Retention of Engineering Students

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***Abstract*—Retention of engineering students is an international concern. Most countries report a shortage of engineers. By increasing the number of retained engineering students it is potentially possible to increase the number of engineering graduates. The purpose of this article is to identify and analyse what retention research has been done in the past to avoid unnecessary duplication. Although duplication may bring valuable new information, progress in this field has been slow. Therefore, the focus is on facilitating progress rather than seeking more accurate results. The three main themes identified in literature are: the individual's internal and external characteristics that affect retention, the models that describe retention, conceptual and predictive, and the interventions attempted to improve retention. Further research into methods for improving student retention is certainly justified since in spite of existing research most institutions still struggle to retain engineering students.**

Retention, Characteristics, Models, Interventions

I. Introduction

Retention of engineering students from admission to graduation as engineers is, and has been for a long time, an international concern. Most countries report a shortage of engineers. Thus by increasing the number of retained engineering students it is potentially possible to increase the number of engineering graduates and to make more effective use of scarce tertiary education resources. Rather than requiring further effort to attract more students to the study area it is perhaps better to more efficiently convert those that already show an interest into graduates.

According to the Engineering Council of South Africa (ECSA), South Africa lags behind other developing countries when the number of engineers per population is compared. ECSA states that in South Africa there is one engineer in 3166 people compared to Brazil that has one engineer in 227 people and Malaysia that has one in 543 [1].

Students that leave engineering faculties without a qualification can be divided into two groups; those that leave in good academic standing and those that leave in poor academic standing [2].

The three main themes identified in literature related to retention research are:

- Characteristics of the student – Internal or psychological and external such as demographics [3]
- Retention Models – Conceptual and Predictive, and
- Interventions to improve retention.

It spite of substantial amounts of research on retention of students over several decades it seems that most institutions have either not been able to implement the research findings or the current knowledge does not adequately address the problems of retention or what we have learnt about student retention still is not fully understood [4].

II. Motivation

The purpose of this article is to identify and analyse what retention research has been done in the past to avoid unnecessary duplication. Although duplication may bring valuable new information, progress in this field has been slow. Therefore, the focus is on facilitating progress rather than seeking more accurate results.

III. Definitions

There are many ways in which researchers define retention. One definition is retaining students at an institution i.e. the students starts and finishes their qualification at the same institution. Another definition is retaining students in a faculty i.e. the student starts and finishes their qualification in the same faculty.

Berger and Lyon define retention as "the ability of an institution to retain a student from admission to graduation" [5]. While "persistence" and "retention" are often used interchangeably they are not the same for faculties charged with becoming more attentive to the needs of students. In the USA the National Centre for Education Statistics treats retention as an institutional measure and persistence as a student measure [6]. Depending on the accepted definition the manner in which to determine the actual retention achieved via measurement can however be fraught with difficulty. Given faculties need for improved resource accountability this paper will deliberately use retention in the sense of the student completing the degree for which he initially registered.

IV. Characteristics

Individual student retention can be described by internal or psychological characteristics which are divided into two groups in literature: Internal cognitive and internal non-cognitive. In the study done by French et al. [7] it was found that different factors play a role in retention of engineering students compared to other fields of study.

A. Internal or Psychological Characteristics:

1) Internal Cognitive Characteristics

Academic ability has proven to have an impact on retention. High school learners who are academically well prepared are more likely to be successful at university and be retained. Mathematics and science ability are strongly correlated to admission and retention in engineering programmes. One naturally wonders whether there is a significant difference between the academic ability of students who drop out and those

who are retained. Tinto [8] found that most students dropout voluntarily and not because of failing to meet academic requirements. In a study conducted by Hartman and Hartman [9] they found that the GPA of female students who switched out were not different than those who stayed, but this was significantly different to male students where there was a significant difference in GPA of students who stayed and those who left.

A. Bandura, a psychologist, defined self-efficacy as individuals' belief about their ability to perform the necessary tasks to achieve the desired outcome [10]. Self-efficacy has a significant impact on retention in engineering fields, and a number of relevant skills have been found to correlate strongly with self-efficacy: teamwork skills, availability and access to help, ability to complete tasks, problem solving skills, academic interest, and learning satisfaction [3].

Different learning attributes and styles mean that students respond differently to the same teaching style [11]. For example, in a lecture-based instruction environment (where lecture content must be absorbed and reproduced), introverts, intuitive thinkers and judgers typically perform better than their extroverted, sensing, feeling and perceiving counterparts [12]

2) Internal Non-Cognitive characteristics

If experiences of engineering education do not meet students' expectations, negative attitudes may occur, which could lead to students dropping out. Enjoyment of the study material seems to also have an effect on students not dropping out [3]. If students have a strong conviction that their degree will lead to career security they are more likely to pursue even if they have a negative view of certain aspects of their course [13]. Assisting students in developing a positive attitude towards their career is an important task for educators.

In engineering courses self-confidence is highly correlated to retention of engineering students. Early identification of students with low self-confidence may enable a deliberate change in their self-perception before they decide to leave [2].

Locus of control is an indication of whether or not an individual believes they are able to control outcomes with their actions. Individuals with an internal locus of control believe that their actions affect outcomes, while those with an external locus of control do not believe that their actions can have a significant impact on outcomes. Unsurprisingly internal locus of control is an indicator that predicts positive GPA scores of students [2].

Students that left engineering in good academic standing often started with less commitment than those who remained in the program. It is important to get students to commit to engineering at an early stage [3].

In research done by Nicholls et al. [14] motivation was a strong predictor of engineering retention. Persistence and resilience helps to motivate engineering students to complete their studies. Social value and personal benefits of completing an engineering qualification could be emphasized to motivate students to stay in engineering.

Conscientious students tend to be more organised, persistent, and responsible. They want to do well and have high aspirations. Students need to be conscientious to succeed in engineering. However the engineering curriculum may be discouraging to students with high aspirations as they become frustrated and often feel overwhelmed when failing to perform to their academic expectations [2].

B. External Characteristics

External characteristics are divided into three areas namely community, university and demographics.

1) Community

In students' communities the influence of peers has been found to be the strongest and most consistent factor in students' development and retention decisions [3]. By increasing opportunities for students to interact with each other, peer influence can be encouraged.

Adults such as parents or teachers also influence students. Parental approval has a direct effect on students' retention decisions. High expectations of students by parents also have a positive impact on student likelihood to persist [2].

2) University

The cultural atmosphere of a university has a significant impact on retention [15]. The faculty has a critical role to play in engineering student retention. [16]. The interaction between faculty and students enhance student satisfaction, faculty instruction and the overall experience of the university [4].

Closely linked to cultural atmosphere is students' "sense of belonging". "Sense of belonging" refers to the extent to which a student has become integrated in the university system [17]. Research has shown "sense of belonging" has an effect on retention of students [18]

Research has shown that engineering programmes are seen as difficult with a high workload and frequently lacking in relevance to engineering practice [19]. This external factor probably has the largest impact on retention of engineering students. It appears that mathematics is the most difficult course and causes the most dropouts in the first year of engineering study. Miller [20], founding president of Olin College believes engineering education needs to speak to the deeper motivations of engineering students. It is generally advised that students should be exposed to engineering projects early on in their training to make their training more relevant to current engineering practice.

3) Demographic characteristics

Female students are less likely to select Science, Technology, Engineering and Mathematics (STEM) majors than male students. Female students are more likely to transfer out of engineering even though they may be in good academic standing. [15]. Even though female students make up just over 50% of the overall student body less than 20% of them will receive degrees in engineering [14].

In the US it is reported that minority groups have been under represented in engineering [14]. In the past in South Africa it has been the majority groups that have been under represented. In South Africa specifically in industrial engineering, there has been significant transformation within the National Diploma in Engineering and the Bachelor in Engineering Technology with regard to demographic intake. However in the Bachelor of

Engineering there is still less transformation with the dominant group being white male students [21]. More role models are required for Black, Coloured and Indian young people in South Africa.

Socio-Economic status refers to the individual or family rankings in terms of economics and social standing [22]. Students of low social and economic standing are typically under-represented in higher education. Yet it has been found that with regard to engineering courses, students from low socio–economic standing experience a higher sense of fulfilment, higher professional persistence and have more financial motivation to attain an engineering degree. The students from a higher socio-economic background tend to receive more familial encouragement to study engineering [2]. At the University of Johannesburg students from poor socio-economic back grounds who have received a bursary from the National Student Financial Aid Scheme tend to show greater persistence than all other students at this institution [23]. This could be because they experience less pressure financially however bursary holders should also be identified and compared to this group to determine whether it is purely lack of financial pressure that leads to increased persistence.

Engineering students from rural areas tend to drop out more often than students from urban areas [24] and students who attended a small high school are more likely to drop out than students who attended larger high schools [25]. However many students from rural areas are also from low socio-economic standing. They are also typically more geographically isolated and less likely to have engineering role models [2].

V. Retention Models

Retention models can be divided into conceptual and predictive models. Some of the main retention models are discussed below:

A. *Conceptual models*

Tinto's conceptual model Fig 1. is the most frequently cited. In this model the theory is that students stayed in university to the degree that they felt academically and socially integrated into the life of the university [26]. He also indicated that individual characteristics that a student enters university with directly affect their persistence and commitment to the institution. This model is accepted by many scholars it has been cited over 700 times. A statistically significant relationship was found between social integration and retention [27]. There is no conclusive empirical proof that the academic integration does lead to increased retention.

Bean adapted a model of employee turnover to address the problem of student departure [28]. According to this model there are ten external variables that influence satisfaction and the level of satisfaction determines the student's intent to leave. The ten variables are routine, participation, instrumental communication, integration and distributive justice, grades, practical value, development, courses and membership in campus organisations [29].

Bean and Eaton later developed a psychological model of student retention integrating four psychological theories [30]. The past behaviour and beliefs of a new student determine how they experience the university environment, and a student's interaction with the institutional environment has an impact on their motivation. Students then experience ongoing adjustments to their internal psychological processes (including self-efficacy, declining stress, and internal locus of control) upon which depend academic and social integration, institutional fit, and persistence [28].

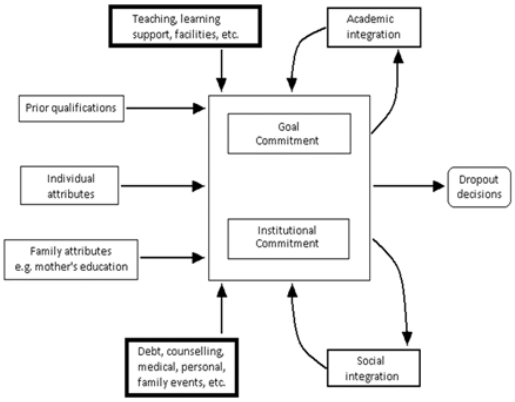

Fig. 1. Conceptual model by Tinto as adapted by Draper [26]

Astin developed a theory of involvement [31]. Involvement refers to the behaviours that students engage in during their time in a higher education institution. The amount of learning and development of each student is determined by the quality and quantity of involvement in a particular program. Involvement can be specific or generalized, and can have quantitative and qualitative aspects. According to this model effectiveness of academic programs are determined by its ability to increase student involvement [29].

Bean and Metzner developed a model for attrition of non-traditional students [32]. The model indicates that for adult students, environmental variables (such as finance, employment, family responsibilities, and more) are more likely to impact the decision to leave a programme than academic variables [29].

Berger [33] applied Bourdieu's concept of cultural capital to the college student departure process. Cultural capital is a resource that students can use to maintain and advance their social status. Educational institutions also have cultural capital. It is suggested that institutions with higher cultural capital will have higher retention rates and students with higher cultural capital will persist longer. It has also been proposed that a cultural capital match is more important than the amount of cultural capital. Students with higher cultural capital are more likely to persist at institutions with higher cultural capital and likewise students with lower cultural capital are more likely to persist at institutions with corresponding lower cultural capital [29].

B. *Predictive Models*

Predictive models use statistical methods to predict which students will be retained and who are at risk for not being retained. Statistical methods used are neural networks, logistic regression, discriminant analysis [13], and structural equation modelling, exploratory factor analysis and classification tree.

The predictive models include internal or psychological characteristics and external characteristics to predict retention. Some of the models use 9 characteristics others use up to 168 different characteristics [34]. When models using different sets of cognitive and non-cognitive characteristics were compared it was found that models with cognitive only characteristics perform better than non-cognitive only models and combination models perform better than either. In this comparative study it was also found that neural networks outperformed logistics regression and structural equation modelling [34]. In a study done by Burtner [13] it was found that as students' progress through the engineering course the predictive models applicable to retention estimation changes.

VI. INTERVENTIONS

Several interventions have been suggested over the years to improve student's retention:

A. Develop Faculty – classroom practice

The development of faculty and specifically the impact of classroom practice is one of the suggested interventions [4]. This intervention specifically addresses academic integration of students as described in Tinto's conceptual model above as well as realistic curriculum requirements and the cultural atmosphere of the university. This requires changes in the manner and functioning of the teaching faculty to bridge the gap.

B. Support programs

Support programs are another popular intervention [35]. Here the focus is on assisting students to improve personal characteristics such as attitude, self-confidence and motivation. These programs could help students improve learning skills. Students should be assisted to improve their interpersonal skills and thereby improve social integration at the university as described in the conceptual model above. Most of these are bolt-on solutions that attempt to address defined shortcomings of the students and act parallel to the formal teaching and learning process.

C. Remedial/ developmental course work.

Remedial or developmental course work could also help to improve retention [35] by improving academic preparation before embarking on the engineering course. Mathematics preparation has been identified as an area that could have an impact on improving engineering student retention [2]. In this case all students can benefit from mathematics support as very few meet the requirements of mathematics in the engineering course.

D. Learning communities

Learning communities could be established to create opportunities for students to interact and learn together [36]. This could improve social integration as well as have positive peer influence. Research on peer impact on retention (as opposed to throughput and overall success) are however equivocal.

E. Tailored intervention programs

Another possibility is to tailor intervention programs for individuals this will probably only be possible for students who ask for help as it would not be possible to develop tailor made interventions for all students.[37]. At an institution where attrition is low the psychological and counselling centre focus their services on the individual student and not the student body as a whole [37]. The development of a self-paced tailoring solution to initial shortcomings has not yet emerged as far as we are aware.

VII. DISCUSSION AND RECOMMENDATIONS

A large amount of research has been done in general education and engineering education to identify characteristics of students that impact retention. This work presents a comprehensive overview of these characteristics, and we note that over several years there has not been significant change.

Various conceptual models exist to explain retention, yet, there is scope to do empirical tests to prove or challenge many of these models. New predictive models are used and developed continuously with different success rates, but are rarely linked to the conceptual models that predate them. Student retention models that are both accurate and conceptually satisfying are still lacking in the literature.

The various interventions that have been identified and used have not significantly increased retention. More research is therefore required into effective interventions.

The different themes of individual, collective and specific impacts are strongly inter-related. Students that are marginalized are unlikely to be attracted to interventions that play on their differences and will rather transfer than accept defeat. Any attempt on retention must be predicated on the results from the above research – it is a multi-dimensional problem that admits of not a simple solution – and this is why the proposal that the material gathered in this overview should be used as a basis for an analysis of the retention shortcomings from an industrial engineering perspective. Several studies have been done using six-sigma and lean techniques on various education problems. There are however many different industrial engineering techniques that could potentially be applied to improving engineering student retention. Quality management techniques such as statistical process control could be used to improve lecturing, by doing a short survey at the end of classes. Processes could be re-engineered, to improve teaching and learning. Decision theory could be used to determine best decisions, in terms of input required for students and the costs thereof. Simulation can be used to test changes and possible impact of the changes etc. In industrial engineering people are always one of the key aspects to consider in any improvement program. This is especially true when trying to improve retention of engineering students.

Models use characteristics to better understand retention and to identify students at risk and determine what types of interventions are required. There are various perspectives from which retention can be approached and analysed.

Some institutions found that it is possible to address retention without knowing the exact cause of why students want to leave [36]. These institution have found that acting quickly to integrate students via multiple means, improves retention by overcoming any number of actual causes that leads to students

leaving. Thus by increasing the reasons to stay, the reasons for leaving become less important.

Certain interventions will impact retention even if it is not clear what the causes are. Yet if one understands the causes it should be easier to tailor interventions that have a more significant impact on retention. Proper assessment of intervention programs should also assist in improving interventions [38].

New engineering students arrive with a variety of characteristics and understandings of their academic future. In order to develop the characteristics required to succeed, even while those characteristics are being identified and analysed, interventions should consider different structures exposing entering students to successful senior students. At the same time, staff need to understand and support the interventions and incorporate appropriate measures into their teaching to support the development of success-linked characteristics.

VIII. Conclusions

Retaining students as a topic has been researched over several decades. Hagerdorn [6] states that "retention not only has an impact on the individual and his/her family but also produces a ripple effect on the tertiary institutions, the work force and the economy". According to Tinto [4] retention has become a big business for researchers, educators and entrepreneurs alike and yet significant improvement in student retention has not been achieved. Further research into methods for enabling student retention is certainly justified if the present concern around cost and resource shortages in tertiary education are to be taken seriously.

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