

Explaining student success in engineering education in Delft University of Technology; a synthesis of literature.

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ABSTRACT

Student success is among the most widely researched areas in tertiary education. The generalizability of research in this field is problematic due to cultural and structural differences between countries, institutions and programmes where research is done. Engineering education in the Netherlands has not been studied in depth so far. In this paper outcomes of studies done outside and inside engineering and outside and inside the Netherlands are discussed to understand the complexity of retention issues. Although generalizability is an issue, there are a number of concepts and variables that surface in many of these studies. These include students' background and disposition variables, education attributes, variables concerning educational climate and student behaviour. In the paper it is argued how these variables are related and how a university can apply the outcomes of research in this field of study.

Keywords: student success, student progress, retention, drop out, tertiary education.

1 INTRODUCTION

The past decade much effort has been put in attracting young people to engineering. Societies around the globe need to train more engineers to fill jobs and to develop the technology of tomorrow. When we look at the rising numbers of enrolment in these fields of study in the Netherlands, we can conclude that we have been successful (VSNU, 2011). Once students are in engineering schools, however, there is another challenge: retaining those students in their programmes until graduation. Many students in engineering are not as successful as their peers in non engineering programmes: they drop out of university more often and they take a longer time to graduate. In this paper the term 'programme' refers to a curriculum, 'course' refers to a subject.



WEE2011, September 27-30, 2011, Lisbon, Portugal.
Editors: Jorge Bernardino and José Carlos Quadrado.

In Delft University of Technology (DUT) for instance, 35 to 50 % of the students leave without a diploma. The students who do graduate take 7.2 years on average for a 5 year programme. These numbers have been fairly stable and resistant to change, even while the national government and DUT have strived to increase the numbers. Examples of measures taken to improve the retention rates include the introduction of a national grant system setting boundaries to the number of years students could study with government support, curriculum changes and improvements in the organization of education. This attrition and the long time to graduation are expensive in many ways: many able students are lost for the profession; students gain a bad experience and usually lose money and time. The university also invests time in those students and since Dutch universities are financed based on the number of diplomas awarded, this is an unfortunate situation. The urgency of the problem has increased unexpectedly the past few years: as a result of the economic crisis higher education everywhere in the world is confronted with severe budget cuts. In many countries student grant programmes are also affected which in turn affects students' financial situation. DUT is, maybe even more than ever, interested in influencing the retention numbers and in lowering the time to graduation. However, the university has attempted this often before and failed. Issues of dropout and study delays are very complex and are influenced by many different factors on many different levels. The question of whether a university can influence these two issues at all has risen. The university commissioned a research project to find answers that can inform practice on effective policies. The question the university posed is a scientific one, because the university would like to be able to predict the effects of policies regarding dropout and delay. Mere descriptive research will not be enough to meet the goal of effective policies. What is needed is an explanatory system's model that identifies which factors matter in the context and how these factors are related. In this paper we describe the first phase of this research project: synthesizing the literature on student success and identify factors that need to be included in a contextualized model. In this synthesis the focus is on degree programmes in general universities and universities of technology¹. The context of engineering education seems to have a number of attributes that justifies looking at this specific context. For instance Van den Berg and Hofman (2005) found that Dutch incoming students in engineering had higher math grades compared to students in non-engineering universities, but were less successful.

The research questions in this paper are:

- Which factors found in the literature determine students' academic success in university?
- How are these factors related?
- Which of these factors apply to engineering education?

¹ In the Netherlands there is a strict distinction between universities of applied science and research universities. This paper deals with research universities only.

The setup of this paper is as follows: in the next section we discuss the definition of student success and move on to describe the methods followed to find and classify relevant literature. We move on to discuss and comment on a number of studies deemed relevant for this work. In the final section the findings are synthesized and reflected upon in the light of the research questions.

1.1 Defining student success

Student success is a broad concept that can be operationalized in many different ways. Many researchers have used different measures to describe student success. Examples include Tinto (1987) who looked at the dichotomous variable 'drop out' and Moller-Wong and Eide (1997) used in their research in Iowa State University "the number of students who successfully received an engineering degree from Iowa State University" (page 8). Other ways of operationalization include looking at student progress i.e. the number of credits students obtain in a set period of time, the average grade that serves as an indication of the quality of the learning outcome (e.g. Bruinsma and Jansen, 2007), reenrolment in the next academic year (e.g. Ohland, et al., 2008). In this work the term student success is used to indicate dropout and progress. If we refer to only one of these two variables, it will be stated clearly.

2 THE IMPORTANCE OF CONTEXT

Education cannot be seen as separate from its context: values that are prevalent in a society are reflected in the way education is organized and who has access to education (McLean, 1995, Wiegiersma, 1989). A striking example is selection prior to enrolment. This is common practice in the Anglo-Saxon world where there are no national exams for secondary education and where universities are free to select their own students. In the United States of America there is a distinction between private and public universities. These universities often have different enrolment criteria but also charge different tuitions to their students. One can safely assume that these universities attract different kinds of students when we regard students' motivation or economic status. Van Stolk, Tiessen, Clift and Levitt (2007) observed that terminology used to indicate the phenomenon of retention has a different connotation: in the USA researchers often use the word 'persistence' to indicate students who persist in pursuing their degree and not dropping out. In Europe many researchers prefer to use the term 'retention' which implies that something or someone needs to retain something, i.e. universities need to retain their students. This is anecdotal evidence that the phenomenon of drop out is looked upon in a different light.

Within Europe there are also large differences between countries. Educational systems in Germany and the Netherlands are based on similar values, but education is organized in different ways. In Germany most pre university students will take a job prior to enrolling in university. When they study they have a fair number of years of work experience and many of them have families. In the Netherlands most university students enrol in university as soon as they qualify. Most of them are 18 years old when they enrol. Most of these students will move out of the parental house during their first year in university and have many other challenges to overcome. Most of these challenges involve learning to take responsibility like an adult. Populations in universities in both countries have very different attributes and that results found in German studies may not hold in the Dutch context and vice versa.

This observation of differences is of paramount importance for this study, because the differences in systems imply that seemingly similar phenomena like failure or dropout are understood in different ways within systems and carry a different weight. Failure has different implications for students. E.g. in the UK students can only sit an exam once. If they fail, they will have only one chance to make up for it. If they fail the second time they will probably be sent away from university. In addition, students are only allowed to progress to the next year when they have passed of the required courses for the previous year. Failure to pass a course will have dramatic implications. In the Netherlands this is not the case. There generally is an unlimited number of resit exams. In addition, there is no progress requirement for academic years. If a student fails to pass a math course in the first year, the student will not be barred from taking part in a second year course. In engineering this could mean that a student takes a course in dynamics while this student has not demonstrated competence in statics. Students have a lot of leeway when they navigate through their programmes, even if this means that they take courses when they do not satisfy entry-level requirements for those courses. These differences in structure and appreciation of phenomena in their context implies that we have to be extremely careful when we study research done in contexts other than the ones we were trained in ourselves (Standaert, 2007; Bereday, 1964). Things that are viewed as success in one system could be understood as failure in another.

One could argue that even within the Netherlands similar care should be taken when we look at research into student success. In the Netherlands there is a distinction between universities of technology and general universities. The universities of technology are the only institutes that offer university level engineering courses. There are three of these universities in the Netherlands. The point is that it is paramount to consider the generalizability of research carefully when we study literature to understand a phenomenon as complex as study success.

3 METHODOLOGY AND CRITERIA

The systems' differences have a large implication for this literature synthesis: the context of any study needs to be taken into careful consideration when we consider using the results as input for our preliminary model. Criteria for searching literature for this work were these:

- studies were published after 1985,
- authors report on rigorous and original research,
- papers are published in research journals and
- studies had to explain (aspects of) student success in higher education.

One exemption was made because it concerned a very specific research project done in DUT between 1949 and 1953. This will be touched upon later. The literature search was conducted between April 2009 and July 2010.

To find studies on this topic we searched through the archives of a limited number of international peer reviewed journals that are in citation indices. We used the snowball method to find studies that were published in other journals. It soon became clear that there were very few studies done in engineering education in the Netherlands. To fill gaps the Dutch national database Picarta and special engineering archives were included in the search. The number of studies included in this literature study and their main topic in presented in table 1. The papers we refer to in this synthesis are summarized in the appendix.

In number of cases this meant that the criterion of having been published in journals was dropped. Some of the studies that are classified as ‘engineering’ may be studies in which populations from universities of technology are included in the research that is reported on. The studies considered in this paper are discussed in short in the appendix.

Table 1: Number of studies included in this research

Degree programmes		
	Engineering	Non engineering
Outside the NL	8	12
In the NL	2	11

In the next sections we present a number of models intended to explain student success. This provides the reader with theoretical frameworks of how researchers look at issues of student success. The first model that is discussed is the generic Student Integration Model (SIM) developed in the USA by Vincent Tinto (1987). We confront this work with comments of researchers who have studied the model and we present findings from researchers who introduced other theories and variables in their models. Next, the findings from that research are confronted with research that was done specifically in engineering. As is shown in Table 1, there is very little information available about engineering education in the Netherlands. In the reflection it is discussed how the variables are interrelated and what the findings from this research mean for explaining student success in DUT.

4 THE KNOWLEDGE BASE ON STUDENT SUCCESS

4.1 Tinto’s model of college student success

As stated in previous paragraphs, student success is among the most widely researched areas in higher education. The work by American researcher Vincent Tinto (1987) is seminal in this field of research. Tinto departs from the assumption that student departure cannot be attributed to individual characteristics: there is no such thing as a “departure prone” personality (page 87). Instead, Tinto states that the role of the social setting of the institution in the withdrawal process should not be underestimated (page 89). Tinto postulates that the more students are integrated in their educational environment, the less likely they are to drop out. There are four main elements in Tinto’s model: social and academic or intellectual integration, intention and commitment. Institutions for higher education have academic and social subsystems, each with its own characteristic formal and informal structures. The academic system mostly concerns itself with the academic affairs of the college and the formal education of the students. The social system of the college centres about the daily life and personal needs of the various members of the institution. It is made up of those recurring sets of interactions among students, faculty and staff, which take place largely outside the academic domain of the college. Both systems are distinct, but integration in one system does not automatically imply integration in the other system as well. Tinto recognizes that sometimes external forces play a major role in student departure and that a model that explains departure has to be able to discern between voluntary departure that may in fact be involuntary, but is invoked by external forces that neither the student nor institution can control. Tinto’s assumption here is that the greater the integration, the greater the likelihood that a student will persist to degree completion.

Intentions reflect aspirations and expectations and these are usually stated in terms of goals. Committed persons are willing to commit themselves fully to the attainment of valued goals and expend the energies and resources required to do so. Persons lacking such motivation may have lofty goals for themselves, but may be unable or unwilling to commit themselves to their attainment. The more committed the person is to the attainment of those goals within a specific institutional context, the more likely she/he will be to complete that degree within that institution. Tinto states that motivation for goal attainment arises from the natural tendency of individuals to maximize their interests, not from the, often counter-productive, fear of punishment.

The model is not a systems model, but explains individual’s departures in a specific institution over time. The model looks only at voluntary withdrawal. Lastly, the model is interactional in character: it emphasizes the longitudinal process of interactions which arises among individuals within an institution and which can be seen over time to account for the longitudinal process of withdrawal of disassociation which marks individual departure. In this sense the model is not merely descriptive, it is also explanatory. The model seeks to explain how interactions among different individuals within the academic systems of an institution lead individuals of different characteristics to withdraw from that institution prior to degree completion. This model is often referred to as the Student Integration Model (SIM).

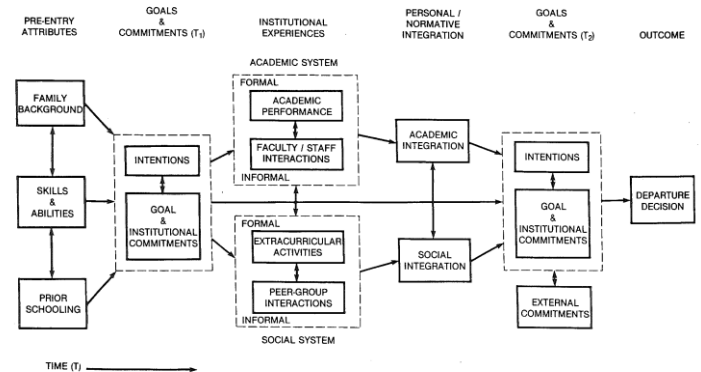


Figure 1: Tinto’s Student Integration Model. (source: Tinto, 1987)

4.2 Critique on Tinto and alternative models for student success

Braxton, Milem and Shaw Sullivan (2000) state that Tinto’s interactionalist theory enjoys “near paradigmatic” status, as it is commonly cited and used as a basis for further research. However, Braxton, Shaw Sullivan and Johnson (1997) tested the model for robustness and found that they could only find support for 5 out of the 13 primary propositions that Tinto postulated in his original theory. Four out of these five propositions are logically related. Put in a narrative form, these 4 propositions read: student entry-level characteristics affect the level of initial commitment to the institution. These student entry characteristics include family background, i.e. socio economic status, parental education level and income, individual attributes i.e. ability, race and gender, and pre college schooling experiences, i.e. high school achievement. The initial level of student commitment to the institution influences the subsequent level of commitment to the institution. The subsequent level of institutional commitment is also positively affected by the extent of a students’ integration into the

social communities of the college. The greater the level of subsequent commitment to the institution, the greater the likelihood of student persistence in college. However, these empirically backed propositions leave social integration unexplained. Tinto fails to describe exactly how these factors should be operationalized. Braxton et al. (1997) therefore concluded that Tinto's model may be an interesting start for research, but the model leaves many things unexplained and unclear.

Bean (1980) criticizes Tinto because Bean believes the model to be incomplete and because it does not pay strict attention to the directional causality of the variables in the theoretical model nor to the discreteness of the variables. This makes the model unsuitable for path analysis. In addition, the model does not work well for commuter colleges (Bean and Metzner, 1985). Bean devised a model that was based on a model of employee turnover in business and turned this into the student attrition model (SAM). Bean found that there are different factors influencing men and women in their decisions to leave a university of college. Unfortunately, Bean's model did not explain more than .21 in adjusted variance for women and .12 for men. Cabrera, Mastaneda, Nora and Hengstler (1992) tested the SIM model against the SAM model using the same data set. They found that SIM appeared to be more robust than the SAM when judged in terms of the number of hypotheses validated. Cabrera et al. (1992) found that both SIM and SAM add relevant knowledge to the understanding of the college persistence process, but that a model integrating the leading factors in each theory may contribute to explain the process better. Further critique to the SIM and SAM models is that they do not give clear directions to how universities and colleges are try to influence the factors that matter to persistence.

Dutch researchers Beekhoven, De Jong and Van Hout (2002) compared the scales used to measure social and academic integration in studies based on Tinto's concepts of academic and social integration. They concluded that different researchers assign similar subjects to different concepts and that "most studies use items focused on satisfaction with the education and its environment, and the personal development of students. Less common are measurements that include the frequencies of interactions and grade point average (GPA) into their integration constructs." (Beekhoven, et al., 2002, page 24). They went on to note that in these studies social and academic integration often contribute to student departure with indirect and sometimes direct effects, but the strengths of the effects differ. Possibly the biggest problem that Beekhoven, et al. observed is that the integration model disqualifies the students from taking an active role in the on-going decision process that results in the decision to stay or to leave university.

3.3 Studies on retention from the Netherlands

Beekhoven, De Jong and Van Hout (2002) moved away from the impractical and fuzzy distinction between the concepts of social and academic integration. They combined the model of Tinto with rational choice theory. The basic assumption in rational choice theory is that a person balances costs against benefits before taking any action. Students' experiences in the first year are expected to influence their actions and experiences in the second year. The same process occurs when students move from the second to the third year. Students are likely to be rational actors who make cost benefit analyses. The researchers combined elements from both theories into a model that may be a more realistic representation of the actual process and give a better

understanding of academic progress. They tested their model by applying path analysis and they found that in this combined model 80 % of the expected paths were found to be significant. A number of background variables: traditional university preparatory education (UPE) student, high school grade point average and educational level of the parents, improved the model modestly. This is an interesting finding, because these variables included in Tinto's model were also found to have a significant effect by Braxton, Shaw Sullivan and Johnson (1997).

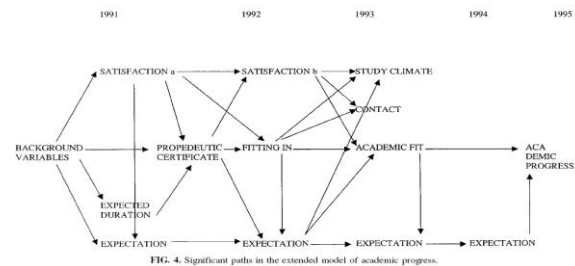


Figure 2: Significant paths in the Beekhoven extended model of academic progress (Source: Beekhoven, De Jong and Van Hout, 2002).

Van den Berg and Hofman (2005) also recognized that the Tinto theory leaves out many theories that could add to the understanding of student departure and study progress. They designed a conceptual model that integrates human capital theory, cultural theory, interactive theory and effectiveness theory in a conceptual model to understand dropout and the long time to graduation they observe in the Netherlands. By effectiveness theory they meant theories that "are directed towards the effects of how the education is organized. The external context factors influence the internal context factors. Both influence the aims and structure of the educational organization and determine the degree of effectiveness." (page 417) Van den Berg and Hofman identified categories of factors that are shown in figure 3 below.

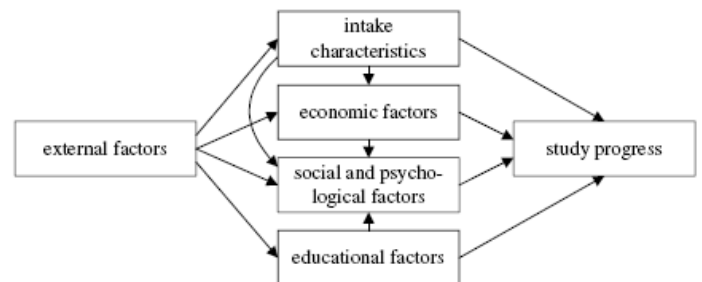


Figure 3: Conceptual model to explain the study progress in Dutch higher education (Source: Van de Berg and Hofman, 2005).

- external factors, i.e. grant related factors;
- educational factors, i.e. course and institute factors;
- intake characteristics of students;
- economic factors and
- social and psychological factors that are all student related.

To test the model, the authors used multilevel analysis and included three levels in the analysis: the student level, the institutional level and the governmental level. Van de Berg and Hofman used an existing dataset that contained longitudinal data of students in five universities in the Netherlands, including DUT. The data was collected between 1996 and 1999. The focus of their research was to find out which factors determine success on the three different levels.

The key finding from this research was that programmes differ to a limited extent only, but that differences in progress between students are considerable. The picture remained constant over time for the four years that were investigated. Findings regarding student background variables include that female students are more successful than male students. Students from an ethnic minority show less progress than non-ethnic students. The authors did not find effects of socio economic status. Age of the students matters, students who enter at 18 make more progress than mature students. The authors tested for hours spent on paid work and hours spent on the programme and found that 'time on task' had a positive effect on model fit. Students who spent up to 12 hours on paid work did not experience a negative effect. Students who spent more than 12 hours experienced a negative effect. The students from Delft stood out in this study: they have higher grades in university preparatory education (UPE, in Dutch: VWO) compared to students in arts and humanities, still the Delft students gain less progress compared to other fields. Females in engineering also progress more slowly than females in other fields.

Regarding educational factors, Van de Berg and Hofman (2005) tested the effects of curriculum organization and of examination attributes. The authors found that the more educational periods there are in a year, the less progress students make. This was mainly attributed to the Delft students in the sample: the Delft students were the only ones in the study who had 5 periods in a year, instead of 4. The authors found that the more subjects are scheduled in one period, the less progress students make. The assumption that courses displace each other and compete with each other seemed to be correct. Exam attributes did not contribute to progress. DUT was the only university in the sample where students were allowed to average exam results and compensate for fail grades. These compensation measures did not lead to more progress. More integrated curricula, like curricula based on problem based learning, did lead to more progress.

This study indicates that there are some interesting differences between the populations of the students from Delft and general universities and also that the different curriculum organisation that is in place in Delft does not have any effects.

Jansen and Bruinsma (2005) postulated that the integration models provide a good theoretical framework for examining academic achievement, but they criticized studies that operationalize the qualitative factors by just looking at very quantitative indicators, such as "number of hours spent" or "academic field". The work by Van de Berg and Hofman (2005) and Beekhoven, De Jong and Van Hout (2002, 2003) are examples of that approach. In this kind of research characteristics related to organizational and departmental level (Jansen and Bruinsma, 2005) and to instruction and the classroom climate receive less attention. (Bruinsma and Jansen, 2007) Furthermore, most of the student variables in these models are limited to background variables, such as age, gender and ability. Studies that include process variables such as motivation, which Bruinsma and Jansen (2007)

believed to be of paramount importance for the learning process, are limited. They specified hypotheses concerning the relationship between achievement and two complexes of factors. The first complex concerned factors related to the manner in which institutions organise their education, focusing on the curriculum level, such as the spread of courses in the curriculum and the policy related to assessment. The second complex concerned student characteristics including background characteristics like gender, age, ability, educational status of father and mother and employment, it also encompassed a student's cognitive and meta cognitive strategies and their positive beliefs, motivation and emotions towards study. Bruinsma and Jansen took great care to gather process data during the year, instead of in retrospect. Their analysis showed that, except for the variable ability, the student process and department variables had various effects on grades. One example is the students' expectancy that had an effect for two groups and the effect of the number of passive lecture hours and the number of hours allocated for independent study appeared to differ in direction between the two departments. Though this study did not provide any information on the significance of these differences, it does not imply that these differences are not relevant. These differences might, for example, be already present at the beginning of the programme when different disciplines attract different students. Additionally, during the programme differences in contextual features might result in different effects of the student input variables and classroom process variables on academic achievement. In the concluding remarks Bruinsma and Jansen (2007) stated that student motivation is an important contributor to the variance found in grades. Students who believe they can do the programme will receive higher grades. University teachers and departments can influence the grades indirectly by empowering students in the classroom.

Some researchers looked into the concept of social integration and the importance of networks. Oseguera and Rhee (2009) found that the support of a peer group had a small but significant effect on student success and Thomas (2000) found indirect but important effects of the social network of students.

There is a number of observations to be made here. Researchers have attempted to explain student success from various theoretical perspectives and they have come up with various models. These models have a number of variables in common, mainly student background variables. In almost all studies 'student ability' is found to be the most important and most stable predictor of success. The study by Georg (2009) is an exception. He found that the most important factor for retention in Germany is student commitment. Other variables including external factors, education factors and social and psychological factors often have different effects in different models or populations. It does seem that some attributes of curriculum organization have proven to have an effect in various educational settings (Van der Hulst and Jansen, 2002; Van de Berg and Hofman, 2005). The university and the programme seem to make a difference. Need and De Jong (2001) tested the effect of the study environment on progress in several universities in the Netherlands, but they could attribute 95 % of the variance to student related factors, only 5 % was attributed to factors related to the study environment. They did not include engineering programmes in their study.

It should also be observed that many of these studies are based on retrospective quantitative analyses and miss out on students' perceptual data on the educational environment and wellbeing. This stresses the importance of a context-based model to explain

success, but also to give enough attention to real-time student data (perceptual). The studies bring forward the complexity of the issues: many variables and factors are at work and they all seem to be interconnected. It makes studies that include only one predictor variable or student background variables look arbitrary. Such studies could be considered the tip of the iceberg at best. The studies discussed so far, were all done in different educational settings. In the next section we will discuss research that was done in engineering specifically and contrast the findings with the findings of this section.

5 STUDIES IN ENGINEERING

Outside the Netherlands there have been many studies into engineering education. Felder in collaboration with other authors published a notable series on chemical engineering student performance and retention in the *Journal of Engineering Education* between 1993 and 1998. They looked at effects of learning styles (Felder, Forrest, Baker-Ward, Dietz and Mohr, 1993), instruction (Felder, 1995; Felder, Felder and Dietz, 1998), gender (Felder, Felder, Mauney, Hamrin and Dietz, 1995) and rural/urban setting of the school (Felder, Mohr, Dietz and Baker-Ward, 1994). It proved to be possible to identify at risk students early on based on student background variables and scores on Myers-Briggs Type Indicators (Felder, Forrest, et al. 1993). Felder, Mohr, et al. (1994) found that rural students are academically disadvantaged compared to students from urban communities and that it is difficult for rural students to catch up with their peers. Felder (1995) and Felder, Felder, et al. (1998) found evidence to support that cooperative teaching strategies are more effective than traditional one-way lectures and Felder, Felder, et al. (1995) he found that in engineering education there are factors at work that makes it difficult for women to compete on equal footing with their male counterparts. Female students reported lowering their expectations of success and of confidence over the years they were in engineering.

Zhang, Anderson, Ohland and Thorndyke (2004) looked at graduation rates in engineering in 6 years after enrolment. They looked at 9 universities and only considered 6 predictor variables. They found that there were differences in which variables mattered significantly for each university. Ohland et al. (2008) and Araque, Roldan and Saguero (2009) compared students who persisted in engineering and students who persisted in non-engineering fields. Ohland et al. (2008) did not find appreciable differences between students in how they rated the quality of their education, nor in time spent on studying. Araque et al. (2009) profiled students who dropped out of programmes in arts, humanities and computer engineering of a university in Southern Spain. They found that the three models were different, but certain variables appear repeatedly in the explanation of the drop out in all of the programmes. These are start age, parental SES, academic performance, success, average grade, prior education and in some cases the number of rounds needed to pass. Students with weak educational strategies and without persistence to achieve their aims in life have low academic performance and low success rates and this implies a high risk of abandoning the degree. These three studies show the importance of the context of the study once again.

French, Immekus and Oakes (2005) followed two cohorts of undergraduate engineering students in a large Midwestern university in the USA and found that SAT scores, high school

rank and gender had a significant positive effect on GPA and GPA was a good predictor of reenrolment together with student motivation. Non-cognitive variables like motivation play a significant role in predicting success in engineering. Lackey, Lackey, Grady and Davis (2003) studied the extent to which scores on a notebook keeping assignment could predict persistence in engineering. This assignment was part of a first year mandatory prerequisite course for students who aspired to enrol in their university's school of engineering. As notebooks cannot be created at the last moment, good grades on this assignment represent student engagement, attitude, initiative, time management skills, study habits, and willingness to persevere. It also represents the willingness of the student to invest time in learning. These attributes associated with obtaining a good notebook grade do not focus on mathematic or scientific principles (i.e., intellectual attributes), but rather on a student's consistent attention to course material. Data indicate that once students were admitted to the engineering programme (i.e., admittance criteria are met, GPA and SAT scores), the score obtained on the notebook kept during the course is a good predictor of academic success, as measured by GPA, for freshmen engineering students.

Other researchers looked at attributes of curriculum organization. Olds and Miller (2004) found that 'average' engineering students who were selected to take part in an integrated curriculum with a fostering learning community did significantly better than their peers and reflected that the experience had had a strong and positive effect on their college careers. Tynjälä, Salminen, Sutela, Nuutinen and Pitkänen (2005) looked at the relationships between characteristics of the learning environment and students' study orientations and study success in a university of technology in Finland. The researchers used GPA, credits per semester and students' qualitative evaluation of their learning outcomes as indicators. The findings indicate that students' perceptions of the learning environment were related to their study orientations, which in turn were related to study success. A deep study strategy was the most important predictor of success. A surface strategy, low academic confidence and a lack of self-regulation were factors negatively related to study success. Meaning-oriented and self-regulated students using a deep strategy showed the most success, opposed to students who were externally regulated using a surface approach. Vogt (2008) looked at the role faculty play in student success. She found that faculty distance lowered self-efficacy, academic confidence and GPA. Conversely, academic confidence had a positive effect on self-efficacy, which in turn had strong positive effects on effort and critical thinking. Consequently, educational reform efforts must encourage faculty to understand the significance of their student/professor relationship and seriously undertake measures to be personally available to students.

Seminal in the field of engineering education is ethnographic work by Seymour and Hewitt (1997). They focused on analysing patterns of persistence in sciences, math and engineering in seven four-year institutions of different type and location in the USA. Between 1990 and 1994 the researchers interviewed over 800 students who had switched away from engineering and can be considered to be dropouts. Seymour and Hewitt report that they did not find switchers and non-switchers to be two different kinds of people. They do not differ by individual attributes of performance, attitude, or behaviour, to any degree sufficient to explain why one group leaves and the other group stays. The

authors also found the most common reasons for switching arose from a set of problems, which, to varying degrees, were shared, by switchers and non-switchers alike. What distinguishes the survivors from those who leave is the development of particular attitudes or coping strategies, both legitimate and collegiate. Serendipity also played a part in persistence, often in the form of intervention by faculty at a critical point in the student's academic or personal life. Switching decisions were never the result of a single overwhelming concern, they were always the upshot of a push and pull process over time. This process typically involved reactions to problems with science, math and engineering (SME) majors, concerns about SME careers and the perceived merits of academic or career alternatives.

Seymour and Hewitt (1997) found that the concerns mentioned most often by switchers are:

- lack or loss of interest in science
- belief that a non-SME major holds more interest, or offers a better education
- poor teaching by SME faculty
- feeling overwhelmed by the pace and load of curriculum demands

Seven issues were cited by Seymour and Hewitt (1997) as shared concerns by more than one-third of both switchers and non-switchers. They include the list above, plus (by rank):

- choosing an SME major for reasons that prove inappropriate
- inadequate departmental or institutional provisions for advising or counselling about academic, career, or personal concerns
- inadequate high school preparation, in terms of disciplinary content or depth, conceptual grasp or study skills.

Only four of the issues which contributed to switching decisions were not substantially shared with non-switchers (Seymour and Hewitt, 1997). Three of these reflect underlying concerns about career prospects: that the perceived job options, or material rewards, of SME careers are not worth the effort required to complete an SME degree; perceptions of low job satisfaction and/or unappealing lifestyles in SME careers, and that careers in non-SME fields have greater appeal. The fourth issue in this group reflects students' experiences of low grades and of curve-grading in their ability to do math and science. Criticism of SME faculty pedagogy contributed to one-third (36%) of all switching decisions, and were the third most commonly-mentioned factor in such decisions. However, complaints about poor teaching were almost universal among switchers (90%), and were the most commonly-cited type of complaint among non-switchers (74%). the significance of this factor does not end here. In one way or another, concerns about SME faculty teaching, advising, assessment practices and curriculum design, pervade all but seven of the 23 issues Seymour and Hewitt found in their study.

Most switchers were found to have worked hard in SME classes and to have invested considerable time, money, and personal commitment in their effort to persist. GPA's are not found to have a significant effect on persisting. Engineering switchers are also found to have entered with higher verbal SAT scores. Women entering SME majors are found in national samples to have a higher proportionate rates of switching than man, in this analysis, both the women and who persisted and those who switched had higher average high school GPA scores than male persisters and

male switchers respectively. Seymour and Hewitt report the length of time switchers pursued their original intention before finally deciding to leave. The average time period spent in the major before leaving it is, for engineering switchers, 2.6 years and for science and math switchers 2.1 years. The authors found many switchers whose level of ability and application should have been sufficient, given a more encouraging leaning environment, for then to complete their major. They also encounter a smaller number of multi-talented switchers, the loss of whose high abilities from science based fields may be of particular concern. Both switchers and non-switchers see their SME majors as prone to lose students who have both sufficient ability and the interest to complete the degree. Student explanations for this wastage stress the counterproductive consequences of a faculty's pre-occupation with weeding out, rather than supporting and encouraging students. Weed out classes also have the unintended effect of driving away some highly talented students because they lack sufficient intellectual stimulation to sustain their interest in the discipline. Seymour and Hewitt found with respect to institutional types is that there is very little difference between them in the nature and level of problems reported by current and former SME majors.

Seymour and Hewitt (1997) find support for the importance of many variables there were found to have effects in the research discussed above. They add to the complexity by observing that good students seem to leave engineering, so ability alone is not enough to stay in engineering. Switchers and non-switchers share concerns, but for some students this leads to a decision to switch. Students need to develop effective strategies to deal with these concerns and competitive culture in engineering programmes. Student dispositions play an important role. Seymour and Hewitt also conclude that there are institutional and programmatic concerns that affect all students.

Only two studies on engineering education in the Netherlands were found. One study dates from 1958 and it concerns a comprehensive study of student success in DUT. The board of the university believed the issues of drop out and delay were becoming urgent and they invited a panel of professors in psychometrics and education science to study the Delft situation. The panel looked at student cohorts 1949 and 1953 to estimate how large the problem really was and to build a regression model that would explain student success. The panel found students who would be delayed at some point, were unable to make up for these delays over the course of their programmes. The panel observed that the real problem of DUT were not the students who dropout as the result of a wrong choice of programme. These students usually became aware of their predicament and decided to leave within two years of enrolment. These student would move on to other degree programmes or a position in society. The real problem were the students who would postpone the decision to leave and who would remain registered at the university but have major delays in their graduation schedule. The panel states that these students are usually delayed as a result of insufficient ability to understand their courses and pass the required examinations. In 2000 Van der Hulst and Jansen were asked to study drop out and delays in DUT once again. They looked at attributes of curriculum organization because study progress does not only depend on student characteristics. Van der Hulst and Jansen (2002) looked at three engineering education programmes in Delft and included 4 cohorts in their study. They found evidence that variation in study

progress could partly be attributed to the spread of study activities over the year, instruction characteristics and examination characteristics were found to have effects on progress. This implies that institutes in higher education may improve their students' progress to some extent by means of efficient curriculum organization.

6 REFLECTIONS AND CONCLUSIONS

In this section the research questions are reflected upon. The research questions that are leading for this work, are:

- Which factors found in the literature determine students' academic success in university?
- How are these factors related?
- Which of these factors apply to engineering education?

Regarding factors that determine students' academic success, we established that there are several theories available that aid us in understanding student success. None of these theories provides us with a definite understanding of the problem: none of the models fully explain why some students drop out and others do not. There are quite a few variables that seem to matter. The single most consistent and stable predictor is students' ability. Apart from this variable, we can distinguish some categories of variables: external attributes, student background variables, student disposition variables, student behaviour, education attributes and external attributes. External attributes include grant schemes, care duties, personal situations, the weather, etc. Student background variables are set attributes like age, gender, SES, prior education, impairments, etc. Student disposition variables relate to motivation, success intention, fear of failure and commitment. Student behaviour refers to the amount of time spent on studying and to how this time is spent. Students need to spend a certain amount of time on their studies to be successful. The amount of time necessary varies per student: it depends on ability, disposition and strategy. Too little time will get the student into trouble, but more time may not necessarily be better. The quality of behaviour includes study strategies like goal setting, the ability to concentrate and to seek help if needed.

Education attributes include the number of lecture hours, exams, rules and regulations, facilities available for students and the way education is organized. Van de Hulst and Jansen (2002) showed that some attributes of organization affect success directly, the fewer courses are scheduled in parallel the more time students can spend on their courses. There is always a certain amount of interaction between the students and the education environment. In primary and secondary education this notion of interaction and its importance is recognized in the term 'education climate'. With education climate researchers refer to quality of the interaction between students, teachers and the context. In case of a mismatch, less learning is likely to take place. What is a good environment for one student may not be good for a student who brings other characteristics or even mood to the classroom. What is a good climate very much depends on personal perception.

That brings us to the second research question: How are these factors related? The relation between educational climate and student dispositions is reciprocal: students' dispositions change as a result of their experience with the climate. They may become more determined to finish their degree, or they may lose interest. These interaction or climate related variables are intermediary to all the other variables. Attributes of students and education are

input for the interaction variables and in students' disposition variables, but also in time on task and study strategy variables.

The educational climate is set within a context and interactions reflect the values underlying the context. If there is agreement between the values of the students and the values at work in the educational institution, it is likely that the students will be successful. If not, students will have to find ways to cope or they need to leave. This is in accordance with the findings of Seymour and Hewitt (1997): they found that persisters find ways to deal with the system.

The third question is which of these factors apply to engineering education? Researchers who have looked into engineering education student success have included many variables in their work and they came up with a range of variables that is very similar to the range found in general universities. We therefore conclude that the variables at work in general universities also apply to engineering education, although conditions in engineering education are somewhat different from those in the liberal arts and social and natural sciences.

What does all this mean for Delft University of Technology? DUT is interested in increasing student retention and decreasing time to graduation. From the literature review it is clear that there are many clues and possible solutions, but very few of these have been put to the test in the context of engineering education so far. Only the effects of UPE grades and of curriculum organization have been verified. Another remark here is that DUT would benefit from gaining in depth understanding of its own context: understanding students' dispositions and how these change over time and understanding the processes and values that shape the educational climate. One way of doing this is to build and validate a context based DUT model of student success. One thing is certain: DUT does not need to start from scratch, but like any kind of engineering: building such a model may require some adjusting!

Acknowledgement

The author wishes to thank the Office of Education and Student Affairs of DUT for supporting this research.

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