Fighting increasing dropout rates in the STEM field: The European readySTEMgo Project

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1. INTRODUCTION

Considerable progress has been recently made in increasing enrolment in Science, Technology, Engineering, and Mathematics (STEM) study programs. High dropout rates in STEM programs, however, tend to undermine the beneficial effects of all current attempts to increase student enrolment in these programs. The readySTEMgo project aims

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at reducing these dropout rates. Research has shown that social and academic experiences in the first year are of paramount importance in predicting dropout and as such we will primarily focus on this pivotal moment. More specifically, the main goals of the project are threefold. The first goal is to identify all key predictors of study success (i.e., key STEM skills) in the first year of university. Second, by means of existing instruments, a diagnostic test will be developed to identify students at risk of dropping out. Third, the project aims at constructing an effective intervention tool in order to support those students at risk. In this paper we will present the results of a literature overview that will serve as starting point for the selection of key STEM skills.

2. WHAT DOES QUANTITATIVE STUDY SUCCESS RESEARCH TELL US?

A key question in selecting studies is to determine whether study success in STEM fields is different from study success in non-STEM fields. The results of several studies suggest that different factors are at stake for STEM and non-STEM fields [1-4]. For example, Veenstra et al. [4] proposed an engineering-specific retention model with a strong focus on quantitative skills. As such, there is substantial evidence that an overview of what contributes to study success, persistence, and failure in the STEM field should narrow its focus on studies performed in the STEM field.

2.1 Success: Different outcome variables

Several definitions of study success have been proposed. Among the most common are: (1) grade point average (GPA), (2) number of credits obtained, (3) degree completion, and (4) dropout/leaving a STEM program (persistence). Throughout the remainder of this paper we will explicitly state which success indicator has been used in the respective study. In a first stage, we only selected empirical studies that explicitly used one of the above indicators as an outcome/dependent variable.

2.2 Previous achievement

In their meta-analysis, Richardson et al. [5] report a correlation ranging between .29 and .40 between achievement in secondary education and performance at university. In the STEM field, several studies have shown that prior achievement (i.e., high school rank, SAT's, ACT's or high school GPA) is the key predictor that accounts for the lion share of the variance of university GPA's and persistence in STEM majors [e.g., 2, 3, 6-11]. More specifically, students' prior math achievement and quantitative skills appear to be the most consistent predictor of STEM study success. For example, De Winter, and Dodou [2] observed strong positive effects of students' physics, chemistry and mathematics high school grades on students' first year GPA and degree completion. Interestingly, Moses et al. [12] found that the scores on a calculus readiness exam was a better predictor of retention in an engineering program than students' SAT scores and high school GPA's.

2.2.1 What about prior verbal achievement?

Is there any added value in the inclusion students' prior verbal achievement scores in predicting STEM success after controlling for prior math and science achievement? In the field of engineering, the role of verbal achievement scores in predicting study success is still under debate. De Winter and Dodou [2] observed no significant effect of prior language achievement over prior math and science achievement when predicting engineering students' first year GPA and degree completion [also see 12,13]. Zhang et al. [14; also see 15, 16] even observed a negative effect of verbal SAT's on graduating in engineering. By contrast, French et al. [17] observed positive effects of verbal SAT scores on cumulative GPA but not on persistence in engineering.

Taken together, these results present a complicated picture in that prior verbal achievement seems to have differential effects on different outcome measures. With respect to persistence and degree completion in engineering, prior verbal achievement does not have much predictive value, but the question remains on how these results could be translated to the whole STEM field. Interestingly, Kokkelenberg and Sinha [13] found that both for engineering students and non-engineering STEM students verbal SAT's were not predictive for obtaining a degree. Similarly, Ackerman et al. [6] showed that verbal SAT's had no effect on STEM persistence and degree completion.

2.2.2 Summary

A substantial body of research supports the key role of prior math achievement and quantitative skills in explaining success in STEM studies. Therefore, in discussing the role of other influencing factors, we will primarily focus on studies that controlled for prior achievement (quantitative skill in our case) in order to determine the incremental value of each factor.

One important footnote should be kept in mind. Based on the large-scale quantitative studies presented above, one could be tempted to solemnly focus on achievement. However, a closer look at the dropout literature interestingly shows that the lack of ability is seldom cited as the prime motive for leaving a particular field of study [15, 18-21]. It should be noted that most of the latter group of studies have been conducted in highly selective institutions and that ability could be a more important factor in countries/universities without rigorous selection criteria. Altogether, one could say that higher math, physics, and chemistry grades at the end of secondary school are a necessary but not a sufficient condition for persisting in a STEM field of study.

2.3 Motivational factors and self-perceptions

2.3.1 Self-efficacy beliefs and academic self-concept

One of the most consistent predictors of academic achievement is students' perceptions of their own academic abilities in different subjects. Confidence in one's academic abilities (i.e., academic self-concept) appears to be a significant predictor of students' performance at the end of the year [e.g., 3, 6, 7, 11, 22-27]. For example, Ackerman et al. [6] showed that a positive math and science self-concept was positively related to persistence in a STEM program and obtaining a degree [also see 28, 29]. By contrast, Perez and colleagues [24] observed that competence beliefs in chemistry were positively associated with students' GPA but unrelated to intentions to leave the chemistry major [also see 30]. From a gender perspective, there seems to be some evidence that the positive effects of an increased self-concept are more pronounced for male than for female students [e.g., 6,11].

2.3.2 Motivation and interests

After controlling for prior achievement, French, Immekus and Oakes [17] found that intrinsic motivation had a positive effect on persistence in engineering. However, the authors observed no relation between intrinsic motivation and cumulative GPA. Jones et al. [22] showed that extrinsic utility value and intrinsic interests (measured at the beginning of the year) respectively explained 39% and 3% of the variance in first year engineering students' likelihood to pursue a career in engineering. Thus, extrinsic utility (i.e., the usefulness of engineering for reaching goals) seems to be an important element in first year engineering students' considerations whether or not to further pursue a career in engineering. Perez et al. [24] observed a similar effect in the field of chemistry. Importantly, Eris et al. [28] showed that persisting and non-persisting engineering students significantly differed in their own perceptions of whether they will complete an engineering degree already at the onset of the first year. This finding is consistent with Georg's [19] claim that dropping out is primarily the result of weak commitment to their field of study and initial doubts about the study program chosen.

With respect to interest congruence (i.e., the degree of fit between a student's interest profile and the chosen major), Huy et al. [8] showed that, after controlling for prior achievement, increased levels of interest congruence were positively associated with persistence in a STEM-degree. However, interest congruence was unrelated to college dropout [also see 9]. It should be noted that, although easily comprehensible, the measurement/operationalization of interest congruence remains a tricky issue [8].

2.4 Self-regulatory learning strategies

In their meta-analysis of correlates of university students' academic performance, Richardson et al. [5] identified effort regulation (i.e., *persistence and effort when faced with challenging academic situations*) together with performance and academic self-efficacy beliefs, as the strongest correlate of tertiary GPA, alongside the traditional cognitive capacity measures and previous achievement. In the STEM field, Ackerman and colleagues [6] showed that, even after controlling for prior achievement, better organizational skills (e.g., effort regulation, metacognitive regulation, and time management) were positively related to persistence in a STEM program. In engineering, Bernold et al. [15] showed that different learning styles (based on Kolb's classification) resulted in different GPA's and persistence patterns. For example, LTM 2 (why learners – preference for critiquing information and assimilating abstract facts into theories) showed higher GPA's and higher percentages of persistence (ever after controlling for SAT scores).

2.5 Student approaches to learning

In the field of engineering, Tynjälä et al. [26] observed that meaning-orientated and self-regulated students had higher GPA and obtained more credits. However, a substantial drawback of their study is that they did not control for prior achievement. Similarly, Zeegers [31] found a negative relation between first year science students' GPA and a surface learning strategy whereas a deep learning strategy was associated with higher GPA's. Although not specifically oriented towards STEM studies, Torenbeek, Jansen, and Hofman [32] found that, after controlling for prior achievement, a less student-centered teaching style than at secondary school was negatively related to the number of credits obtained. Conversely, a more student-centered teaching style than at secondary school had a positive effect on their CSE. Analogously, Doolen and Long [33] point at potential mismatches between teaching and learning styles as major concerns in engineering retention.

2.6 Psychosocial contextual influences

Institutional integration (social and academic) has often been put forward as an important predictor of study success. French, Immekus, and Oakes [17] found that institutional integration was positively related to persistence in engineering. Also in the field of engineering, Vogt [27] showed that academic integration had no direct effect on students' GPA but was positively related to students' self-efficacy beliefs (which in turn positively predicted their GPA).

3. WHAT DOES QUALITATIVE DROPOUT RESEACH TELL US?

Most of the studies reported above are large-scale quantitative studies. Hereafter we will discuss the results of studies with a more qualitative approach since this increases our understanding of subjective motives underlying decisions to leave a STEM study program.

The landmark study of Seymour and Hewitt [21] offers valuable insights into students' decisions to switch away from a STEM program. Based on in-depth interviews with over 800 students (with a math SAT score of at least 650), the authors conclude that 'stayers' and 'switchers' could not be discriminated based on a clearly defined set of individual attributes of performance, attitudes or behavior and that both groups largely share the same concerns and problems. It is important to note that the decision to switch is not the result of single overwhelming problem but rather a combination of the interplay of several mutually influencing factors. The authors managed to identify some concerns commonly expressed by 'switchers' only:

(a) *perceived job options/material rewards are not worth the efforts required to complete a STEM degree* [also see 30, 34],

(b) *perceptions of low job satisfaction/unappealing life styles in STEM-careers and non-STEM-careers in a non-STEM field have greater appeal* [also see 20], and

(c) *experiences of low grades* [also see 20].

Additionally, critics of the STEM faculty pedagogy contributed to one third of the switching decisions [also see 20]. One of the most notable differences between 'switchers' and 'stayers' was that the intrinsic interest related to the chosen major was stronger among the 'stayers' [also see 18]. Additionally, Seymour and Hewitt [21] conclude that what really distinguishes between both groups is the development of certain coping strategies in dealing with commonly shared concerns and problems. The authors stress the importance of the acquisition of particular set of attitudes in order to (a) sustain their motivation (by finding sufficient academic/personal support), (b) maintain their interest in the discipline despite a weeding-out culture, and (c) insulate them from loss of self-confidence (e.g., not taking displays of indifference by faculty members as personal, development of criteria for academic progress that are independent of grades).

On a smaller scale, Baillie and Fitzgerald [35] surveyed 40 STEM dropout students. As the main contributing factors of non-completion, the authors identified three key elements: (1) *course content* (too theoretical, too hard, too much math, not interesting); (2) *teaching* (tutorials not useful, lack of support, classes too large and impersonal); and (3) *personal* (isolation, financial issues, lack of confidence). The authors found that dropout students often perceived their engineering classes as not challenging and uninteresting, especially when memorization was the primary required learning skill. Also, the workload was higher than most students expected [also see 33].

4. DISCUSSION: DROPOUT A COMPLEX PHENOMENON

4.1 Success and failure: How different are they really?

An important issue that needs to be resolved is the question whether success and failure (e.g., dropout) are just different sides of the same coins. In other words, are the factors that contribute to study success in STEM also indicative for dropping out of a STEM program (just with a reversed sign)? The answer to this question might further complicate the matter. Research by Lotkowski et al. [36; also see 37] state that performance (i.e., GPA) and retention (i.e., persistence) are different outcome processes with a differing set of predictive factors. In investigating college retention, the authors established that high school GPA and academic related skills (e.g., time management, study skills) have a better relation with persistence than with performance, whereas ACT test scores, academic self-concept and achievement motivation are more closely related to performance.

4.2 Pinpointing key skills: In search for the holy grail

Based on this literature overview, we are unable to identify the key ingredients that play a decisive role in students' decision to stay or to leave a STEM program. We managed to select a number of marginal conditions (e.g., strong quantitative skills in high school, a positive math self-concept, self-regulatory learning skills & motivation) but these should be considered as necessary but not sufficient conditions in explaining STEM success.

4.3 Dropout: An individual problem?

Some authors argue in favor of a shifts toward a more interactional approach of dropout where decisions to leave a STEM study are no longer considered an individual problem but as a relationship between a students and their study program [38]. According to these authors, the focus should be more on teaching and the learning experience, rather than on students' prior knowledge or preparedness. This line of research posits the development of a 'science identity' [also see 7] as a possible way out of the dropout morass and more specifically *"highlights the importance of being recognized as a legitimate member of the group of science students or 'science people'"* [38 pp. 232].

4.4 Focus of the ReadySTEMgo project

In the readySTEMgo project we will not attempt to formulate suggestions to change the curriculum, nor will we corroborate a specific structural model as proposed by, for example, Tinto [39]. Empirical tests of these models too often show high degrees of a rigorous 'model predisposition' wherein causal inferences are drawn based on shaky assumptions (e.g., variables measured at a single time point are put in a sequential straightjacket and often violate the temporal precedence condition). In our opinion, there is more gain in focusing on a smaller set of key variables.

For this project, we will employ a dual focus based on the premises of mixed method research. First, in line with the more quantitative empirical line of research we will develop a questionnaire in order to predict students' GPA (linear regression) and non-completion (logistic regression) based on the empirical research findings stated above. Second, in a more qualitative part, we will try to uncover crucial mechanism underlying leaving decision on the basis of in-depth interviews with a sample of academically able first-year students who switched away from a STEM program.

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