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What makes them succeed?
Entry, progression and graduation in Computer Science[1].

by

R D Boyle & J E Carter[2] & M A C Clark[3]

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[1]Submitted to *Journal of Further and Higher Education*.
[2]Computing Laboratory, University of Kent at Canterbury.
[3]School of Continuing Education.

Abstract

Significant attention has been paid in recent years to student attrition, and rightly so, since rates are rising and need diagnosing. Little attention seems to have been paid to the converse – the successful student. It is widely believed among academics that high school grades – in the UK, A-levels – are poor indicators of final performance, although we persist in using them as entry criteria in the absence of any other index into a student's potential. This study, conducted in parallel in two traditional (pre-1992) UK universities, focuses on one discipline that has peculiar characteristics in intake, student expectation and entry criteria. We confirm some widely held beliefs, and scotch some others. As with all such studies, the number of confounding factors is large, but we draw conclusions where possible that are of relevance to all disciplines, and discuss how we mean to proceed.

1 Background

1.1 Students who don't fail

Changes in the patterns of student attrition have been much discussed over recent years, notably by the Higher Education Funding Council for England (HEFCE) [HEFCE 97]; there is some understanding both of the trends observed and the reasons behind them. The complementary issue of what makes a successful student, either in the sense of seeing it through to the end, or of excelling, has received rather less attention.

There is much academic hearsay and gossip that school level qualifications (in the UK, the A-level) provide a very poor indicator of eventual university performance, although in the UK these remain the primary recruiting criterion of the traditional 18-year old. Behind the raw grades of these pre-university qualifications lie a number of other indicators: obvious ones include discipline specific indicators (for example, the necessity to 'excel' at physics in order to study the subject in a university), but there are others which are less tangible. Popular hypotheses include the (school originated) assumption that 'good' students study more than the average number of pre-university qualifications (in the UK, this is the '4 A-levels' syndrome) and the (university originated) assumption that 'maths is good for you', particularly for scientists and engineers. Assumptions such as these often have a profound effect on candidates' chances of entry to institutions, with attention being paid to the number and area of qualifications offered in addition to their quality.

Similarly, there is hearsay and anecdotal evidence about what drives success in progression, and indeed what determines 'success' (in the sense of high classification[4]). With the significant recent growth in the number of non-traditional entrants (mature, and with qualifications other than A-level from school), a lot of this is indeed literally anecdotal as staff draw conclusions about the likely performance of the unusual faces they are starting to see with increasing frequency in the lecture theatres.

Already we have found it necessary to use value-laden words such as 'good'. We realise, how-

[4] In the UK, it is customary to classify most degrees as I, IIi, IIii, III. A First (I) is an academic accolade, while an upper Second (IIi) might be interpreted as a good, or better than average, performance.

ever, that teachers respond to a wide range of student attributes. For some it is vital that students show characteristics of 'maturity', 'honesty', 'likeability' and even 'a sense of humour', while for others aspects of 'extroversion' or 'aggressiveness' are important [Rowntree 87]. One study [Wood and Napthali 75] identified over fifty ways in which teachers differentiate between students including: natural ability, ability in subject, interest in subject, class participation, confident approach, quietness, behaviour, tidiness.

In a specifically HE environment teachers ambitions for their students' learning are apt to focus on areas such as 'critically assessing the arguments', 'compiling patterns to integrate their knowledge', 'becoming aware of the limitations of theoretical knowledge in the transfer of theory to practice' and 'coming to accept relativism as a positive position' [Laurillard 93]. For academics, how students approach their subject is as important as the knowledge they acquire – 'missing out some keypoints will be forgiven if the argument is good: high praise is offered not just for accuracy, but more often for evidence of integrating lectures with background reading: accuracy is a sine qua non, perhaps, but more is needed' [Laurillard 93].

Here we are not concerned with the meaning of entry or exit grades. Specifically, we make no claims about the validity or reliability of different assessment methods and instruments. Rather, we are concerned with whether it is possible to identify correlation between certain characteristics on entry and success as an undergraduate as indicated by degree classification.

1.2 Computer Science

The discipline of Computer Science[5] (CS) is one of more than 100 recognised by the UK Universities Central Admissions Service (UCAS) [UCAS 00], but is one of the more unusual ones;

- Some parts of the syllabus are extremely fast-moving; several core areas of the subject experience regular rewrites to remain current. The syllabus is also potentially extremely broad, running from highly formal material through many applications areas such as AI, to business-related areas such as IS.
- The range of CS programmes is very broad [ACM 00], corresponding to the breadth of the curriculum; it is very hard to identify syllabus parts common to all programmes. Even 'computer programming' may be interpreted in many ways and may offer no area of commonality. Some of these programmes are clearly vocational, while others take pains to avoid this appearance.
- It is in very high demand – admissions agency (UCAS) figures [UCAS 00] indicate a surge in interest in CS in the wake of the establishment in the UK of a £1000 contribution to student fees. The reason is widely understood to be a student view that 'if I have to pay, I'm going to ensure I get a degree that will get me a job'.
- There are rarely advanced (in the A-level sense) subject pre-requisites. No programme is known that requires A-level CS of its entrants. Many will require some fluency in

[5] 'Computer Science' is used to describe the whole range of degree programmes in the area – the number of these in the UK exceeds 2000 and the number of different titles is enormous.

maths, often to A-level, but far from all. The entry requirements are often cited as '3 A-levels with suitably high grades, subjects unimportant'. This contrasts sharply with most disciplines – it is hard to imagine a university programme in physics that did not demand a good quality 16-18 physics qualification.

- The discipline is relatively new. The first CS degree programmes were offered in the 1960s [ACM 00, Parnas 90] and, in many respects, the disciplinary value system is still emerging. For example, many of the early programmes evolved from mathematics or engineering and the value systems of these disciplines have become embedded in a very narrowly defined 'Computer Science'. Increasingly, however, it is recognised that the discipline also has roots in disciplines such as psychology, management, design, etc. [ACM 00, QAA 00]. At the same time, there are calls for the discipline to return to its scientific and/or engineering roots (see, for example, [Holcombe 00]). In this respect, computing as an academic discipline may be said to be pre-paradigmatic [Kuhn 70].
- CS may also be unusual in the large proportion of its academics who have come to the discipline with a first degree in another subject. Although the evidence for this remains anecdotal, personal experience suggests that CS academics are likely to have first degrees in mathematics or, perhaps, one of the physical sciences, rather than computing. Of course, this may be related to the newness of the discipline but, interestingly, the phenomenon seems to apply as much to recently recruited academics as to those who are well established in their careers.

Thus we are considering a very popular subject, under continual change and review, that means different things to different people, and which will admit anyone considered to have sufficient intellect, often without specific curricular pre-requisites.

1.3 What makes them succeed?

We consider the problem of trying to identify what makes students succeed as a complement to the issue of identifying what makes them fail. Anecdotally we are told that pre-university 'success' is a poor indicator, and if this should prove to be the case then we would seek to learn what we might use instead.

In this paper, we investigate whether entry grades, and subjects studied, do actually bear any correlation to final year outcomes, or if it is indeed the case that they bear no relation. There is a danger here of assuming that a I or a IIi, which is our measure of success, is also the goal of the students. We view high grades as an indication of achievement and intelligence because we view the acquisition of knowledge and understanding as an end in itself; we often offer prizes for exceptional examination performance to reinforce this view. Many of our students see their degree simply as a route to future employment – a high grade would be nice, but any grade that provides the letters BSc after their name is sufficient to provide an edge over those without. This having been said, most of our students do aim to achieve the best marks they can.

Previous studies have shown that the expectations held by academics are often based upon the presumption that 'what worked on them as students will work for them as teachers' [Floyd 97], and that past teaching experiences are an acceptable standard against which to judge new students [Hargreaves et al. 75]. Unfortunately the increasing number of non-traditional entrants combined with the recent radical changes in the UK school system are making this position increasingly flawed.

2 Related work

How students adjust to university and perform, especially in the first year, is a topic of significant interest. HEFCE commissioned a study in the area of non-completion [HEFCE 97]; conclusions include the observations that primary causes are a lack of commitment from the student and a lack of preparation or preparedness for the 'HE experience'; other, commonly cited, explanations (in particular, financial pressures) come lower down the list. The issue of commitment is often seen as bound to choice of university – in the UK, the 'clearing house' system allocates unplaced students to unfilled places, and this is often seen as a cause of potential dropout [Baxter and Hatt 00]. It is noted that student expectation (whether of locality or discipline) is key, and that 'clearing' students' performance is not correlated with school grades. Cook and Leckey [Cook and Leckey 99] consider the development of attitudes among first year students, recognising that they are at their most vulnerable early in the academic career. Most students adapt quickly and their attitudes develop accordingly, but lack of preparedness and unsuitable study skills are seen as primary causes of casualties in this group.

Ozga and Sukhnandan [Ozga and Sukhnandan 98], in following up the HEFCE study, note that a common cause of problems is reactive, rather than proactive, selection among students, and that 'mature' students, often thought to be at greater risk, do not seem to drop out in disproportionate numbers; there is no doubt that their sacrifices, motivation and background pressures are different. It is noted that traditional university processes are often inadequate for identifying problems that might signal casualties, and that prestige institutions can often escape these problems by being able to depend upon a better level of preparedness among their entrants (although this is a position of privilege that is likely to change under growing pressure to expand into new areas). The need for early deployment of techniques that set student expectation (for example, active learning) is stressed. The issue of expanding intake rightly preoccupies studies in this area – over a decade ago, Oldham [Oldham 88] noted that non-traditional entrants could no longer be regarded as 'unusual', and disparaged special courses in 'study skills' suggesting instead that a university culture change was required if retention problems were to be addressed.

In summary, 'dropouts' seem to be connected with lack of preparedness, lack of preparation, lack of motivation and poor expectations. Despite the warnings over many years, attempts by HE to address these problems have been piecemeal and uneven. We are concerned here with the complementary issue of which students *don't* drop out, and it may be that this can be informed by the remedies already proposed.

The issue of 'success' in CS has received some attention in recognition of the unusual syllabus the subject involves. Computer programming in particular is a significant challenge to students and its successful teaching has pre-occupied CS staff since the subject's birth; all conferences in the area will have papers addressing these issues – see for example [Haller 00, Manaris 99]. Evidence about the value of prior experience is mixed – anecdotally, university admissions staff might say that the teenage 'hobbiest' does not make good undergraduate material, having been self-taught poor habits that are hard to change, and having developed narrow or inaccurate views about the subject. On the other hand, programming is a craft skill that is known to be hard for many to master satisfactorily, and there is counter-evidence that those who are well experienced are more likely to do well, although the nature of the experience is likely to be critical [Hagan and Markham 00]. The precise value of pre-university CS qualifications, and of pre-university 'experience', are things that we would like to gauge.

The importance of mathematics in the mastering of CS is a raw nerve in most staff common rooms. In the UK there is a long running change in the 16-18 mathematics syllabus (for example, with the withdrawal of material on matrices) that leaves universities having to start at a more elementary level than they did a decade or more ago. Reducing the importance of algebraic manipulation in both pre- and post-16 maths due to the current 'breadth not depth' regime has had an impact upon the formal reasoning and abstraction skills of all our students. It is unfortunate that topics which are relied upon by CS have been dropped or reduced in importance to make way for topics we don't require. Of course, it is not the entire mathematics syllabus that is needed, but rather particular parts of it – logic is of key importance to the CS curriculum, and this can be demonstrated to be, in relative terms, 'hard' [Almstrum 96]. Equally important is the ability to abstract and represent formally that practice in algebraic techniques can communicate. The importance of preparation in mathematics is a key point of interest in judging 'success' in CS.

3 Aims and Methodology

3.1 Nature of the intake

Arguably, the CS intake is unusual for a number of reasons;

- Demand for CS places in HE is growing, usually faster than other disciplines [UCAS 00]. The reasons for this are simple to understand – a degree in the discipline is seen as a better route to employment than many others. Of course, this motivation brings problems with it; the student can be fixated on the qualification rather than the learning (the 'strategic student' [Entwistle and Ramsden 83, Kneale 97]), and the more traditional academic often finds her- or himself at odds with this tunnel vision approach to study.

- For the same reason, the demand from non-traditional students is also greater than in many other disciplines. Applicants who are returning to work, seeking a career change, or who 'missed out' on HE when 18 will naturally focus on disciplines in which they are going to maximise their future chances.

- As noted, entry requirements for CS programmes frequently *don't* include specific subject requirements. The discipline is not alone in this but is certainly unusual.

- Along with a number of other disciplines, there are gender issues that cause a significant pro-male bias in entry figures. This has been widely documented [Spender 95] and is increasingly well understood, but nevertheless remains an imbalance and potential problem in teaching.

Each of these factors has an effect on the expectations of students, acknowledged as a key issue [Baxter and Hatt 00]. They may be coming to university for reasons driven by economic (or employment) necessity, and may have a poor idea of the true nature of what they are going to study since they have little if any academic experience in the area. The induction issues are consequently more problematic: anecdotally, many CS staff will comment on how surprised large numbers of their students are about what they are expected to learn, and that many of them graduate without ever coming to grips with the more academic aspects of the subject.

The consequences for this study are interesting and problematic. A priori, it seems likely that students geared to academic study with a clear understanding of the discipline and its requirements will do better – unfortunately, in an environment of admissions staff receiving thousands of applications, it can be extremely difficult (and practically impossible) to use these as entry criteria. In the absence of well developed tutorial support, it is indeed hard to determine this information even when the students have registered and commenced their studies.

3.2 Two departments

The universities of Kent and Leeds come from different ends of the spectrum of the 'older' (pre-1992, at which time polytechnics acquired university status) UK institutions. Leeds is some 100 years old, very large in every respect, urban, and based in a dense, post-industrial area. Kent is smaller, some 40 years old and based in a sparsely populated area. The significant cultural contrast between them make common conclusions of interest, since it is reasonable to extrapolate them to a significant proportion of the sector.

The Kent CS programme that this study considers is a full-time, three year Honours degree which requires traditional entrants to score BBC in A-levels – no specific subjects are specified.

The Leeds intake has the choice of studying Computer Science or Information Systems. Both programmes are full-time, three years Honours degrees that require traditional entrants to score BBC in A-levels – the Computer Science scheme also requires one of these to be maths.

Without corresponding precisely, the programmes are comparable. Both institutions have seen the same trends in recent years – career-focused entrants, growing demand, increased interest from mature entrants, and very good employment prospects for graduates. These properties are common to most such programmes in the UK, of which there are more than 2000 in total. Of course, this large number includes a wide variety of curricular and other 'flavours', but the two we present here are representative in many ways of the education presented to thousands of CS students.

3.3 Data collection

In each institution, we consider an arbitrarily chosen cohort of single honours students; the only thing special about it is that the data were easily accessible. It is possible that the patterns exhibited are anomalous, but there is no reason to think that this is so.

We analyse by entry qualification, with some detail attached to A-level grades won by traditional entrants, and year-by-year grade averages. The analysis conceals

- The significant number of special cases (students stumbling on sickness or other impediments); these give rise to various apparent inconsistencies in the data subtotals.
- More globally significant factors such as the performance of returning 'sandwich' students (some 15%-30% of the cohort), which we have observed is statistically better than those who do not 'go out' for a year.
- The existence of more students in the first and second years than are recorded here, since we omit those who do not complete – arguably, including these would depress figures associated with Years 1 and 2. We realise that we should repeat these experiments after deleting the known and understood wild outliers, and making allowances for other known effects.

3.4 Aims

We seek to identify what makes a successful CS student – the only measure we have of this is high classification on graduation, so we are happy to proceed assuming Class I or IIi graduates are 'successful'. Presumably they are, at least, what universities are hoping to produce. This may be seen as odd, since programme specifications rarely if ever make this clear – there are many fine words on the aims and objectives of programmes, but what is required in order to excel remains implicit.

The aim is to try to correlate exit performance – measured by average final year grade – with a variety of input measures. In this study we have restricted ourselves to the obvious (and easily accessible) ones, not least because they are the ones under the control of admissions staff.

We also try to correlate the same measures with first year performance, it being another academic truism that the first year performance is the best indicator we have of overall academic potential [Oldham 88].

4 Findings

Fine grained details on the analysis of data may be found elsewhere [Boyle and Clark 00, Carter 99, Carter 00] and we present here a coarse summary of results. In view of the noise in the data, it may well be misleading to give more detail in any case. For various criteria, we have partitioned the data and searched for significant differences; in most cases we cite for each university the difference in the means and the associated z, thus normalising out any strictly 'local' effects – the source data contain finer grained information.

We have noted that the cohorts that make up this study are arbitrarily chosen, and believed to be representative. Their profiles (in both institutions) are very similar; among traditional entrants there is a preponderance of science based qualifications (especially mathematics and physics), but there is a very wide variety of others as well, crossing the entire school curriculum. This reinforces the observation that subject based pre-requisites are not an issue in CS. 'Computing', or some variant, is naturally a popular qualification for these applicants. The percentage of non-traditional entrants in both institutions is about 30% – the background of these students ranges through non-traditional school and college qualifications (e.g., BTEC, GNVQ), to preparatory 'Foundation' or 'Access' courses geared to the mature entrant. A large number of miscellaneous qualifications is also presented by this group.

1. **Entry score:** The traditional UK entrant offers 3 A-levels, each graded A-E. An A is ranked as 10 points and an E as 2; a common university offer might then be '22 points', or perhaps '22 points including a C in maths'.

   Simultaneously, great store and scepticism is set by these scores – they represent the easiest and most efficient way to filter huge numbers of applicants, but few would expect them to be a guarantee of quality.

   We have thresholded the entrants at a variety of levels, seeking statistically different performances at the end of the first and third years – we see evidence that a 24-point threshold (corresponding to 3 B's) indicates stronger performance in the first year, but that this makes no such indication of strong performance in the final year (Table I).

	Kent		Leeds	
	$\leq$ 23 points	$\geq$ 24 points	$\leq$ 23 points	$\geq$ 24 points
Sample	33	10	61	23
Level 1	10.6 (4.61)		4.1 (2.05)	
Level 3	4.9 (1.28)		4.9 (1.64)	

Table I: Thresholding A-level scores: the difference between the mean scores of those above and below a threshold of 24 points (z in parentheses). The significance evident at Level 1 has disappeared at Level 3.

   Table II illustrates that there is scant evidence of correlation between entry and exit 'score';

2. **Non-traditional entrants:** (Table III) We could detect no distinction between the performances of traditional and non-traditional entrants at either level 1 or level 3.

3. **Prior maths qualification:** The Kent degree accepts students without A-level maths, and one of the Leeds ones does. We have examined student performance of those with and without (Table IV) – there is no evidence that this qualification has any influence.

4. **Prior Computing qualification:** It should not be surprising that many CS recruits study the subject at school, but this is far from universal for reasons of availability, inter

	Kent	Leeds
Level 1	0.55	0.24
Level 3	0.32	0.17

Table II: Correlation between entry score and first and final year average grades.

	Kent		Leeds	
	Trad.	Non-trad.	Trad.	Non-trad.
Sample	64	35	85	26
Level 1	0.3 (0.04)		-0.3 (-0.19)	
Level 3	0.2 (0.01)		1.3 (0.59)	

Table III: Non-traditional performance: between the mean scores of A-level and other students (z in parentheses).

alia. There is, in universities, a scepticism about the value of this qualification since the background of the school or college (in facilities) and the staff (in qualification) can be a complete unknown. Many students score very highly in this subject on the basis of project work that has not necessarily instilled the habits and discipline that university CS departments seek.

Table V illustrates that the possession or not of this qualification has no perceptible effect on university performance.

5. The standard regime in UK high schools is for students to study 3 A-levels; often this is augmented by a fourth in ‘General Studies’, a semi-elective subject. Many schools will encourage their *perceived* high fliers to study four A-levels (excluding General Studies). Table VI illustrate the relative performance of these sets.

   We see that this partition does not influence university performance.

6. We consider performance as students progress through their career. Table VII gives the correlation coefficients of individuals' grades.

   While there is clear correlation between consecutive years, this is less clear between

	Kent		Leeds	
	Maths ‘A’	Without	Maths ‘A’	Without
Sample	31	33	15	32
Level 1	-0.6 (-0.20)		0.5 (0.20)	
Level 3	1.5 (0.60)		-1.5 (-0.16)	

Table IV: Relative performance of students with and without A-level maths (z in parentheses).

	Kent		Leeds	
	CS 'A'	Without	CS 'A'	Without
Sample	30	34	36	75
Level 1	-2.4 (-1.01)		1.2 (0.68)	
Level 3	-3.7 (-1.33)		-1.9 (-0.03)	

Table V: Relative performance of students with and without school level CS (z in parentheses).

	Kent		Leeds	
	3 'A' levels	4 'A' levels	3 'A' levels	4 'A' levels
Sample	49	15	72	12
Level 1	-0.9 (-0.26)		0.0 (0.00)	
Level 3	5.3 (1.59)		5.9 (1.59)	

Table VI: Relative performance of students taking four A-levels (excluding General Studies) (z in parentheses).

initial and final years. This effect is obvious if we inspect the inter-year differences (Table VIII).

It is clear from this that improvement or deterioration between the first two years is a very poor indicator indeed of final year performance. This is a surprising observation for which there is no clear reason – we discuss possibilities below.

General observations on the data we have inspected are that the variance of final year grades is enormous, and obscures the statistical significance of any perceived correlation with pre-university performance; for example, Figure 1 illustrates the aggregation of data from both universities, plotting A-level score of traditional entrants against final year average. A lot of entrants who we might have been regarded as weak ultimately excel, and correspondingly a number of potentially strong ones do not. Even if we delete the outliers from this plot, there is no evident correlation between input and output scores – we are thus no closer answering the question of what makes a 'good' student.

There is some evidence, although the samples are small and noisy, that students who can score an 'A' grade in an A-level qualification seem to do better [Boyle and Clark 00,

	Kent	Leeds
Level 1 against Level 2	0.67	0.78
Level 2 against Level 3	0.74	0.72
Level 1 against Level 3	0.53	0.53

Table VII: Correlation of student performance between years.

	Kent	Leeds
(1-2) against (2-3)	-0.23	0.06

Table VIII: Correlation of inter-year differences; (Level 1 - Level 2) against (Level 2 - Level 3).

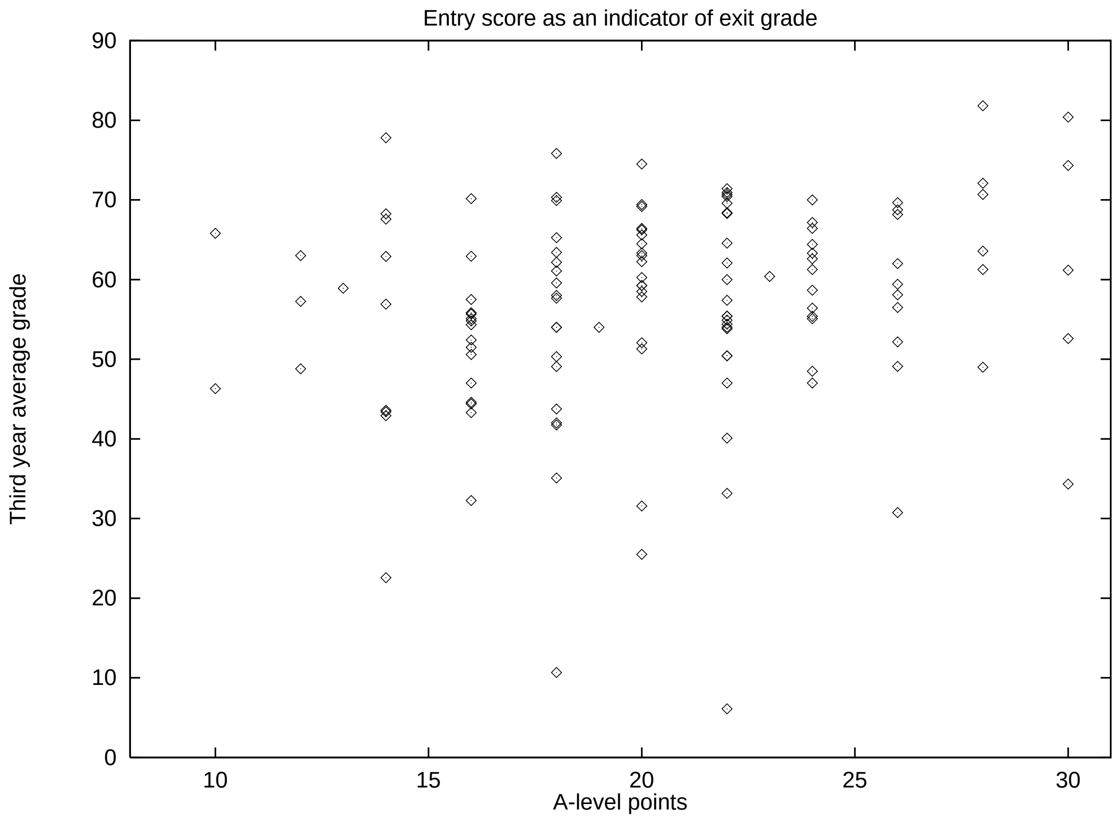

Figure 1: A level score and final year grade for the entire data set. The variance in finalist performance is large.

Carter 99, Carter 00]. It is possible that the study skills and academic discipline that make a successful university student can produce this effect. Nevertheless, there is no suggestion that such a performance is either necessary or sufficient for the Class I or IIi that we wish to see graduate.

5 Conclusions

We observe that, at the coarse level we are considering, the grade profiles of the two universities are very similar – there is nothing in the data we present to suggest that there is a qualitative difference between the two and we hypothesise that what we see would be repeated at the majority of UK universities.

The other major conclusion we draw is that we cannot correlate student performance, particularly final year (graduation) performance, with any of the measures we have inspected. In particular, the A-level grades beloved of admissions tutors simply do not indicate with any confidence how a student will perform. While this confirms what a lot of staff already suspected, it is useful and interesting to see illustrations such as Figure 1; corresponding pictures for other disciplines would illustrate whether there is anything special about the CS discipline.

The issue of discipline-specific qualifications for university entry also makes unhappy reading for those seeking simple criteria on which to judge their entrants – something about CS makes the school-level qualification irrelevant to university performance (although we do not suggest it is a handicap). More interstingly, A-level mathematics cannot be demonstrated to help when comparisons are drawn with students without this qualification – this is especially noteworthy for two reasons

- Students without 18-level maths will have stopped studying it (presumably through some element of choice) at age 16; not only have they only a very elementary education in mathematics, but they have not rehearsed it for at least two years. That these significant disadvantages do not impact on their university study seems a conclusive demonstration that this is not a major issue.
- Among CS staff, 'the maths problem' is endlessly debated. It is widely (anecdotally) believed that many of the problems in the education of CS students would evaporate if only they were fluent mathematicians.

An issue we did not inspect that also preoccupies staff gossip is students' abilities in general scientific technique. The argument over whether CS is science or engineering [Loui 95, Plaice 95, Stewart 95, Tichy 98], neither or both, will continue inconclusively perhaps for ever, but it is certainly the case that laboratory practice (for example, maintenance of logbooks and the ability to design, conduct and record an experiment) is often missing in CS students and arguably would be of value. It is rare to find training in these activities in CS curricula. We have insufficient data to look for the value of, for example, physics and chemistry qualifications as indicators of strength in university level CS.

It is satisfying to note that the non-traditional entrant seems to be at no disadvantage, although it is well known that issues of motivation and sacrifice are wholly different within this community. Nevertheless, there is no compelling argument that non-traditional students will jeopardise the quality of results, which has implications for the 'widening access' arguments currently driving the growth in UK student numbers. Also intersting to note is that schools' opinions of which students are 'best' (via being directed toward more A-levels) do not translate into universities' opinions of success. Perhaps we are measuring different things, or the students change a lot over five years, or the school measurement at age 16 is flawed. There are no simple answers to any of these issues since we also note that the first year in university is not as good an indicator of final performance as we might wish; in particular we were surprised to see that grades through the three years of a UK CS degree are as likely *not* to be monotonic as they are to be so. The confounding effect of growing maturity between the ages of 18 and 22 is significant and hard to measure from raw numbers such as we see here.

We conclude that entry qualifications are not limiting; 'weak' (as measured by school grades) entrants seem to have as good a chance of doing well as 'strong' ones. We have noted that expectation is key to student response to university life, and it is therefore important for those entering an institution who may have a (relatively) low academic opinion of themselves to learn as quickly as possible that it need not be the case that they are in any sense handicapped. This is clearly a duty on staff, whose expectations too in many cases will need adjusting. It is tempting to see the '30-pointer' (three A grades) as the jewel in the undergraduate community, but we discover that jewels might have much humbler origins – all our entrants should be in receipt of the same academic expectations, and develop them themselves.

6 Further directions

The data and conclusions we present here pose as many questions as they answer, and we have to be cautious about the weak conclusions that we feel we can draw. The confounding factors in studies of this nature are significant – for example;

- We have taken no account of the (known) different behaviours of various categories of student – for example, 'sandwich' students who experience an industrial year, and mature students, are known anecdotally to have better motivation and powers of personal organisation that impact on final grades. Gender based issues (male bias) are also strongly suspected to influence behaviour.
- Many degree programmes are (inadvertently) structured to encourage lax performance in the first year, by only binding final and penultimate year grades into final classification. Many students will return weak first year results (sometimes failing badly), but will pick themselves up to perform to their true level later on.

We hypothesise that 'success' is much more to do with intangible influences such as attitude and pre-university experience of the educational regime that universities deploy – of course, these are particularly hard to measure in applications forms. Nevertheless, it has been seen in other studies that accuracy of student expectation is certainly an influence on their behaviour and success [Baxter and Hatt 00, Ozga and Sukhnandan 98].

This study will proceed in two directions. Firstly we mean to repeat the sort of analysis we present here in a range of other countries (currently Australia, Sweden and the US) since we suspect there is nothing particularly special about the UK, but need to verify that. Secondly we would seek to conduct a longitudinal study of as many students as was practicable, consulting them and the staff with whom they interact, to try to pin down the precise nature of the intangibles that seem to make some succeed where others fail. Certainly the variance in finalists' performance we have exhibited here when indexed against entry 'grade' suggest that the simple entry criteria currently used are flawed at least.

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