Academic commitment and self-efficacy as predictors of academic achievement in additional materials science

F. Ruric Vogel[a]* and Salomé Human-Vogel[b]

[a]*ENGAGE, Faculty of Engineering, Built Environment, and Information Technology, University of Pretoria, South Africa;* [b]*Department of Educational Psychology, University of Pretoria, South Africa*

A great deal of research within science and engineering education revolves around academic success and retention of science and engineering students. It is well known that South Africa is experiencing, for various reasons, an acute shortage of engineers. Therefore, we think it is important to understand the factors that contribute to attrition rates in university students, and engineering students in particular. The theoretical framework for the present study draws on self-regulation theory, with particular reference to the role of self-efficacy and academic commitment. Participants comprised 127 engineering students in the second year of an augmented programme. They completed the *Academic Commitment Scale* and the *Materials Science Self-efficacy Scale*. Statistical analysis included correlation and regression analysis to test the hypothesis that self-efficacy and academic commitment would predict the semester mark. Our results indicated that materials science self-efficacy and meaningfulness are significant predictors of investment, and that investment predicts the final semester mark. We discuss the results in terms of debates about throughput and retention for engineering students and also implications for teaching and learning.

Keywords: Academic commitment ; augmented programmes ; engineering ; investment ; meaningfulness ; self-efficacy ; self-regulation

Introduction

The retention of students in higher education, particularly in Science, Technology, Engineering and Mathematics (STEM) fields, is the subject of a great deal of research worldwide. In the United States just over half (50%) of students who were enrolled for a bachelor's degree at four-year institutions completed their studies within six years at the institutions at which they started (National Center for Education Statistics, 2005). Retention figures for Europe and the United States reported by the Organisation for Economic Co-operation and Development (2004) remain steady at about 30%. Within the fields of science and engineering a study involving nearly 70 000 students using MIDFIELD data from nine institutions in the United States, retention of science and engineering students did not differ significantly from other majors (Ohland, Sheppard, Lichtenstein, Eris, Chachra, & Layton, 2008). They found that 57% of engineering students were still enrolled in engineering by the fourth semester. An earlier report highlighted the fact that only between 40%-60% of engineering students complete their engineering degree (National Academy of Engineering, 2005). In 2007, only 17.0% of Science, Engineering, and Technology students at South African higher education institutions completed their degrees (Scott, Yeld, & Hendry, 2007). Of these students, 32% of engineering students and 21% of students in the Life and Physical Sciences managed to complete their degree in the minimum allotted time. South Africa is experiencing, for various reasons, an acute shortage of engineers (Du Toit & Roodt, 2009). Understanding the factors that contribute to attrition rates in university students is not only relevant to STEM fields but to higher education in general.

*Corresponding author. Email: ruric.vogel@up.ac.za

Indeed most scholars agree that attrition and retention must be understood against the framework that emphasizes complex interactions among academic, non-academic and institutional factors (Human-Vogel & Mahlangu, 2009). Research on academic achievement and retention in higher education often refer to the work of Tinto (1975, 1998, 2006), which emphasizes academic and social integration, commitment and persistence, or Bean (1980, 1982), which emphasizes interaction between background variables and organizational factors. While students' ability is a consistent predictor of achievement, factors such as student background (e.g. age, gender, prior academic performance), student disposition (e.g. motivation, commitment), student behavior (e.g. time management, goal setting), educational factors (institutional rules and regulations, facilities, educational climate), and external factors are also important to consider (Van den Bogaard, 2012; Wilcoxson, Cotter, & Joy, 2011). Although very little research on the second year attrition and beyond has been done, factors related to staff, quality of teaching and university policies seem to play a more prominent role (Wilcoxson et al., 2011). In addition to institutional and academic factors, authors also acknowledge that psychological factors such as the ability to self-regulate one's learning (Bjork, Dunlosky, & Kornell, 2013), self-efficacy (Zajacova, Lynch, & Espenshade, 2005), persistence (Wright, Jenkins-Guarnieri, & Murdock, 2013) and more recently, academic commitment (Human-Vogel & Rabe, 2015) are relevant to academic performance. Self-regulation refers to the ability to engage independently and proactively in monitoring one's learning, to sustain motivation, and engage in behaviours that lead to goal attainment (Zimmerman, 2000). Related to self-regulation, is the notion of self-efficacy, which refers to a belief in one's capability to successfully execute a course of action necessary to reach a desired outcome (Bandura, 1977, 1986). In an academic context, self-efficacy may be viewed in a general sense (Gore, 2006), but is more frequently understood as domain-specific confidence (as suggested by Zajacova, Lynch, and Espenshade, 2005) in students' ability to master a specific subject such as Chemistry (Dalgety & Coll, 2006). Self-efficacy correlates positively with academic performance (e.g. Bong, 2001; Gore 2006; Chemers, Hu, & Garcia, 2001; Lane & Lane, 2001), academic persistence (Wright, Jenkins-Guarnieri & Murdock, 2013) and achievement for undergraduate students in science and engineering courses (Brown, Lent, & Larkin, 1989; Lent, Brown, & Larkin, 1984, 1986; Multon, Brown, & Lent, 1991). In addition, Khezri azar, Lavasani, Malahmadi, and Amani (2010) report a direct effect of self-efficacy on mathematics outcomes. Self-efficacy influences performance because it determines the resources (time and effort) people choose to allocate to tasks (Beck & Schmidt, 2015). We could find no research examining self-efficacy in the domain of Materials Science, although we would expect a similar pattern of results to those reported by Dalgety and Coll for Chemistry (2006).

Recently, some authors have suggested academic commitment as a construct relevant to understanding attrition and retention at higher education institutions (Human-Vogel & Rabe, 2015). Using an investment model of commitment, Human-Vogel and Rabe (2015) measured students' *satisfaction* with their studies, longterm persistence with their studies (*level of commitment)*, the size of the investments students make (*investment)*, competing alternatives (*quality of alternatives)*, and the perceived personal significance of their commitment to their studies (*meaningfulness).* Their results suggest that meaningful academic commitment can be predicted by students' satisfaction with their studies, time and effort investments, quality of alternatives to studying that they perceived, as well as a clear and differentiated sense of self. An important limitation of their research, is that they did not have academic achievement data to examine whether academic commitment can predict academic achievement. In the present study, we utilised their academic commitment scale to explore whether academic commitment will indeed predict academic achievement. We do so by viewing commitment as future-oriented self-regulation (Human-Vogel, 2008) where people set goals based on selfknowledge (i.e. identity), and then regulate their behaviour to set and achieve goals as constrained by their identity. To explain how identity-relevant commitment determines behavioural choices, Human-Vogel and Rabe (2015) draw on Lord, Dieffendorff and Schmidt's (2010) model of self-regulation as a hierarchical self-regulatory process happening on four increasingly higher levels of abstraction and cycle times. Human-Vogel and Rabe (2015) describe (i) identity-relevant commitment, (ii) goal commitment, (iii) task commitment, and (iv) physiological commitment. In the context of the present study, physiological commitment refers to assigning and committing available mental resources to direct attention and to sustain concentration, and it generally happens on a non-conscious level. Task-level commitment implies moment-to-moment decisions to complete a task such as solving a problem, or consulting a textbook, and includes behaviours that must be coordinated to achieve a goal. It implies investing available resources (such as time and effort) to complete tasks. Task commitment can be goal-driven by goals, or be unattached to goals. Goal commitment involve longer time cycles that include goal setting such as learning for an exam or, in the longterm, to complete the course in a specific time. Goal-driven task commitments increase the coherence of a students' learning behaviour because tasks that help to accomplish a learning goal, will be preferred over tasks that are irrelevant to goal attainment. Therefore, when students report that their studies have personal significance, they are more likely to report behaviours consistent with that perception, such as setting learning goals or managing their studies to achieve their learning goals. Identity-level commitments involve ideas about one's future self, such as becoming an engineer, wanting to become a professional, or perceiving oneself as a lifelong learner. Identity-level commitments determine the relative significance of certain goals in relation to others. In other words, if a student's sense of self includes becoming an engineer, that student will presumably be more likely to select goals that will help her achieve that identity, with the resultant constraint that resources will more likely be allocated to tasks that help the student achieve the goal of becoming an engineer (such as studying for a test), rather than competing goals (such as wanting to be a good friend and social with friends often - measured by quality of alternatives in the academic commitment scale).

The four levels of commitment also have relevance for the role of self-efficacy in academic performance. The mechanism primarily responsible for the association between self-efficacy and performance is resource allocation (Beck & Schmidt, 2015). So, students who perceive themselves as having high levels of self-efficacy in academe (identity-level, i.e. I *am a hardworking, responsible student who can achieve*) are more likely to allocate resources to academic goals (goal commitment, i.e. *I want to do well in a test, I want to complete my degree cum laude*), with the consequence that more time and effort will be invested in completing certain tasks (task level commitment, i.e. *I need to study every day, I need to prepare for class*). Conversely, evidence that one's labour bears the fruit of achievement, and helps one to achieve one's goals, reinforces one's sense of self-efficacy, so that identity-level commitments are maintained. Within this hierarchy, identity-level commitments reflect meaningful commitments that provide coherence and predictability to people's actions, and impose internal constraints on behaviour towards identity-relevant goals (Human-Vogel & Rabe, 2015). The internal constraints that identity-level commitments impose can possibly be viewed as moral behaviour, so that commitment is, essentially, also a moral construct. People can - and they do - make goal commitments that are not necessarily identity-relevant, but our argument is that while such goals do not reflect meaningful commitment, they can still provide the person with a sense of satisfaction and they still impose external constraints on the types of tasks chosen to accomplish the goal. However, goal commitments that are not identity relevant may be more vulnerable to attractive alternatives available at any given time. For example, when the student's goal is to study for a test (goal commitment), and this goal is not linked to an identity goal (e.g. *I'm a hard worker; it's important to me to do well)*, then other competing identity-relevant commitments (e.g. *I am a social person; my friends are important to me)* will introduce attractive alternative goals (e.g. going to the movies, or visiting a friend) that will compete for available resources and may override goal commitments that are not identity-relevant.

Using Human-Vogel and Rabe's (2015) measurement of academic commitment, we hypothesised that academic commitment would be positively associated with materials science self-efficacy, and we hypothesised that academic commitment and materials science self-efficacy would predict academic achievement in the additional materials science module (using the semester mark). Lastly, we wanted to test the theoretical argument that identity-level commitment, as measured by *Meaningful Commitment* and *Materials Science Self-efficacy* will predict goal- and task commitment, as measured by the *Investment* subscale of the Academic commitment scale.

Study context

Universities have responded to the poor retention rate in various ways, such as introducing bridging programmes, extended (augmented) curricula or adding a foundation year to the degree. In the present study, we report on a sample of engineering students who did not meet the formal selection criteria for admission to a four year B.Ing degree and who were consequently placed in an augmented curriculum programme. The augmented engineering curriculum comprise mainstream, developmental, and augmented modules, which run parallel to the main modules. The augmented modules typically consist of one lecture and three discussion classes a week (Grayson, 2010).

Materials science is a prerequisite for most first year undergraduate engineering students. The engineering students in the augmented programme complete the materials science and the additional materials science module in their fourth semester. The study was approved by the Faculties Ethics Review Board. Participation was voluntary and informed consent was given by the respondents for the completion of the questionnaire, and use of the final semester mark. Students in the augmented programme do not write a formal examination, so academic achievement can only be predicted by a composite semester mark that includes assignments, class tests, and two semester tests. After all the data had been collated, and to ensure anonymity, identifying details were deleted.

The respondents completed a questionnaire that included biographical variables, the Academic Commitment Scale (Human-Vogel & Rabe, 2015), and Materials Science Self-efficacy Scale adapted from the Chemistry Science Self-efficacy Scale (Dalgety & Coll, 2006). The questionnaire was administered during an Additional Materials Science lecture in the seventh week of the fourth semester. At the time, students had already written two class tests and one semester test, and they had received feedback on these tests. Participants were made aware of the voluntary nature of the study. Of the 182 students registered for the Additional Materials Science module, 127 completed the questionnaire. Academic achievement was equated to the final semester mark (as a percentage).

Methods

Measures

Academic Commitment Scale

The Academic Commitment Scale (Human-Vogel & Rabe, 2015) was adapted from the Investment Model Scale (Rusbult, Martz, & Agnew, 1998) to suit the academic context. The scale measures level of commitment, satisfaction level, quality of alternatives, and investment size, and meaningful (identity-relevant) commitment. Participants responded to 29 items on a 6-point Likert scale ranging from 1 (*strongly disagree*) to 6 (*strongly agree*). One item from the Meaningfulness scale reported in Human-Vogel and Rabe (2015) was omitted from the analysis (*My studies fulfill me)* because it was a repetition of a similar item on the Satisfaction scale (*My studies are fulfilling to me).* An example of an item for Satisfaction is *My studies give me a great deal of satisfaction*. The Alpha coefficient for the full scale in the present study was 0.89, while the alphas for the subscales for the present study were 0.81 (*Level of Commitment*), 0.91 (*Satisfaction*), 0.80 (*Quality of Alternatives*), 0.91 (*Investment*) and 0.87 (*Meaningfulness*) which compared well with the values reported by Human-Vogel and Rabe (2015). Interestingly, the alpha for the *Quality of Alternatives* subscale for the present study was higher than that reported previously by Human-Vogel and Rabe (0.68).

Materials Science Self-efficacy Scale

Materials Science Self-efficacy Scale (MSES) was adapted from the Chemistry Self-efficacy Scale (CSES) (Dalgety & Coll, 2006), which was part of the Chemistry Attitudes and Experiences Questionnaire (Dalgety, Coll, & Jones, 2003). The purpose of the MSES was to measure the respondents' sense of self-efficacy with respect to additional materials science. The Materials Science Self-efficacy scale has one scale made up of 22 items giving a measure of a respondent's perceived self-efficacy regarding additional materials science. The Chemistry Self-efficacy Scale on the other hand consists of 17 items. Adaptation of the Chemistry Self-efficacy Scale to a materials science context involved changing the term *chemistry* to *materials science* for nine items, removing two items as they were not applicable *(Achieving a passing grade in a chemical hazards course; Achieving a passing grade in a Part Two chemistry course)*, and adding seven new items. The items that were added are presented in Table 1.

Table 1: Items added for the adaptation of the Materials Science Self-efficacy Scale.

Items added to the Materials Science Self-efficacy Scale
Achieving a pass in the assignments
Obtaining a pass mark in the class tests
Knowing how to manipulate a chosen formula to obtain the appropriate answer
Writing a summary of the main points of a chapter found in the prescribed textbook on materials science
Obtaining a pass mark in the semester tests
Preparing the relevant materials science topic before a lecture
Completing the given assignment before its due date.

Participants responded to each item on a 7-point Likert scale ranging from 1 (not confident) to 7 (totally confident). An example item from the Materials Science Self efficacy scale requires participants to indicate how confident they feel to choose *an appropriate formula to solve a materials science problem.* The Cronbach alpha coefficient for the full scale in the present study was 0.90. In the case of the Chemistry Self-efficacy Scale values obtained were 0.79 and 0.94 (Dalgety & Coll, 2006).

Participants

The participants were all undergraduate students in their second year of study. Complete data were gathered for 127 participants, comprising 21 females (16.5%) and 106 males (83.5 %), after completion of the Material Science module. Students who completed the questionnaire but who had deregistered were omitted from the sample. The mean age for the group was 20.1 years (*SD* = 0.089). About half of the respondents were black (N = 63) and half were White (N = 53), with the remainder comprising Coloured, (N = 1), Indian (N = 9) and Asian (N = 9). Of the total sample, 33 were Afrikaans speaking and 35 were English speaking. Four participants did not indicate their home language and the remainder (N = 54) indicated one of the other nine official languages of South Africa.

Results

As a first step, we examined whether the study variables (*Academic Commitment* and *Materials Science Self-efficacy)* would vary as a result of gender. An independent samples *t-test* indicated no significant differences between males and females. We then obtained descriptive statistics of the Academic Commitment Scale and the Materials Science Self-efficacy Scale which are given in Table 2.

Table 2: Descriptive statistics of the Academic Commitment Scale, Materials Science Self-efficacy Scale, and Semester mark.

	N	Minimum	Maximum	Mean	SD	Skewness	
						Statistic	Std. Error
Material Science Self-efficacy (MSSE)	120	2.73	6.41	4.77	0.65	-0.03	0.22
Satisfaction (CS)	125	2.63	6.00	4.79	0.76	-0.72	0.22
Level (CL)	127	3.00	6.00	5.68	0.50	-2.83	0.22
Quality of Alternatives (QA)	127	1.00	6.00	2.86	1.29	0.34	0.22
Investment (CI)	127	2.00	6.00	4.68	0.91	-0.74	0.22
Meaningfulness (CM)	126	2.00	6.00	4.40	0.83	-0.59	0.22
Semester mark (%)	127	17.9	84.3	55.84	9.66	-0.12	0.22

The *Level of Commitment* subscale was, as also reported in Human-Vogel and Rabe (2015) severely negatively skewed. Following similar analytical procedures as reported by Human-Vogel and Rabe (2015) we then conducted a factor analysis of the Materials Science Self-efficacy Scale full scale using a maximum-likelihood estimation model with promax rotation. Because the Chemistry Self-efficacy Scale is reported to be unidimensional (Dalgety & Coll, 2006), we assumed that a one-factor solution would also fit the data reported in our study. Results of the factor analysis confirmed the one-factor solution with one factor explaining 32% of the variance (KMO - 0.83; and Bartlett's Test for Sphericity was significant (χ^2 = 1025.30, p = 0.00) (Bartlett in Pallant, 2010). Parallel analysis confirmed that only the first eigenvalue was greater than the criterion value of 1.84. In addition, model fit indices indicated that the one-factor solution explains the data adequately (χ^2= 422.69, df = 209, p = .000; *RMSEA* = 0.089).

Next, we conducted a correlational analysis of the Academic Commitment Scale with the Materials Science Self-efficacy Scale (MSSS) to examine the relationship between academic commitment and self-efficacy. The results are presented in Table 3.

Table 3: Correlations for Academic Commitment Scale and Materials Science Self-efficacy Scale (N= 117).

	MSSE	CS	CL	QA	CI	CM
MSSE	1	.288**	.250**	-.074	.363**	.356**
CI (95%)						
- Lower		.113	.087	-.227	.226	.190
- Upper		.441	.402	.087	.495	.497
Satisfaction (CS)		1	.671**	-.467**	.562**	.620**
CI (95%)						
- Lower			.551	-.597	.394	.453
- Upper			.774	-.320	.708	.739
Level (CL)			1	-.359**	.316**	.497**
CI (95%)						
- Lower				-.486	.178	.341
- Upper				-.215	.471	.628
Quality of Alternatives				1	-.191*	-.388**
CI (95%)						
- Lower					-.351	-.561
- Upper					-.028	-.197
Investment (CI)					1	.613**
CI (95%)						
- Lower						.481
- Upper						.725
Meaningfulness (CM)						1
CI (95%)						
- Lower						
- Upper						

* - $p < 0.05$; ** - $p < 0.01$

We obtained moderate, but significant correlations for Materials Science Self-efficacy and Academic Commitment variables, except for *Quality of Alternatives*. Intracorrelations for the *Academic Commitment Scale* were in the expected directions as reported previously (Human-Vogel & Rabe, 2015), providing additional support for the construct validity of the scale. The *Academic Commitment Scale* and the *Materials Science Self-efficacy Scale* correlated with academic achievement - expressed as a percentage - with two significant correlations reported with *Investment* (r = .276, p < .002) and *Materials Science Self-efficacy* (r = .296, p < .001).

Regression analysis

Regression analysis is typically used when researchers are interested in understanding how much variance in a dependent variable (academic achievement in the case of the present study) can be accounted for by study variables (such as commitment and self-efficacy) (Freund, Wilson, Sa, 2006). The first hypothesis that we tested was that materials science self-efficacy and academic commitment will predict academic achievement. We conducted a multiple hierarchical regression with the final semester mark as the dependent variable. We entered materials science self-efficacy as an independent variable (block 1) and the academic commitment subscales as independent variables (block 2). Level of Commitment was omitted from the analysis because of the severe skewness of the scale. Multicollinearity was not problematic in the model, with the VIF values ranging between 1.33 and 2.08. Tolerance values ranged between 0.48 and 0.84. In addition, there were no outliers that affected the regression analysis, and the scatterplot of the standardised residuals revealed no systematic patterns. The results are presented in Table 4.

Table 4: Materials Science Self-efficacy and Academic commitment as predictors of semester mark.

	β	*t*	*p*	R^2	*F*	*df*	*p*
Model 1				0.09	11.63	1	.001
MSSE	.30	3.41	.001				
Model 2				0.14	3.63	5	.004
MSSE	.25	2.59	.01				
Satisfaction	.02	.17	.87				
Quality of Alternatives	.10	.96	.34				
Investment	.25	2.05	.04				
Meaning	-0.09	-.69	.49				

Dependent variable: Semester mark

Next, based on the theoretical argument that identity-relevant commitment will determine goal- and task commitments, we tested the hypothesis that self-efficacy and meaningful commitment would predict investment. A multiple hierarchical regression model was specified with investment as the dependent variable and meaningfulness (block 1) and materials science self-efficacy (block 2) as independent variables. The results are presented in Table 5.

Table 5: Meaningfulness and Materials Science Self-efficacy as predictors of Investment

	β	*t*	*p*	R^2	*F*	*df*	*p*
Model 1				0.37	69.72	1	.000
Meaningfulness	.61	8.35	.000				
Model 2				0.40	38.15	1	.000
Meaningfulness	.55	7.17	.000				
MSSE	.16	2.12	.036				

Dependent variable: Investment

Meaningfulness emerged as a robust predictor of investment, and Materials Science Self-efficacy contributing significant additional predictive value as well.

Discussion

In the present study we sought to examine the relationship between Materials Science self-efficacy, academic commitment and academic achievement. Our study is situated in the on-going debates on student retention in higher education, particularly in STEM (Fischer, 2011; Scott, Yeld, & Hendry, 2007). We examined whether self-efficacy and academic commitment predicts academic achievement within a self-regulatory framework and described whether identity-relevant commitment as imposes constraints on, and influences goal- and task-related commitments. Our study contributes to the growing literature on academic commitment (Human-Vogel, 2013; Human-Vogel & Rabe, 2015) and we hope to contribute to the national access-success debate in South African universities (Lewin & Mawoyo, 2014), as well as retention debates in other parts of the world such as the USA, Europe and Australia (Ohland et al., 2008; Wilcoxon et al., 2011; Van den Bogaard, 2012). The complex interplay between institutional, academic and non-academic factors that contribute to student success (Human-Vogel & Mahlangu, 2009) make it unlikely for any single study or intervention to offer definitive suggestions for solving the problem of student access and success (Lewin & Mawoyo, 2014). Therefore, we want to highlight that while our results are necessarily limited to the role of individual factors as they unfold in the microcosm of the classroom, they are broadly relevant to understanding how self-efficacy and academic commitment impact on retention in general, not only in the field of materials science. Success in life is a human endeavour, and success at one's chosen occupation no less so. Our results have specific implications for the teaching and learning interactions that occur between lecturers and students in the classroom across different fields, and can perhaps also serve as an early warning system where students who continue to be at risk for failure beyond the first year can be identified for further academic support and development.

At the most basic level, the association we found between academic commitment, materials science self-efficacy and academic achievement indicate that academic success is partially a function of how students regulate their academic commitment, and how confident they feel about their ability to do well academically. We have argued that, for academic commitment to ultimately influence student investment and engagement, it must have personal significance, i.e. be experienced as identity-relevant. An earlier study of academic commitment among a small sample of postgraduate students in Psychology (Human-Vogel, 2008) indicated that students who were described as committed by others, were more likely to emphasise identity investment in their studies. Engineering students and Psychology students both study towards obtaining a professional qualification, and the value of self-reflection to develop a professional identity is well recognised in these fields (Eliot & Turns, 2011; Elman, Illfelder-Kaye & Robiner, 2005). If lecturers facilitate professional identity development through self-reflection in their students, they can help students to foster identity-level commitment. The notion that engineering studies is not just a goal to accomplish, but entails identity transforming implications of becoming a professional, implies that students have to make a commitment not only to complete their studies, but to invest in their future self of *becoming* a professional. Once the commitment involves investment of the self, then goals that support the students' sense of self should become more significant and desirable to achieve. Also, developing a sense of self-efficacy is therefore needed to maintain identity-level commitments.

With respect to materials science self-efficacy, our results support previous findings with respect to the role of self-efficacy in academic achievement in general (Van Dinther. Dochy, & Segers, 2011). In our study it was a robust predictor of the students' final semester mark, and it also added significant value to predicting investment, indicating that students′ whose self-descriptions included feelings of competence in a subject, are more likely to succeed academically, not only in materials science but most likely in other subjects as well. To explain the relationships between self-efficacy, academic commitment and academic achievement, our results suggest the following model (see Figure 1 below).

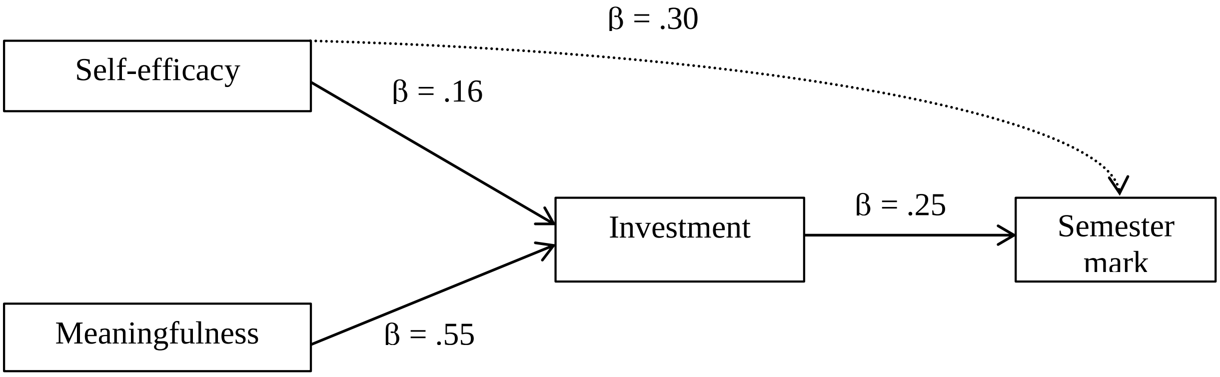

Figure 1: Regression model for Self-efficacy, Meaningfulness, Investment and Semester mark

Consistent with our theoretical reasoning and in line with previous research, our results indicate that self-efficacy predicts academic achievement in the additional materials science module directly, as well as indirectly through its influence on investment. Contrastingly, meaningfulness impacts the semester mark only indirectly through investment. The question arises as to whether self-efficacy alone is sufficient to explain academic commitment. According to Luszczynska, Gutiérrez-Doña, and Schwarzer, (2005) high self-efficacy leads people to set higher goals, perform more challenging tasks, generally invest more effort, and they remain committed to their goals. Our results support their line of reasoning. However, our results suggest that meaningfulness had a stronger effect than self-efficacy on the prediction of investment, which points to the fact that personal meaningfulness may be a useful, additional construct to consider when explaining academic commitment. The fact that self-efficacy showed direct as well as indirect effects on academic achievement, may possibly be explained by the distinction between general and specific self-efficacy. Although we only measured domain-specific self-efficacy for Materials Science, it is highly likely that there would be some overlap between general and specific self-efficacy. As Luszcynska et al.,

(2005) point out, general self-efficacy involves a "broad and stable sense of personal competence" where as specific self-efficacy is "competence based, prospective and action-related". Thus, whereas self-efficacy makes a difference to how people "feel, think, and act", personal meaning makes a difference to the kinds of goals people choose and direct their actions to (see Human-Vogel, 2008). In terms of our argument on the relevance of reflection to the personal development of students, it might make sense to encourage students to reflect not only on their developing confidence and competencies, but also to what extent their career choices and long-term goals are personally meaningful to them.

In terms of academic commitment, our results support the argument that self-efficacy and meaningfulness are identity-level constructs that influence achievement outcomes through investment, which operates on the task level. Broadly, our results provide evidence for a self-regulatory model of academic commitment, in which goals that are identity relevant influence achievement because goals are perceived to personally meaningful. For the majority of students additional Materials Science is a prerequisite for the completion of their degree, and many do not perceive its relevance (i.e. personal meaning) to their career choice. Students also experience Materials Science as a difficult subject (i.e. low self-efficacy) that requires a high investment in terms of time and effort. Therefore, students who generally experience lower levels of self-efficacy and less personal meaning, will probably invest less of their time and effort in their studies, which affect their overall academic commitment and, ultimately, achievement.

A notable limitation of the present study, and consequently the interpretation of our results, is that we did not measure general self-efficacy and its relative effect on different levels of self-regulation in academic commitment. Various authors (Gore, 2006; Luszcynska et al., 2005) suggest that it would be important to make such a distinction. Also, we have not operationalised the construct of identity, and there is sufficient evidence to indicate that it is not at all a simple construct. Human-Vogel and Rabe (2015) demonstrated that the level of self-differentiation of one's identity matters in academic commitment, so it would be useful in future research to investigate whether for example, identity style (Berzonsky & Kuk, 2005) might be relevant to the construct of academic commitment. Berzonsky and Kuk (2005) did find a modest but reliable positive association between the informational identity style and academic achievement.

With the present study we wanted to contribute to student access-success debates at institutions of higher learning (Scott, Yeld, & Hendry, 2007) and understand how self-efficacy and academic commitment might impact on academic achievement. Given the high rate of attrition in higher education (Fischer, 2011; Scott, Yeld, & Hendry, 2007), our results suggest that there is much that lecturers can do in the classroom to help students, via professional development and reflection, to develop a sense of self-efficacy in the general sense of the word, as well as in the specific subjects that they take. Their academic commitment can also be strengthened if they are encouraged to develop goal hierarchies that are personally meaningful to them, so that their career choices have personal relevance and they are able to find their studies more meaningful.

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