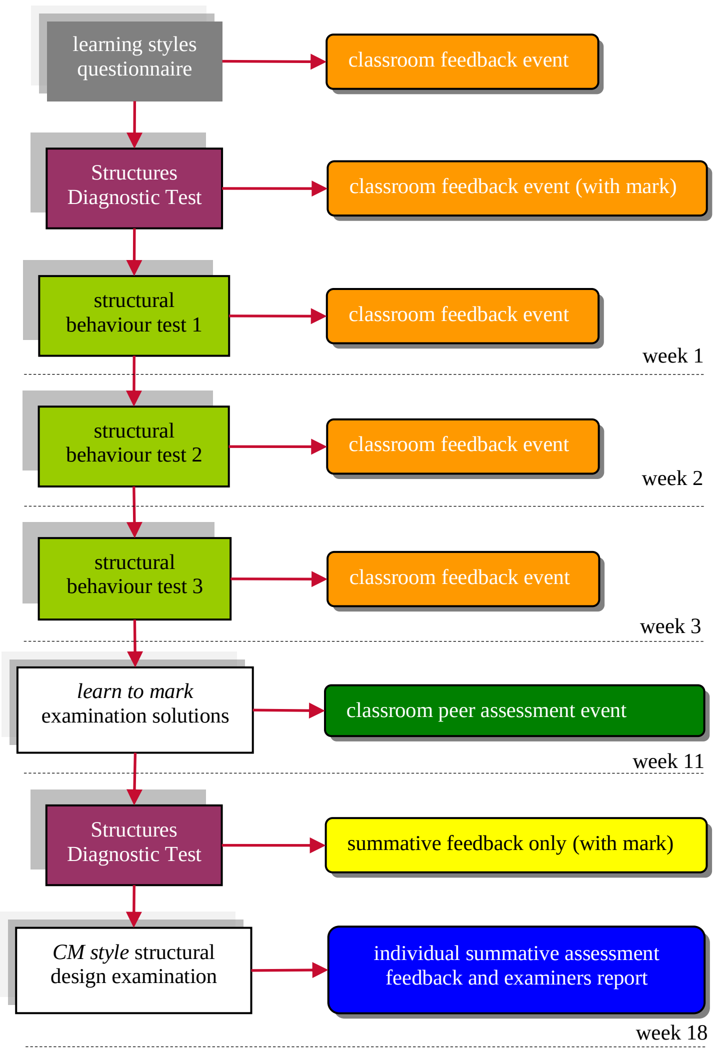

Figure 1. Formative assessment and feedback events for the ISDCA module.

In the ISDCA module, the wider definition of structural behaviour is taken from Morreau [5].

3 Results

Trends presented in this section are for amalgamated data for six consecutive cohorts, taking the same modules. These trends are not discernible when a single cohort is examined.

3.1 Trends in LSQ

The scale of LSQ values is virtually continuous for the six year sample, currently being 14-357. The shape of the LSQ quadrilaterals tend to fall into one of three categories; a) very low scores on all four axes, which result in LSQ less than 100; b) relatively high scores on three axes, which result in LSQ between 100 and 250; and c) relatively high scores in all axes which result in LSQ over 250. These are depicted in **Fig. 2**.

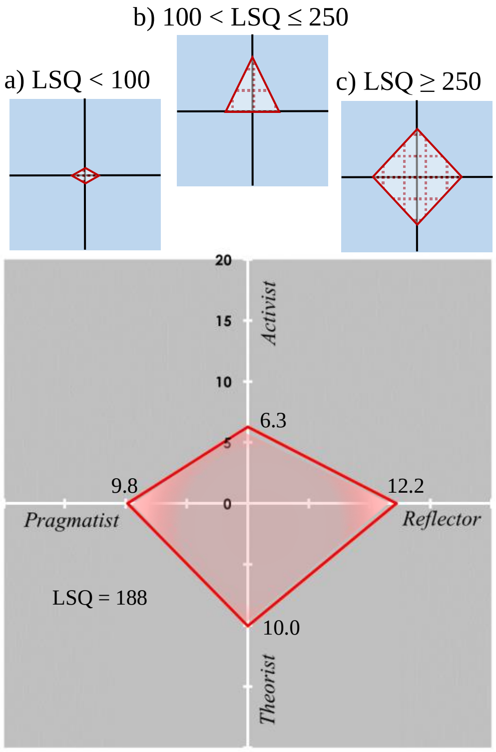

Figure 2. Average LSQ for six cohorts, and generalised LSQ shapes for three score ranges.

Table 1 shows LSQ statistics for three consecutive cohorts of students. The values are comparable though with variations that would be expected in any population. The relative values for activist and reflector were the opposite of those expected when the research began, as engineering students were believed to be activists rather than reflectors.

3.2 The diagnostic tests

Results for the initial diagnostic test, shown in **Fig. 3**, suggest that there is no useful link between LSQ and initial diagnostic test mark.

Results for the final diagnostic test, shown in **Fig. 4**, also suggest that there is no useful link between LSQ and final diagnostic test performance but shows that there is an upper limit to the number of marks which may be obtained in the test, and that there is greatest potential to improve the diagnostic test mark for those with higher LSQ scores. This effect appears to be linear up to an LSQ of approximately 250.

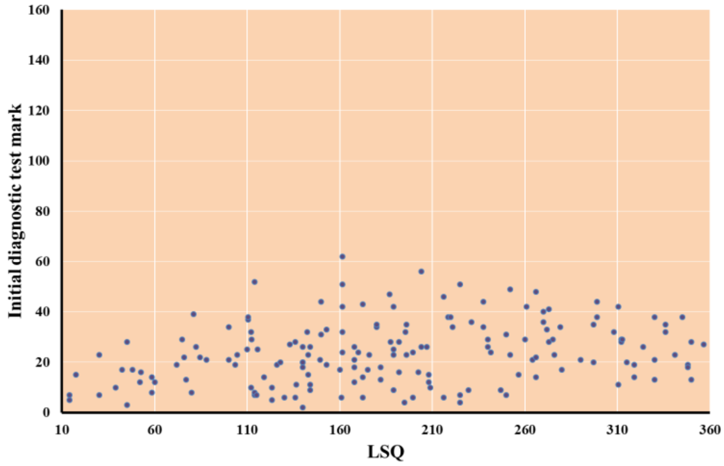

Figure 3. Results of the initial diagnostic test.

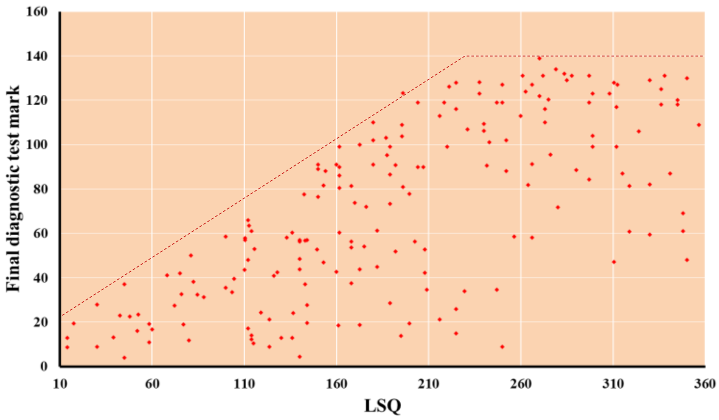

Figure 4. Results of the final diagnostic test.

When the data is divided by programme (full-time MEng Civil Engineering / Civil & Architectural Engineering, and full-time/part-time MSc Structural Engineering), the initial diagnostic test scores are approximately 20% higher for MEng students, however their improvement is not as great as MSc students over the module, and similar final diagnostic test scores can result. This suggests that input standard has little effect upon final performance but is a significant factor in base performance.

3.3 The structural behaviour tests

Results for the first structural behaviour test, shown in **Fig. 5**, suggest that there is no useful link between LSQ and structural behaviour test 1 mark.

Results for the second structural behaviour test, shown in **Fig. 6**, suggest that there is a marked improvement in test marks obtained by students with LSQ above 250.

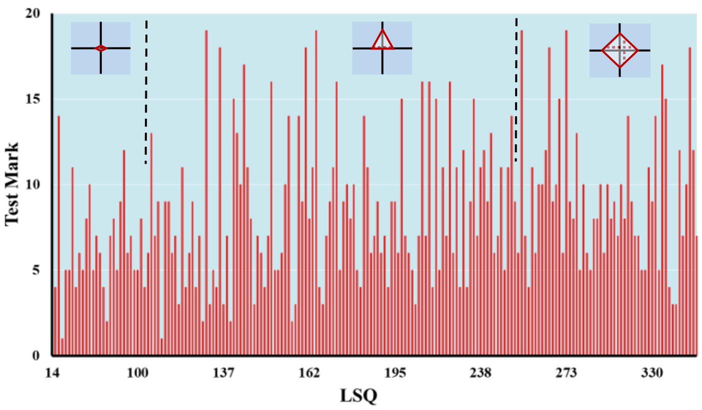

Figure 5. Results for structural behaviour test 1 – multiple choice BMD's.

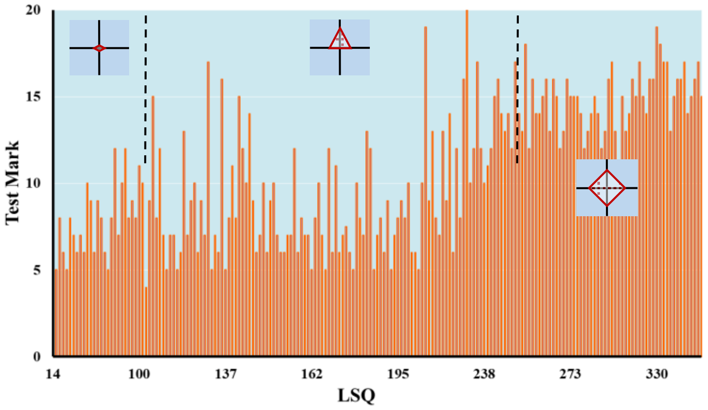

Figure 6. Results for structural behaviour test 2 – multiple choice deflected shapes.

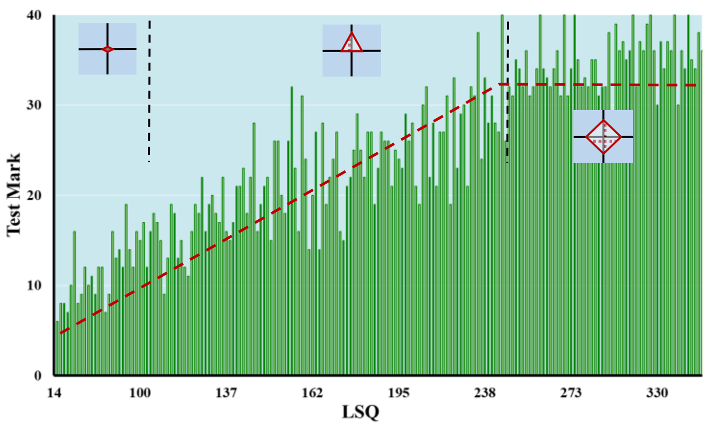

Figure 7. Results for structural behaviour test 3 – sketching BMD's and deflected shapes.

The third structural behaviour test differs from the first two in that it is not multiple choice. Results for the third structural behaviour test, shown in **Fig. 7**, suggest that there is a positive and approximately linear relationship between test marks and LSQ, which may have a limiting value for LSQ above 250. Virtually all the students who obtained full marks in this test were in the LSQ 250+ range.

3.4 The module examinations

Fig. 8 shows the relatively weak relationship between final diagnostic test mark and ISDCA examination mark. There is significant spread in the data, and many outliers to the elliptical bi-variate boundary, which is also superimposed on **Fig 9**.

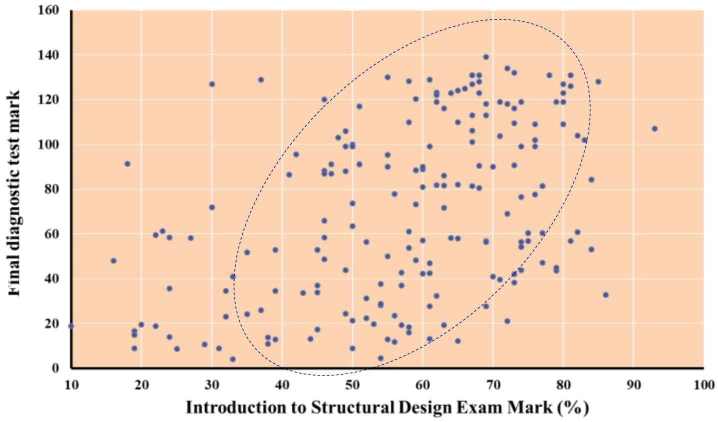

Figure 8. Relationship between the final diagnostic test and ISDCA examination mark.

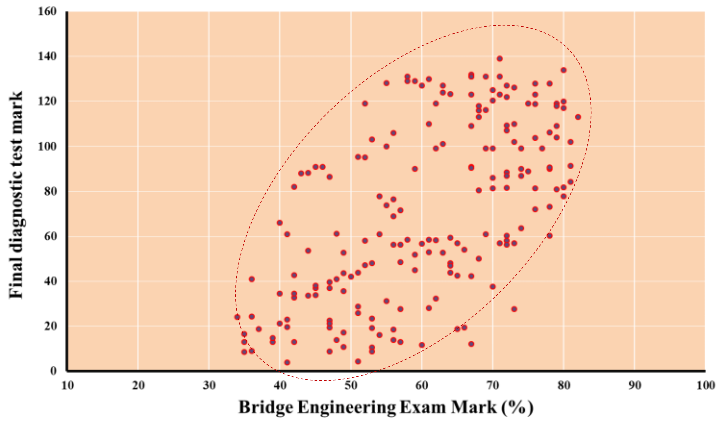

Figure 9. Relationship between the final diagnostic test and BE examination mark.

Fig. 9 shows the significantly stronger relationship between final diagnostic test mark and Bridge Engineering examination mark. The elliptical bi-variate boundary suggests there is a useful relationship between the variables. The BE examination is taken one trimester after the ISDCA examination, and takes a similar format and content. The extra cycle of learning may be a contributing factor to the more predictable nature of the second examination results.

3.5 Sketching workshops

One outcome of the first rounds of this action research was an intervention to create a sketching event for level 7 students. This was later also delivered as a Lancashire & Cheshire Young Members IPD event. Participants at seven such events were asked to complete a Kahoot! poll which asked nine questions, as shown in **Table 2**.

Over three quarters of respondents had neither an art or technical drawing qualification, and would have liked more drawing and sketching activities at university. About two thirds were taught to draw and sketch at university but an equal number have not been trained by their employer to draw or sketch. The vast majority need to sketch at work, know they will need to sketch to pass an IStructE entrance examination, and improved their ability by practicing sketching at an organised event.

4 Discussion

UoS master's students taking the semester 1 *ISDCA* module take a *learn to be a marking examiner* session in which they mark a specimen paper, receive feedback and then mark another students work (the Institution refers to this as *Trial Marking*). The marks produced are statistically analysed at the event and used by students to moderate their own marking. The general outcome was that the cohorts average mark was about 10% higher than an examiner would award. The marks for five cohorts are shown in **Table 3**. This process was repeated for the trimester 2 *BE* module. However, the general outcome was that the cohorts average mark was within 3% of that awarded by an examiner.

A similar technique was used as part of the Lancashire & Cheshire Regional Group examination preparation course, run at The University of Bolton between 2008 and 2017, as shown in **Table 4**. Graduates preparing for the CM and AM examinations had completed a two trimester programme of general engineering design and examination technique taught by eight lecturers from academia and industry. The week immediately before a mock examination, graduates were given a specimen solution to a selected, ambiguous, CM question and asked to mark it in accordance with a marking plan. With the exception of one year, the cohorts average mark was 12% higher than an examiner would award. Although some individual graduates awarded a fail mark, no cohort has ever failed the specimen paper on average, in either part 1 or 2. The marking examiner awarded a fail mark for part 1, largely because scheme 1 sketching lacked adequate information to show it was viable and stable.

The elliptical bi-variate boundaries shown in **Fig. 8** and **9** indicate that there is a mathematical relationship between the final structures diagnostic test mark and examination marks; and that the relationship strengthens as practice increases. Ordinates of the ellipse are eigenvectors and lengths are eigenvalues, the *condition* of data is the quotient of the longest and shortest eigenvalue; therefore the condition of the data increases as more assessments are taken, and more feedback is received.

This suggests that students initially overestimate the value of their work – they are not aware of what is *missing* or wrong. However, the amount of overestimation reduces with practice. During feedback events, students learn to identify what is missing from their examination answers, and how to improve the quality of their sketches and annotation. Students learn to calibrate their examination trial marking, by comparison with the lecturers marks; many establish peer assessment marking circles to facilitate this. The value of inter-peer discussion has not been assessed in this action research but it is observed in *Structurescope* [6] events that individual students are far more likely to seek assistance from another (older) student than a lecturer, and subsequently adopt the advice given; whereas, peer learning circles will often defer to a lecturer to resolve disputed opinions.

The outcome of the initial structures diagnostic test is not useful to anyone except the student, who has an indication of their starting level of competence; and indicates topics where they would best concentrate their future study efforts to reach the expected input standard for level 7.

The structural behaviour test feedback events have established that students answer multiple choice questions by using structural behaviour rules to *eliminate incorrect answers*. They do not decide what the answer should look like and find it in the list. This may be one reason why there is a marked improvement in the performance between test 1 and 2, i.e. students actively relearn the rules after test 1, and are therefore better prepared for test 2 the following week. Although results for test 3 are also better than test 1, the standard deviation, or spread of marks, is greater than test 2. This suggests that:

- the ability to sketch shapes is not necessarily related to the knowledge of what to sketch (some students have been observed in feedback to *say* parabola but *draw* triangle),
- the ability to sketch is not necessarily related to LSQ (initial observations suggest students with an art qualification outperform students with a technical drawing qualification), so there may be a craft element which is common amongst exponents of structural behaviour sketching,
- the appearance of sketched output improves dramatically with very little practice (2-4 hours). This led to the creation of a sketching event, at which most participants improved their ability.

Fig. 4 suggests there is potentially greater benefit from feedback for students who have higher LSQ, this may be because they are open to use of a wider range of learning styles during the learning process. This does not preclude low LSQ students from performing well but it does appear to limit the learning benefit available to them. Once students have been introduced to LSQ, there is a discussion about how they might adopt a wider set of learning techniques, this can be fraught as those with lower LSQ values often believe themselves to be at a disadvantage.

Table 1. LSQ data for three cohorts of masters level students.

Year	**2014-15**	**2015-16**	**2016-17**
Cohort size (sample size)	30	36	47
Average LSQ	176	174	176
Average scores for style quantities questionnaire (activist, reflector, theorist, pragmatist)	5.9, 11.7, 9.6, 9.5	5.2, 12.1, 9.3, 9.3	6.1, 12.2, 9.9, 9.4

Table 2. Sketching straw poll conducted on Kahoot! averaged over seven workshops.

Question	**Yes**	**No**
Q1. Do you have an art qualification ?	19	81
Q2. Do you have a technical drawing qualification ?	22	78
Q3. Were you taught to draw at university ?	62	38
Q4. Were you taught to sketch at university ?	57	43
Q5. Would you have liked more drawing / sketching at university ?	86	14
Q6. Has your employer trained you to draw / sketch ?	33	67
Q7. Do you need to sketch for work ?	86	14
Q8. Do you need to sketch to pass the IStructE Exam ?	91	9
Q9. Did this event improve your sketching ?	96	4

There may be implications for the learning behaviours reported by current students, as a function of the ubiquitous nature of computing:

- a tendency to subject themselves to constant bombardment from a range of digital media when self-learning, which in most cases is accepted as normal,
- a tendency to be distracted whilst using digital media to access information, leading to *a YouTube tangent*,
- a tendency to be swamped by too much reference material, and subsequently needing help to filter out unhelpful or misleading sources.

The traditional view of educators that learning should be a solitary and quiet activity, which is inhibited by electronic distractions, is not held by many contemporary students. However, most contemporary students must be prompted to use low, or non-tech learning techniques.

This data offers no differentiation for gender or age. It does however include both part-time and full-time MSc Structural Engineering students. Many employers would expect part-time students to out-perform full-time students, however, there is no evidence that initial or final performance is differentiated.

Once a learner understands their learning styles, they should seek new ways to use them but also expand their learning *capacity* in other styles. In this research higher LSQ indicates wider spread of learning styles, which correlate to potentially greater design ability enhancement.

The majority of engineers in this study exhibit triangle-like LSQ shapes (nominally 100≤ LSQ ≤250) but it appears to make no difference which score (activist, reflector, theorist or pragmatist) is deficient.

Clearly, in reality learning is not a linear process, so there are more complex interactions to consider than have been discussed here. It is believed there may be parallels to be drawn with work on self-assessment of competence by Kruger & Dunning [7] who identified the lower quartile of a student test group as unskilled and unaware, and bound to remain so in spite of training.

In this context, **Fig. 3** supports the notion that all students beginning level 7 are to some extent, unskilled and unaware. The difference between Figures **3** and **4** may be a result of some students improving their base knowledge and understanding. The improvement shown across Figures **5**, **6** and **7** by students in the LSQ 250+ range may be a result of awareness of their potentially greater ability to improve.

It is possible that **Fig. 10** identifies groups within these cohorts who have improved skills, or awareness, or both, and have thus moved out of the unskilled and unaware subset. This is necessary for any student who wishes to demonstrate their competence at a professional level.

Table 3. Averaged marks awarded at trial marking of ISDCA mock examination Q2, for five annual formative feedback events, by students.

		Part 1							Total part 1	Part 2					Total part 2	Total Marks	Sample size
	a	**b**	**c**	**d**	**e**	**f**	**g**	**h**		**j**	**k**	**l**	**m**	**n**			
	Two Schemes	Material Selection	Recommend Scheme	Construct ion Sequence	Designer's Risk Assessm't	Durability Issues	Scheme Sizing	Sustainability		Frame	Floor	Detail Joint	Stability System	Foundati on			
Possible Mark	40	5	5	10	5	10	15	10	100	15	25	5	25	30	100	100	
Students 2015	26.9	3.1	3.1	5.0	3.0	8.0	11.4	6.0	67	11.2	16.8	3.5	18.5	24.0	74	70	30
2016	25.3	2.7	2.9	6.0	2.9	6.4	9.3	5.2	61	10.5	17.0	3.8	16.5	21.0	69	65	36
2017	27.8	2.8	2.9	5.4	2.2	6.9	10.3	4.2	62	9.0	16.2	3.3	15.3	17.6	61	62	47
2018	30.2	3.4	3.6	7.3	3.4	8.0	11.3	6.0	73	10.7	17.6	3.8	19.1	22.5	74	73	39
2019	28.2	2.2	3.2	6.5	3.0	8.2	10.5	6.8	69	10.9	17.3	3.9	18.5	23.3	74	71	34
Mean	27.7	2.8	3.1	6.0	2.9	7.5	10.6	5.7	66	10.5	17.0	3.7	17.6	21.7	70	**68**	
Std Dev.	1.7	0.5	0.3	0.9	0.5	0.8	0.8	1.0	4.9	0.9	0.5	0.2	1.6	2.5	5.5	4.8	
Lecturer	24	1	3	7	1	7	11	3	57	7	12	3	15	16	53	**55**	

Table 4. Averaged marks awarded at trial marking of IStructE CM exam Q2, 2002 for nine annual formative feedback events, by graduates.

	Part 1					Part 2						Total Mark	Sample size
	a			**b**	Total Part 1	**c**	**d**	**e**	**f**		Total Part 2		
	Scheme 1	Scheme 2	Recommend Scheme	Letter		Calculations	G.A's	Sketches	MS	Programme			
Possible Mark	16	16	8	10	50	20	15	5	6	4	50	100	
Students 2008	6.8	9.3	5.1	5.9	26.8	12.8	9.5	3.0	3.2	2.3	30.7	57.5	32
2009	4.0	9.0	4.6	6.3	23.9	11.7	9.5	2.9	3.5	2.6	30.2	54.1	21
2010	4.8	9.0	4.6	5.7	24.0	10.8	8.9	2.4	3.5	2.6	28.2	52.2	18
2011	3.7	10.3	4.8	5.7	24.5	11.1	10.3	2.6	3.4	2.6	30.1	54.5	17
2013	4.2	10.4	4.6	5.1	24.3	10.1	9.2	2.5	3.2	2.2	27.2	51.5	13
2014	4.9	7.1	5.1	6.8	23.9	12.6	9.8	3.0	3.6	2.9	31.9	55.8	10
2015	3.8	9.6	3.6	5.2	22.2	11.0	10.2	2.8	3.2	2.3	29.5	51.8	13
2016	4.3	10.4	4.1	5.0	23.8	10.4	8.6	2.5	3.6	2.9	27.9	51.7	16
2017	4.3	8.1	4.5	5.3	21.3	10.1	8.0	3.3	3.4	3.0	27.7	49.0	22
Mean	4.6	9.2	4.6	5.8	24.2	11.4	9.6	2.8	3.4	2.5	30	**54**	
Std Dev.	1.1	1.1	0.5	0.6	1.4	1.0	0.5	0.2	0.2	0.3	1.6	2.3	
Examiner	1	9	4	4	18	8	9	2	3	2	24	**42**	

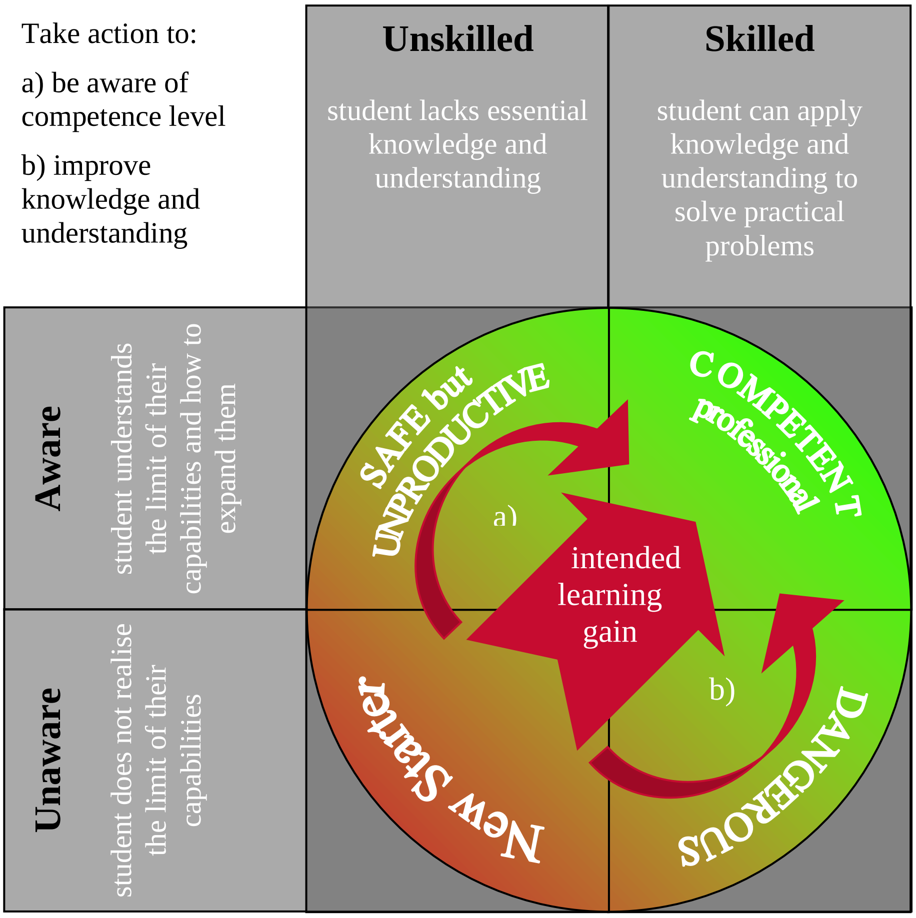

Figure 10. Possible learning gain for unskilled and unaware students.

5 Conclusion

This action research studies performance in an unusual set of level 7 modules, which show more similarities with the Institution's professional examinations than most academic assessments. However, the outcomes are of general use to all academics who intend to assess applied skills; and to the Institution when considering the validity of its Structural Behaviour Course [8].

Some general trends have been reported, from which relationships have been proposed. However, it must be noted that these are only obvious once a sample size close to 200 was achieved; indeed, no single year's data yields useful relationships. This action research sought to furnish students with knowledge of their particular learning styles and develop systematic feedback events designed to facilitate improved performance in structural behaviour tests.

Learning styles remain a topic of controversy in the pedagogic literature, so a commonly used questionnaire was used to establish a Learning Style Quantity, which indicates each student's propensity to use a wide spread of learning styles. Increasing LSQ appears to correlate to *potentially* greater learning gain, in the ability to complete structural behaviour tests and structural design assessments.

The initial assumption that students would, largely, be activists was not upheld.

It is evident that practice and consistency in assessment help students to improve their ability.

Structural behaviour is a skill to be learned and improved. However, the form of test is important as all students over six cohorts have been found to answer multiple choice questions by elimination. This is, perhaps, not shocking but does have implications for the greater challenge of answering free-hand drawing questions, where a flair for art is an advantage, though moderate levels of practice can have great impact on results.

Students can improve their ability to answer professional level questions by developing peer assessment skills (trial marking), which should include benchmarking against the assessment of a lecturer (or examiner).

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Ethical approval and conflicts of interest

Data presented in this study was collected and processed with full approval of the University of Salford Ethical Approval Committee and the Data Protection Act 2018. The author is solely responsible for the writing of this paper, content and copyright, and has no conflicts of interest to declare, nor any financial interest or benefit arising from this research

In 1990 Morreau [5] offered the following definition...

What does 'understanding structural behaviour' mean?
What does *having a good understanding of structural behaviour* imply? What characterises someone who possesses it? I believe it means having certain quite definite abilities:

- to distinguish between a structure and a mechanism, to be on the look out for stability as well as equilibrium
- to identify load paths
- to identify the mode of structural action by which the load is transmitted (tension, compression, bending, shear)
- to predict the deflected shape (how the structure moves under load)
- to predict the shear diagrams
- to predict the bending moment diagrams
- the ability to communicate these by sketches and all this at a level that is almost instinctive, intuitive, a *feeling* for how structures behave.

Predicting does not mean numerical computation, though some rough calculation may be necessary to confirm that the laws of statics are not violated.

…and the following plea to industrialists:

First and foremost, it is by giving them *hands-on* project-based experience in the design and analysis of structures. But, crucially, this must be *under guidance*, **not** *under direction* (do this, do that, and then do the other), but as a conscious teaching exercise in which the inexperienced engineer *learns* from the experienced.