From Trailing & Failing to Learning & Progressing: A bespoke approach to failure in engineering education

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Abstract: *Starting with the research question "How can we reverse the negative impact of failure on engineering students' futures?" the 'Changing Futures Project' is a five year longitudinal project which aims to identify and address the pedagogy of failure, and in doing so make a positive difference to students' educational outcomes and progress. It builds on previous work [1, 2] to look at the issues behind 'failure' from the perspectives of individual students. In looking at the issues through the eyes of the students themselves this paper makes a distinctive contribution to current debates to the field of engineering education in general, but particularly in the areas of attrition, retention and student support. The paper ends with a total of 10 recommendations for institutions, colleagues and students.*

Introduction & Background: The EU & Higher Education in the UK

This paper looks at an issue which presents something of an ongoing conundrum, how to support those individual students who are struggling with their studies when funding is short[3] and over two decades of widening participation, massification and marketization has resulted in more young people entering Higher Education (H.E.) than ever before. At a time when the UK H.E. Sector is facing an uncertain future as the country moves to disentangle itself from the laws, policies and procedures indicative of membership of the European Union [4], the issue of student attrition is something of a universal issue. Data suggests that in Europe attrition rates vary from, at best, around 85% of students completing their studies, whilst at the lower end of the scale the figure is just over 50% [5]. Likewise, in the USA the percentage of students graduating after six year of undergraduate study is just over 55% [6].

One of the inevitable impacts of attrition is the effect it can have on individual students; many of whom leave Higher Education with nothing to show for their efforts. Whilst the impact of attrition on individual student's futures and life-chances may well be significant, when considered from a wider perspective the implications of attrition are potentially much more far-reaching. Indeed, the cumulative effect of attrition combined with current and predicted skills shortages within the Engineering Sector, means that as the impact of Brexit begins to be realised, the UK economy is at risk of being damaged by scarcities of engineering talent [7]. In discussing this, Peter Finegold, Head of Education & Skills at the Institute of Mechanical Engineers, London, stated "*Without the development of these [engineering] skills, the UK will be unable to complete the vital infrastructure projects in the transport and energy sectors the country so desperately needs. We need enough people with the right skills to be confident of the country's economic growth*" (www.imeche.org 2016) [8]. Give the potential dire consequences of attrition for the future prosperity of British society, the subject has been much debated across policy, professional body and educational circles alike [9, 10, 11, 12, 13].

Within this context this paper focuses on how one, relatively well placed university located in the centre of the University is dealing with attrition. A university since the 1960's, and a Technical College well before that, Aston University has an attrition rate of 6% overall. In its School of Engineering this rate doubles to around 12% [14]. Whilst this means that 88% of the School's students go on to complete their education and graduate, the two project leads are both very concerned about the impact that 'failure' can have on individual students. It was this concern, together with institutional drivers, that prompted the *Changing Futures Project*.

Literature Review: What Determines Failure or Success in Higher Education?

Under the auspices of 'the student experience' the question of what determines failure or success at university has been the subject of much discussion across the Higher Education Sector; resulting in a number of socio-psychological, economic and pedagogic related variables being linked with the student experience [15, 16, 17, 18]. Yet despite this, no clear determinants of success or failure have been identified. Indeed, much of the literature seems to ponder upon the intransigence of attrition, noting that it is a complex issue indicative of a number of factors which vary in character from the learning environment through to a lack of individual engagement with studies [19, 20, 21].

With regards to engineering education in particular, one of the key influences on student success is arguably the nature of Science teaching in High School; with some studies suggesting that limitations in the content and context of the secondary school science curriculum is a key driver impacting students' poor performance once they get to university [22, 23, 24]. Whilst a lack of positive role-models in engineering is arguably relevant in terms of inspiring young people to embark on a study of engineering, a number of studies suggest that once students enrol upon an engineering programme, demographic factors, including gender, social class and ethnicity, come into play and may indeed influence individual student's chances of success or failure [25, 26].

From a pedagogical perspective, the way in which students learn can have a significant impact on success at university. Indeed, research suggests that engineering students are less likely to succeed when subjected to traditional pedagogic approaches, such as didactic 'traditional' lectures, and are more likely to benefit from active, hands-on and blended learning approaches [27, 28, 29, 30].

The Changing Futures Project at Aston University.

Located in the UK's second largest city, Aston University comprises a forward-thinking diverse institution where more than 60% of the students originate from Black and Minority Ethnic (BME) backgrounds. The university prides itself on delivering high quality learning and teaching, with an emphasis on social mobility and graduate employment.

Studying within one of six distinctive Faculty areas, Aston University School of Engineering & Applied Science students study a range of BSc, BEng, MSc & MEng degree programmes in the following areas: Chemical Engineering & Chemistry: Computing Sciences: Electronic, Electrical Engineering & Physics: Engineering Systems and Engineer Management: Information Engineering & Maths: Mechanical Engineering & Design. Additionally the School houses internationally recognised research expertise in, amongst other areas, Bio-Energy: Engineering Education Research: Logistics: Photonics: and, Systems Analytics; meaning that students are have access to world class researchers and cutting edge knowledge. In year 1 of the Project the School had just over 2,500 students. In year 2 this number had risen to 3,200. This rise was indicative in an increase in full time undergraduate students at Bachelor's and Foundation levels, as well as an increase in Part Time students.

Despite such expertise, like many UK Schools of Engineering, Aston University experiences some difficulties in attracting new students onto its engineering and applied science programmes. Moreover, as elsewhere, once students enrol on engineering programmes at the university they are more likely to drop out that students from the other subject areas [7, 8] a situation that has not been helped in the short term by Brexit; in the *aftershock* of the referendum applications to universities in general have dropped [31].

Within this somewhat tumultuous environment, the question of ***why*** engineering students are more likely to drop out of university than any other students is becoming increasingly important. Yet despite numerous studies and considerable investment, the answer to this question remains largely unknown. What is evident however, is the negative impact that attrition can have both on the individual student and on the institution in which they are enrolled. From an institutional perspective each student who "drops out", for whatever reason, means a loss of income of between £9000 to £12,000 per year (including fees, housing accommodation costs and other money spent at university). From an individual perspective, leaving university without a graduating qualification leaves a large 'hole' in the CV! It can subsequently result in an individual missing out on future career opportunities and all of the associated benefits with having a graduate level job. It is this second, individual impact of attrition, that prompted the two project leaders into action. Both were, and are, acutely aware of the individual externalities associated with 'failure' and 'dropping out'. Hence, in putting together the proposal for the project the decision was made to consider in some depth the individual perspective in terms of both failure and attrition.

Adopting an 'Action Research' methodology, the Changing Futures Project began in November 2015. The project is of a longitudinal nature and so will run until 2020 and will provide an on-going evidential basis for organisational change. The first cycle of the project ran until September 2015 whereupon the second cycle, which is now mid-way through, began. This paper follows the first cycle of the project through to completion and, where appropriate, provides comparative data with year 2 of the project. It focuses on student failure, considering in depth the issues and drivers behind the student experience, whilst looking at a number of interventions and actions taken to address the problem. In doing so the paper makes a notable contribution to current discussions in this area.

Project Aim & Objectives

The underlying aim of the Changing Futures Project is:

> "To directly tackle the issue of attrition and student failure in engineering and applied science at Aston University".

A number of objectives were articulated in year 1 of the project:

- Using data-analytics, identify students at risk of attrition.
- Investigate students' perceptions of the reasons behind their failure.
- Identify modules with high levels of student failure
- Develop cost-effective and academically appropriate interventions to support failing students including Study Skills Packages
- Work with individual 'at risk' students to identify bespoke 'Study Pathways' with the aim of engendering success.
- Work with individual 'at risk' students to identify and, where necessary make referrals to appropriate counselling, medical, financial or other support services both within the university and externally.

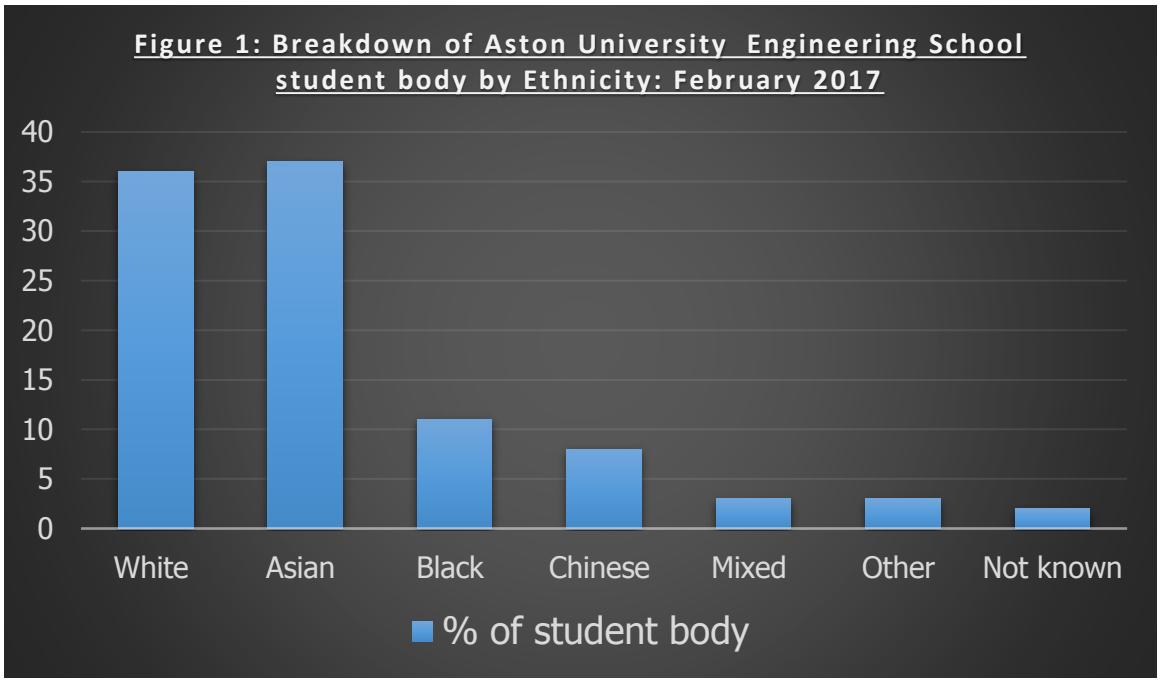
Midway through year 2 of the project, following an insertion of cash to enable the development of further resources and interventions, a number of additional objectives were introduced:

- Work with the Student's Union to identify how better to support at risk students
- Put in place a series of student-focused interventions including *Attrition Advocates* and Peer Mentoring
- Further expand the Study Packs to encapsulate a wider-range of discipline specific resources

Project Approach

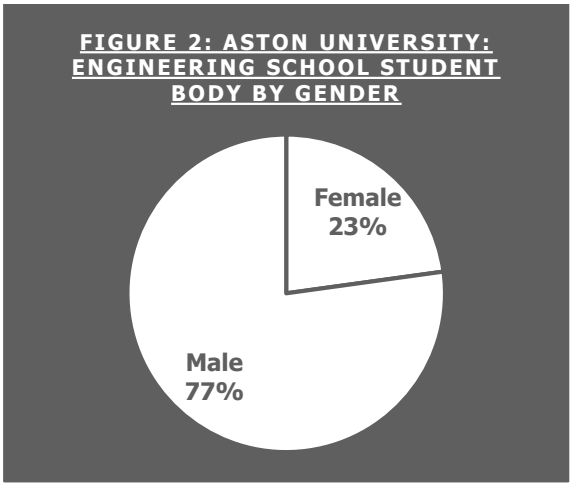
Defining "At Risk" Students: Sample Identification

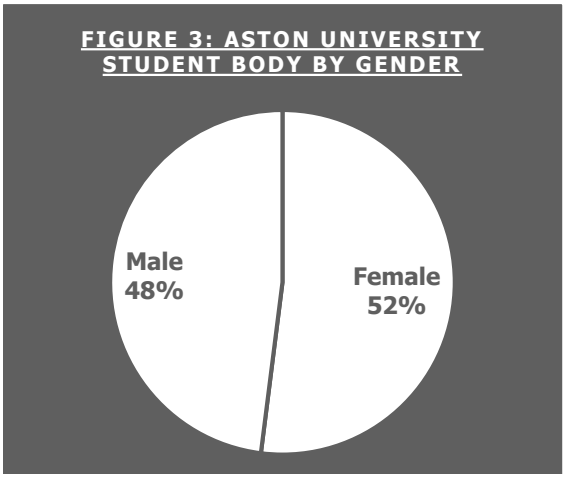
In seeking to articulate exactly what is meant by the term 'At Risk Student' and hence identify the sample, the first stage of the project involved an examination of the demographic make-up of the student body. Figures 1 shows the current breakdown of the study body within the School of Engineering by ethnicity.



The above table shows that the largest ethnic group originate from an Asian background (37%) whereas White students make up 36% of the student body in the School, Black students represent 11% and Chinese students, 10%. This demography reflects that of the wider University, which is one of only a handful of 'minority-majority' universities in the UK.

Gender on the other hand is a completely different matter. Figure 2 shows that 23% of the population of the School of Engineering are female; whereas the university female population comprises 52% females (as shown in Figure 3).





Having identified the ethnic and gender constitution of the study-body in the School the next stage of the project was to try and access data about attrition and cross-tabulate this with ethnicity. However, attrition data by ethnicity was not available at School level, hence a wider perspective was adopted and university data examined. A cross-tabulation of ethnicity and attrition at a university level for full-time undergraduate programmes (excluding pre and sub degree programmes) was undertaken. This analysis indicated that more students leave the university for non-academic reasons than actually fail.

In examining the attrition data at the University, what became apparent was the complex nature of the student body. Unlike elsewhere in the UK, British Asian and British Black students are slightly more likely to succeed than other ethnic groups at Aston University; a phenomena that may be explained by considering the students' place of residence. British White students are more likely to live on campus than British Asian & British Black students; the majority of whom live locally and remain at home with their parents during their studies. However, the difference between different ethnic groups and likelihood of attrition was not found to be significant, a factor that reinforced the project leaders belief that no single ethnic group at the university are more at risk of failing or dropping out than any other.

That ethnicity is not a determinant of 'risk of attrition' is not surprising in an institution where the majority of students are classified as being from 'non-traditional' backgrounds, with most originating from a BME (Black & Minority Ethnicity) background. In seeking to put aside demographic indicators, the decision was taken to focus on academic achievement and the term 'at risk' initially defined as *"Those students who have on at least **two** occasions failed one or more modules".* This was amended in the second year of the project to *"Those students who have on at least **one** occasion failed one or more modules".*

The UK is part of the European Higher Education Area, which, under the Lisbon Convention and Bologna Agreement, has three distinctive stages of study: Bachelor's: Master's: Doctoral [32]. The Changing Futures Project is focused upon students enrolled on undergraduate (Bachelor's) programmes only. This means that the above definition includes all of those students who achieved less than 40% in one or more modules.

In the first year of the project, the Sampling Field comprised 1368 students. This figure excluded Foundation Degree[1] students who, whilst registered as 'fulltime', attend university under the auspices of a 'blended / block learning' arrangement. In year 2 the decision was made to include the 159 Foundation Degree students who were enrolled within the School as it became apparent that a small number of these students were 'at risk' of failing. Including Foundation Degree students, the sampling field four the second year of the project was 3,384, the significant rise on the previous year being due mainly to an increase in the numbers of students accepted into the first year of study.

Changing Students' Futures through Positive Actions & Interventions

Data Trawling & Analysis

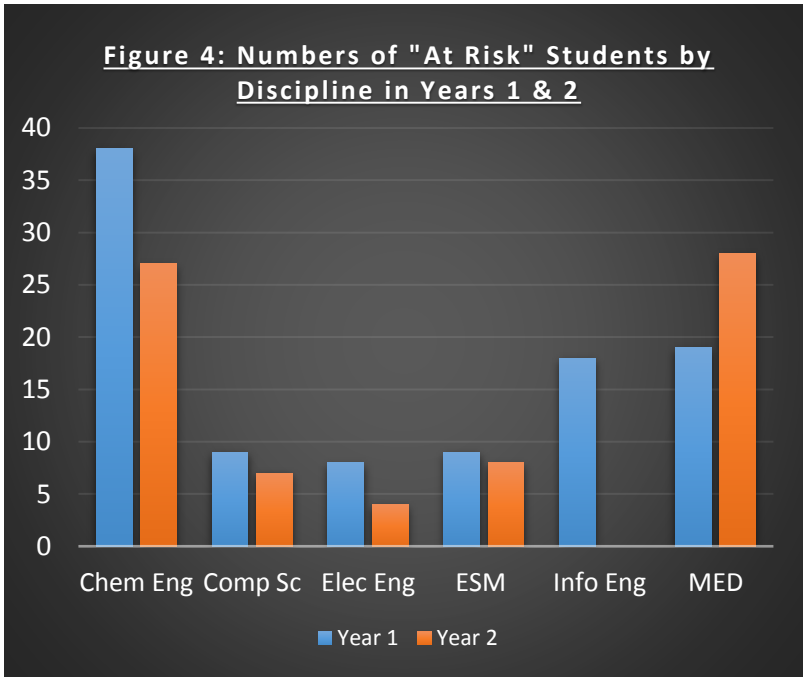
The first task within the 'Action Research Cycle' was to identify those students 'at risk' of attrition. A data-trawling exercise was taken in October and November in both year 1 and 2 of the project. In year 1 this resulted in a total of 96 students being identified as 'at risk' of attrition; equivalent to 7% of the sampling field. In year 2 a similar number of students, 94, were identified as being 'at risk' as attrition; however, this figure only represented 2.8% of the total sampling field, much lower than the previous year. The drop in the percentage of students

[1] Foundation Degree: A blended learning programme which runs over three years. A Foundation Degree is a UK specific qualification similar to a College Degree in the USA. At Aston University each Foundation Degree has a 'progression pathway' to enable students to top up their qualification to Bachelor's level. All Aston Foundation Degree students are in full time employment.

being identified as being ‘at risk’ of attrition is somewhat difficult to explain, other than to suggest it may be indicative of the success of the first year of the project

In considering the students’ demographic and background characteristics one of the unexpected characteristics identified in the initial data trawling exercise conducted each year was that a number of students had an ‘AAB indicator’ attached to their file. This indicator is linked with achievement and given to those who are in the top percentile of the intake in terms of academic achievement at the pre-university stage. In year 1 of the project 5 students fell into this category, whereas in year 2 the number more than tripled to 18 students. The reasons for this increase is not known, although it may be that the university is, year on year, recruiting ‘higher achieving’ students.

Having identified which students should be identified as being ‘at risk’ of attrition, the next action was to clarify which discipline groups the students were part of and to contact their subject group heads and individual tutors. Figure 4 provides an overview of the students’ subject groups in both years. The data indicates that in year 1 of the project, Chemical Engineering & Chemistry had the highest number of ‘at risk’ students enrolled upon their programmes, whereas in year 2 it was Mechanical Engineering & Design where most of the sample students were housed. It should be noted, however, that both Chemical Engineering (Chem Eng) & Mechanical Engineering and Design (MED) represent the biggest groups in the School.



Key: All Programmes are UG level: MEng: BEng: BSc (with Honours)

Chem Eng: Chemical Engineering & Chemistry
Comp Sc: Computing Sciences
Elec Eng: Power, Electrical & Electronic Engineering
ESM: Engineering Systems & Management including Logistics and Construction Management
Info Eng: Maths & Physics
Mech Eng: Mechanical Engineering & Design

The final demographic characteristic which was examined was the students’ prior qualifications. Figure 5 shows that the two different cohorts of students brought with them very different academic backgrounds. In the first year of the project the majority of those identified as being ‘at risk’ had undertaken a university Foundation Year programme; whereas in the second year most of those included within the project had entered university with traditional GCE ‘A’ levels grades B and / or C in Maths and at least one other science (including Physics, Chemistry, ICT).

Figure 5: Entrance qualifications of 'At Risk' Students

ENTRANCE QUALIFICATIONS	Yr 1	Yr 2
University Based Foundation Programme	46	15
Traditional GCE 'A' Levels Grades B,C in Maths, Physics and / or Chemistry	29	25
Traditional GCE'A' Levels Grades 'A' / 'A*' in Maths, Physics and / or Chemistry (High Achievers)	5	16
Vocational Qualifications	12	19
College Based Access Course	3	8
Undergraduate Bachelor's Degree	1	1
Other	0	10
Total	96	94

To check validity the in both cycles of the project the data was disaggregated and then individual students' records accessed and cross-checked using content analysis techniques. This process, which took place in November and December in year 1, and October and November in year 2 was extremely time consuming. It did however enable the researchers to confirm that all those within the sample were correctly identified as being 'at risk'.

The content analysis of each individual student record involved making a note of the following data:

- Gender
- Ethnicity
- Programme
- Failing / Trailing Modules
- Exceptional Circumstances recorded (such as illness or family bereavement)
- Physical or learning disabilities
- Personal Tutor
- Qualifications on admission
- Address of work-placement (where relevant)
- Email

Analysing the data at an individual level allowed for errors in student records to be identified and corrected. It also meant that the Project Leaders were able to identify patterns of behaviour in terms of engagement and academic achievement.

The purpose of undertaking the content analysis was not only to make sure that the correct students were targeted to be included in the project, but was also to allow for the Project Leaders to develop appropriately targeted resources and interventions. The following section provides an overview of the interventions and actions specifically aimed at supporting those students identified as being 'at risk' of failure in both year 1 and 2. The first year of the project is followed through to its end and the discussion shows how the second year of the project is built upon the first. Emergent data from the second year of the project, which is still very much underway, is used to frame some discussion. The conclusion builds on the findings and outcomes of the first year of the project to provide three key sets of recommendations.

Academic Study Skills Pack & Tutorial Support

Having undertaken the data-trawling exercise and content analysis the Project Leaders set about developing an Academic Skills Study Pack. In year 1 the Skills Study Pack was divided into two main sections: Learning at University: Studying Engineering & Applied Science.

Written specifically for Engineering and Applied Science students, the first part of the pack contained the following:

- Learning Styles: Information about learning styles and approaches including a 'learning styles' quiz for students to identify their own approach and guidance on how to maximise one's own approach.
- Academic Writing: Advice and guidance for STEM students on how to write reports: essays: lab reports.
- Referencing: Advice and guidance mainly focused on the Harvard System (which is the Universities preferred style).
- Self-Management: Including advice and guidance on; time management; maintaining a work-life balance; and, being a Professional.
- Where to go for help: Referral points within the University relating to both academic and personal matters listed and identified
- Virtual Resources: Useful websites

The second part of the pack was much smaller and provided virtual resources about:

- Maths
- Physics
- Chemistry

At the time of writing the paper the Study Skills Pack is under review. It will be relaunched in October 2017 for the third year of the project and will include far more Engineering-Applied Science content.

Individual & Bespoke Support

One of the key aims of the data trawling exercise was to identify each student's Personal Tutors. The 'massification' of Higher Education has resulted in a university system whereby each academic member of staff has up to around between 20 and 60 students for whom they are responsible for in terms of being the individual's appointed Personal Tutor (the number varies so much dependent on the discipline and area of study). Given such numbers, it is somewhat difficult for academics to be fully cognisant of each individual's profile and circumstances. Hence, in linking each trailing student with their Personal Tutor, the project acted as an 'additional' safety-net, making tutors aware of trailing students' situations and reinforcing the need for individual tutors to make contact with students and vice-versa.

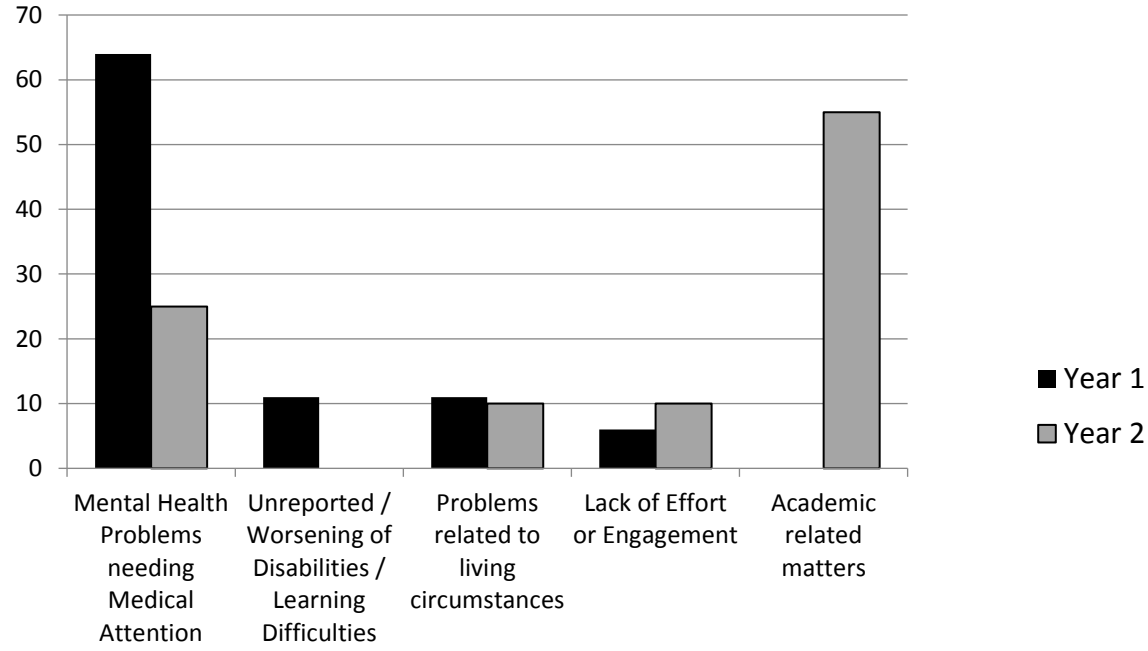
Having made contact with the Personal Tutors, each 'at risk' student was contacted individually and invited to a one-to-one meeting with one of the Project Leaders. In the first year of the project ninety six students were contacted and over the course of terms 2 and 3, fifty-two attended face to face meetings. The project is now in its second year. To date (midpoint of term 2) ninety-four students have been contacted this year and 22 have attended meetings thus far.

The purpose of meeting with students on a one to one basis is to identify any issues the students feel may have effected their academic performance. Given the confidential nature of the meetings no 'formal' recording mechanism was utilised during the discussions. Instead, a contemporaneous hand-written note was made of students' general responses to three key questions:

- *How are you?*
- *What went wrong last year with regards to your studies?*
- *What can we do to help you get things back on track?*

During the course of the ensuing conversations the students are encouraged to discuss why they believe they failed. Figure 6 provides an overview of their answers (given in percentages) for both years of the project (bearing in mind that at the time of writing the second cycle of the project is only midway through – hence the findings will change).

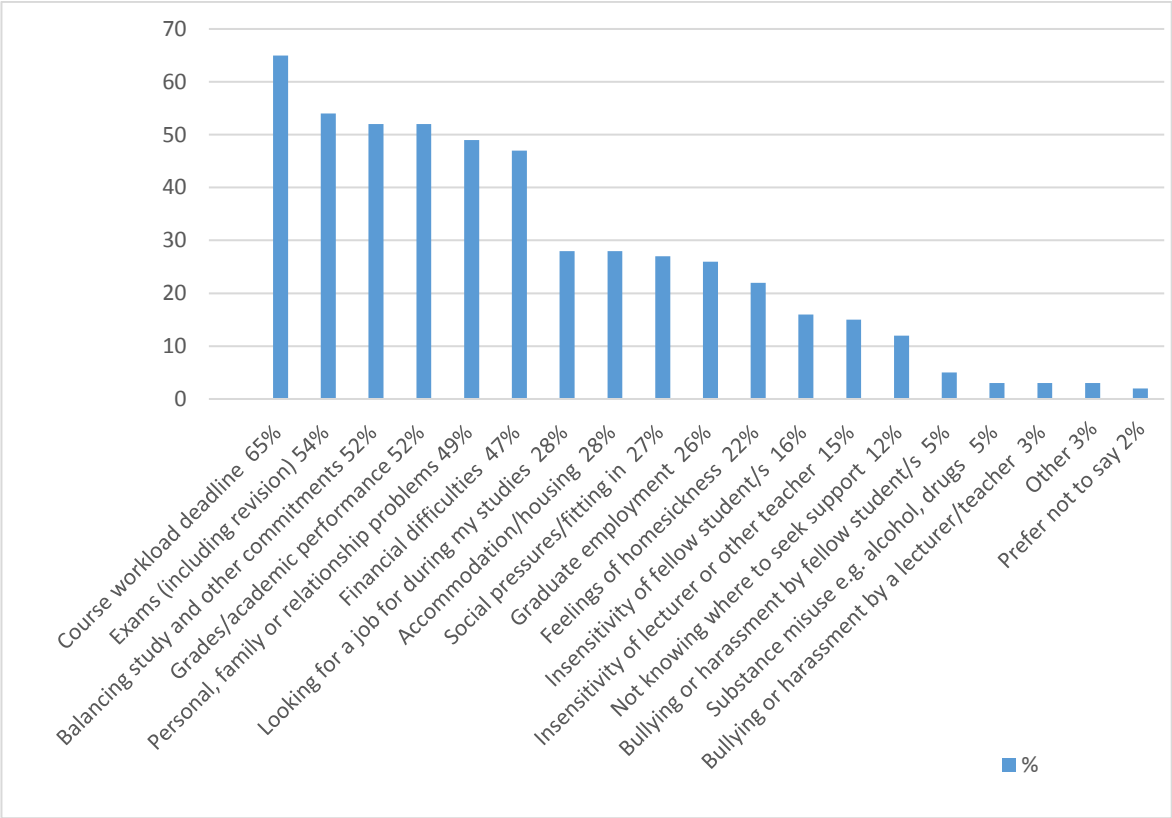
Figure 6: Students' perceptions of the circumstances leading to failure (% per year)



Within a few weeks of the first round of one-to-one meetings in year 1, it quickly became evident that many of the students had experiencing a serious problem with their mental health. Conversely, at the point of writing this paper, it would seem that mental health is slightly less of an issue in year 2 (this year). However it should be noted that the second cycle of the project has another one and half terms to run (5 months). This period includes several assessment deadlines and an examination period. In the first year of the project three students were identified during term 2 who were experiencing a serious 'mental health crisis'. All three were quickly referred to appropriate mental health support, and in the case of one student, his parents notified. Midway through term 2 in the second cycle of the project, one student has been identified as currently experiencing a mental health crisis. This individual is currently in hospital and one of the Project Leaders has taken responsibility for liaising with his family and sponsors. Although not taught by either of the Project Leaders, this particular student has been allocated a new Personal Tutor from within the project team.

In looking at the data in Figure 6 it would seem that the incidence of mental health problems reported in the second cycle is typical of the wider picture in terms of mental health problems in the UK Higher Education Sector. A recent study undertaken by the National Union of Students found that 25% of students experience mental health problems whilst at university. Conversely, most do not report such problems to their university [33] (possibly because of the stigma still attached to mental illness within the UK). Whilst 'pastoral care' is an important part of the 'Changing Futures Project', identifying the aetiology of students' mental health problems is not. Indeed, neither of the Project Leaders are mental health experts, although one is a trained counsellor. Hence, in seeking to try and make sense of the findings a literature search was undertaken in an attempt to identify key 'crisis' points and 'triggers'. This confirmed that, with regards to the student population, the causes of mental health crises are extremely complicated. However, amongst the most frequently reported 'triggers' are deadlines and exams. Figure 7 provides an overview of the findings of a national survey conducted to examine this issue amongst the UK student population.

Figure 7: Reasons why students experience mental health problems (NUS, 2016) [33]

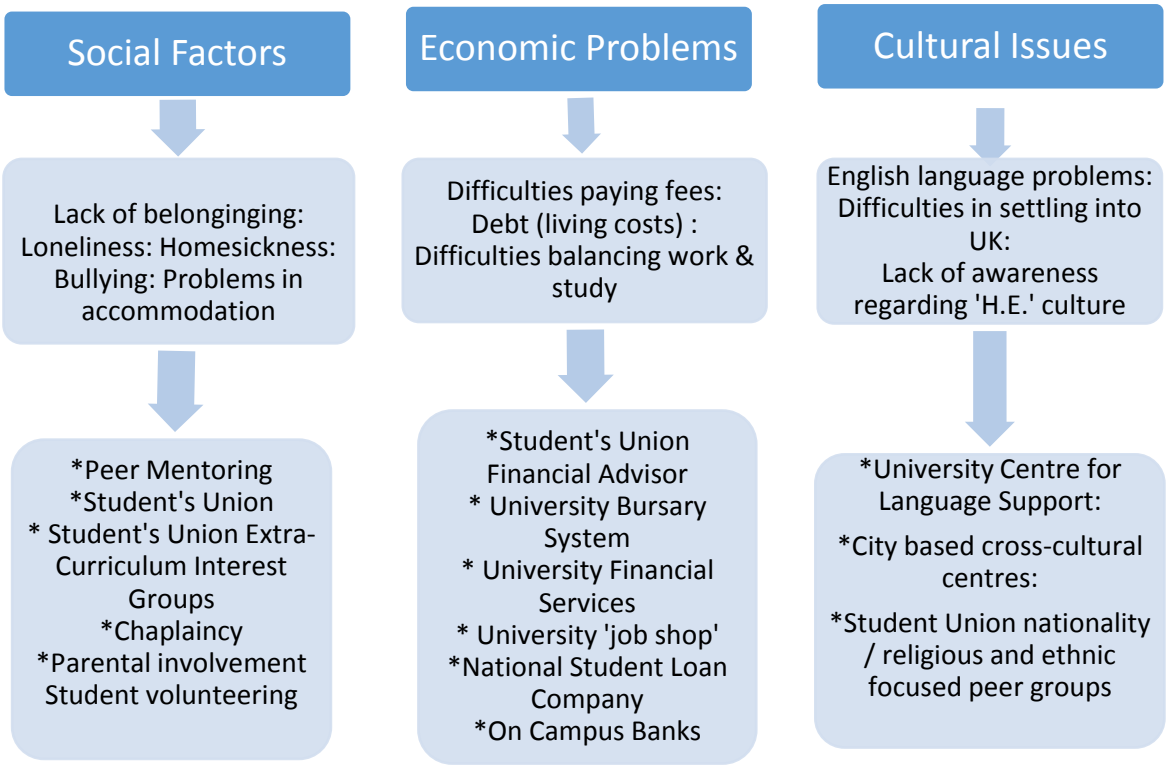


Support & Study Pathways.

In the first year of the project a number of non-academic issues were identified by students as being a factor they believed influenced their performance. Bearing this in mind, the two Project Leaders worked together to develop and put in place appropriate support mechanisms to provide students with individual 'Support Pathways'. Whilst acute mental health problems were dealt personally by the Project Leaders; the Project Leaders worked with individual students to work out bespoke Support Pathways on a one-to-one basis. Having done this, responsibility for accessing other support service was firmly placed on the student.

Figure 8 provides an overview of the various components of the support services used to develop individual pathways for students.

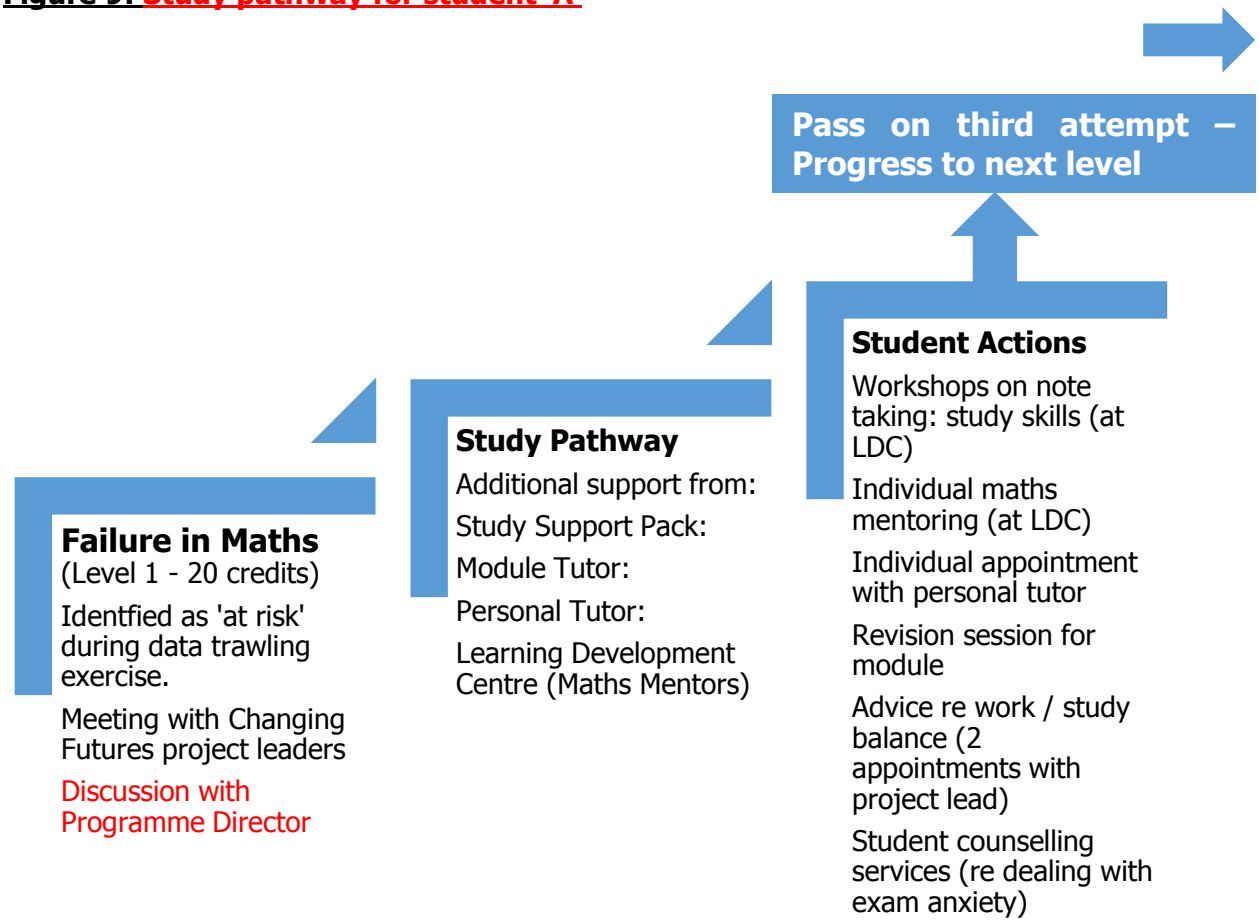
Figure 8: Support Pathways: Problems and Solutions for Pastoral Care



Whilst student support represents an important aspect of the project, in both years of the project cycle, academic issues have been prioritised. During the first cycle, the majority of the students indicated that they felt that the causes of failure were due to matters generally outside of their study. However, at the time of writing this has not been the case during the second cycle whereupon over half of the students have identified ‘problems at the modular level’ as being a factor determining their failing.

Such problems vary in nature from difficulties understanding the course content, misunderstandings regarding what is required in terms of the learning outcomes, issues around the type of assessment and, from the students’ perspectives, a lack of constructive alignment in one particular assessment [34]. Following a similar approach to that described above, the Project Leaders worked with individual students to develop bespoke Study Pathways. Figure 9 below provides an example of one such pathway followed by ‘Student A’, a young male student, from a BME background who was aged 19 years at the time of the intervention. Student ‘A’ is studying Chemical Engineering, he is the first in his family to attend university and during term time he works part-time for 20 hours a week to support his mother and siblings.

Figure 9: Study pathway for student 'A'



Project Outcomes and Next Steps

At the end of the first cycle of the project, the attrition rate within the School dropped markedly, resulting in a higher than predicted number of students registering to study this academic year. That the percentage of students identified as being 'at risk' dropped from 7% in year one to 2.8% in year 2 is perhaps the best indicator of the success of the project.

Within the School and University the most significant unpredicted outcome of the *Changing Futures Project* has been a raised awareness of the issues around student Mental Health. Grounded in the emergent findings, a number of symposia and training events have been held whereupon colleagues have been encouraged to make themselves aware of the various processes and services available for students experiencing acute or chronic mental health problems. The Exceptional Circumstances Application Process has been simplified and a top-level drive made to encourage tutors and students to make sure that the process is used when appropriate.

In conclusion, whilst the first cycle of the *Changing Futures Project* was very successful, the intensive nature of the support given to individual students has demanded a lot of commitment from the Project Leaders; with much of the work being done on top of usual academic duties, and resulting in the working week being extended considerably! Yet, in reflecting upon the project thus far both agree that the positive impact on each individual student's prospects and life-chances makes the effort worthwhile.

Ten key recommendations for institutions, colleagues and students are made:

Recommendations for Institutions:

1. **Financial Resources:** Funds needs to be made available to employer an 'Attrition Project Worker'.
2. **Staff Training**: Mental Health Awareness and Personal Tutor Training needs to be made available.
3. **Academic Support Services:** Need to be effectively marketed internally so students are aware of what support is available and how to access it.
4. **Social & Cultural Support Services**: There is a need for a more cohesive approach to student support, with all agencies working together

Recommendations for Colleagues

1. **Personal Tutors:** Need to meet with all tutees at least once a term, with contact maintained as frequently as possible. Training regarding mental health should be accessed. All tutors need to make themselves aware of what support services are available.
2. **Support Staff:** Non-academic colleagues are more likely to develop close working relationships with students and as such need to access mental health training also make sure they are aware of where and when to refer students in all circumstances.

Recommendations for Students

1. **Individual Students:** Need to take responsibility for proactively seeking academic and social support
2. **Mental Health Awareness:** The Student's Union needs to consider how to better support individual students with mental health problems
3. **Access to Tutors:** Individual students should make sure they meet with their Personal Tutor when needed, and access help from Subject Tutors when needed.

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