

Does Studying Latin in Secondary Education Predict Study Achievement in Academic Higher Education?

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Abstract

Studying Latin in secondary education is still widespread in Europe and believed to result in cognitive benefits, even beyond the linguistic domain. The present study set out to explore the relation between studying Latin in secondary education and later academic achievement in higher education ($N = 1,898$). First, we demonstrated that Latin students exhibit increased levels of study achievement in higher education, and particularly in non-STEM study programs. Second, we explored where the instruction of Latin was a significant predictor in models of academic achievement, explaining incremental variance over 21 other cognitive, attitudinal, and demographic factors. Latin instruction was included as a factor in the prediction models in 42% of the (mainly non-STEM) programs, but the incremental predictive validity was only substantial in the linguistic programs. This study highlights how the variable 'instruction of Latin' can be a valuable predictor of academic achievement, in other (un)related study fields.

Keywords: Latin, classical languages, academic achievement, higher education

While Latin has not been commonly used as a means for spoken or written communication for several centuries now, the language is still present to a considerable extent in the European educational field. Data from the European Commission (2023) show that in two-thirds of all European countries, central education authorities regulate classical language provision for upper secondary level. Moreover, the study of Latin is even compulsory for some secondary students in one-third of the European countries, such as Romania, Croatia and Montenegro (European Commission / EACEA / Eurydice, 2023). In Flanders specifically, Latin continues to persist as quite a prominent option in the curriculum of secondary education, as students have the option to choose Latin from their first year of secondary education onwards (Flemish Department of Education, n.d.). One might wonder why this classical language is still offered to such a sizable extent, while it does not offer an immediate practical use (Bracke & Bradshaw, 2020).

One of the main arguments in favor of offering Latin as a subject in schools, is that studying Latin is often perceived as a challenging cognitive endeavor. Consequently, students of Latin are rated more positively on their social status, while also receiving a higher appraisal of their general and cultural education, in comparison to those who partook in the education of modern foreign languages (Gerhards et al., 2019). Indeed, Latin is considered to be a high-level study program that targets cognitively strong students (Bennett, 2021).

Despite the considerable presence of this language in education and its reputation for being academically challenging, the position of Latin in the present-day educational field has been questioned on numerous occasions (Bennett, 2021; Katz et al., 2020). Bracke and Bradshaw (2020) expounded on this contrast in the literature concerning Latin as part of modern-day education as follows:

On the one hand, it is praised as an aspirational subject that opens doors to modern foreign languages and European history. On the other, it is attacked for being a tool of social exclusion and a difficult dead language without practical application. (p. 1)

This criticism could explain why a diminishing trend has been observed in the number of enrolments and the amount of schools offering Latin (Bracke, 2015; Katz et al., 2020). Can this decline be justified, given the fact that the assumptions about the benefits of studying Latin are still generally accepted by parents of secondary school students (Gerhards et al., 2019; Livingstone, 2013)?

Research has shown that studying Latin is believed to promote the development of learning and reasoning strategies, and to cause achievement gains in more formal (also non-linguistic) domains, such as mathematics (Devane, 1997; Sussman, 1978). However, the existing literature on these cognitive benefits is mostly outdated and definitely not as extended as the widespread practices and beliefs in classical languages education. Furthermore, very little research has investigated whether the supposed benefits of studying Latin extend beyond secondary education to higher education. Previous research is difficult to generalize to the current educational field, as several reforms have been made to the structure of higher (and secondary) education (e.g., the Bologna Process, a reform aimed at harmonizing European higher education systems) (European commission: Directorate-General for Education, Youth, Sport, and Culture, 2018). Reforms like this could have affected the relation between studying Latin and academic achievement, which is why we explore this association in the context of current higher education. As such, the present study addresses the following research question: ‘Does studying Latin in secondary education predict study achievement in academic higher education?’.

The Linguistic Advantages of Studying Latin

Several studies demonstrate a clear link between studying Latin and various linguistic benefits. For instance, the literature reports a robust relationship between the study of Latin and accelerated achievement levels in native language (L1) skills, such as comprehensive reading, vocabulary knowledge, syntactic competence, and spelling ability (Barber, 1985; Mavrogenes, 1977; Sussman, 1978; Vanheule, 2015; Wiley, 1984). Notably, advancement in vocabulary knowledge is not unique to words derived from Latin, as knowledge of words derived from other foreign languages (e.g., from Anglo-Saxon or Greek origin) was also improved (Bowker, 1975; Gilliland, 1922). These advantages in L1 skills remain present when Latin students were compared to pupils who studied a different foreign language (e.g., French, English or Spanish) (Carlisle & Liberman, 1989; Fromchuck, 1984; Haag & Stern, 2000; Masciantonio, 1977). In sum, the majority of the literature seems to be in agreement about the beneficial effect of studying Latin on native language proficiency, with only slight differences in the observed effect sizes (Bracke & Bradshaw, 2020). However, as the majority of these studies is rather old, so is their methodology. For example, most of the previously mentioned studies do not control for individual difference effects, for instance of pupil intelligence. Then, group differences may merely reflect confounding effects of existing pupil differences unrelated to classical language education, reflecting a preselection mechanism in classical languages tracks. Indeed, even though some studies controlled for differences in cognitive abilities (Haag & Stern, 2000; Sheridan, 1976; Vanheule, 2015; Wiley, 1984), most of them did not (Barber, 1985; Fromchuck, 1984) or only vaguely addressed the matter (Carlisle & Liberman, 1989; Gilliland, 1922; Sparks et al., 1995). For instance, Carlisle and Liberman (1989) report that the intervention group and the control group were matched, as they both performed ‘consistently above average in general intelligence’.

Research has also shown that Latin students outperform non-Latin students on foreign language aptitude (Sparks et al., 1995). Such findings support the statement that Latin appears to promote meta-linguistic awareness (Bowker, 1975; Jessner et al., 2018; Mavrogenes, 1977). However, more recent – but still dated – research by Haag and Stern (2003) has demonstrated that Latin students are actually at a disadvantage when learning a new foreign language (Spanish), in comparison to those who studied another language (French). The authors suggested that the apparent superficial similarities between Latin and Spanish may actually complicate modern language learning because of cognitive interference.

The Non-Linguistic Cognitive Implications of Studying Latin

Besides the more obvious advantages in the linguistic domain, non-linguistic cognitive benefits have also been reported, such as improvements in reasoning strategies, analytical thinking, and achievement in formal domains such as mathematics (Devane, 1997; Sussman, 1978). For instance, Sheridan (1976) demonstrated that after only five months of studying Latin, students had an advantage of approximately a half year's progress in related linguistic skills (e.g., reading) and in non-linguistic domains (e.g., math computation), compared to non-Latin students. Once again, these studies often do not report whether (or how) they controlled for differences in intelligence. While Sheridan (1976) states that the control group was matched based on academic profiles, the matching procedure is discussed in a rather vague manner. Besides that, a study by Haag and Stern (2003), who employed a well-thought-out matching procedure, has contested the claims that studying Latin elicits cognitive benefits. The researchers reported no beneficial effects of studying Latin on IQ, mathematics achievement and deductive and inductive reasoning.

The assumed cognitive implications of studying Latin are also reflected in the academic success of its students. Research has shown that the relation between the study of a

foreign language in high school and overall college academic success in the United States, measured by the cumulative college GPA (Grade Point Average), is strongest if the foreign language is Latin (Wiley, 1984). In Flanders specifically, studies report that pupils who study classical languages in secondary education show the greatest study efficiency and highest success rate in higher education (Duyck et al., 2017; Rombaut et al., 2006).

In sum, research suggests that studying Latin may create not only linguistic, but also non-linguistic cognitive benefits. However, there currently is a need for more up-to-date and methodologically rigorous research on the cognitive outcomes of studying Latin. The present study partially addresses this crux in the literature, by evaluating how studying Latin in secondary school is associated with study achievement in higher education.

Mechanisms Behind the Effects Associated with Studying Latin

The working mechanism behind the benefits associated with studying Latin remains a topic of discussion. Classicists typically justify the instruction of this ancient language by implicitly or explicitly referring to the theory of cognitive transfer (Haag & Stern, 2003; Sussman, 1978). This theory states that training some skills in one domain will affect skills in another domain, implying a generalization effect beyond the skills acquired in the original training domain (Harrison et al., 2013; Jaeggi et al., 2014). According to the cognitive transfer taxonomy proposed by Barnett and Ceci (2002), a distinction between various types of transfer can be made across different domains (e.g., physical, temporal, etc.). For Latin studies specifically, the assumed transfer effects primarily pertain to the knowledge domain. More specifically, near transfer involves generalization to skills closely related to the training task, such as the linguistic benefits associated with studying Latin. Assertions of Latin's potential to enhance general cognitive capabilities can be considered as far transfer, as this implies improvement in skills of a different nature (Vereeck et al., 2023). Whether cognitive functions are actually trainable, and to what extent, is however still heavily contested in the

field of cognitive psychology. Especially the possibility of far transfer is a subject of debate, with both believers (Buschkuehl & Jaeggi, 2010; Jaeggi et al., 2014) and sceptics (de Simoni & von Bastian, 2018; Gobet & Sala, 2023).

However, why would Latin evoke transfer effects to domains beyond just language, more than any other foreign language would? Latin is often assumed to be a rather difficult language for students to master. Indeed, Latin syntax and morphology are considered to be quite complex (Pelling & Morgan, 2010; Vantassel-Baska, 1987). Because of this complexity, the education of Latin is mainly centered around training the pupils' understanding of the grammar, which is often associated with additional development of students' logical reasoning skills (VVKSO, 2013). This type of instruction method is at odds with the education of modern foreign languages, where pure analytical training is rather sparse. Indeed, the study of modern foreign languages is more centered around communicative skills and language fluency, in order to ensure the practical use of the language afterwards (Brandl, 2007; Richards, 2006). This different instructional approach to Latin courses might promote deeper learning than modern foreign languages courses do. According to Chi and VanLehn (2012), fostering deeper learning facilitates more transfer than surface learning.

Opponents assume that it is not transfer, but preselectivity effects that are at the root of group performance differences and thus deny that the positive effects associated with studying Latin are causal and originate from the intrinsic value of the language. Put differently, according to the preselectivity theory, the performance benefits that Latin students show are due to the fact that they are cognitively stronger than other students prior to enrollment (Pond, 1938; Vereeck et al., 2023). Furthermore, the benefits found in higher education could be partially due to the overlap between the knowledge learned in Latin classes and what is taught in certain academic study programs. For example, in many medical

disciplines, various parts of the human body are still referred to by the Latin terms and names (Lysanets & Bieliaieva, 2018). If a student already understands Latin before starting in such programs, he or she already has a leg up compared to other students who never studied Latin. Another example of such overlap can be found in law, as Latin has a strong historical connection with the origin of European legal systems (Ristikivi, 2005). These considerations illustrate that it is important to assess any positive effects of studying Latin on academic achievement on the level of specific study programs.

The Present Study

Before unravelling the origins of why Latin students could perform better in educational settings, it should first be firmly established whether and to what extent Latin students are more successful in higher education. Hence, the present study does not aim to explore whether cognitive transfer offers a causal explanation for classical language education benefits, as only a more controlled and experimental longitudinal design would be appropriate for such a research goal. Instead, we address the lack of research on how Latin education in secondary school is associated with student performance at university. More specifically, we examine whether studying Latin in secondary school explains incremental variance in future academic achievement, above and beyond important predictors of academic achievement in higher education literature. We use a uniquely large sample of students, controlling for each of the cognitive, attitudinal, and demographic measures discussed in the following paragraph. Importantly, by controlling for such a wide range of measures, we can rule out confounding effects of the included individual differences. We address the following hypothesis:

The study of Latin in secondary education predicts study achievement in academic higher education incremental to other cognitive, attitudinal, and demographic predictors.

Predictors of Academic Achievement

In order to investigate the relation between studying Latin in secondary education and later academic achievement, it is important to consider the common predictors of academic achievement that have already been established in the literature, and that may be relevant for the preselectivity hypothesis. Historically, the predictors of academic achievement have been subdivided into three main categories: cognitive, attitudinal, and demographic factors (Richardson et al., 2012).

Cognitive Factors

The first category comprises the cognitive measures, which entail skills that refer to our ability to comprehend, process and work out complex ideas. These skills are used in literacy and numeracy, among others, and are typically grouped under the concept of cognitive ability (Pierre et al., 2014). Few would contest that cognitive ability is recognized as the strongest predictor of academic achievement: its role in predicting academic success has been long established (Farsides & Woodfield, 2003). For example, a study by Roth and colleagues (2015) investigated the relation between intelligence (one of the operationalizations of the concept ‘cognitive ability’) and scholastic achievement, measured as school grades. The authors reported a population correlation of $r = .54$, a result in line with various other studies concerning the relation between cognitive ability and GPA (Frey & Detterman, 2004).

Measures of study antecedents are also included in this category, as they are valuable predictors of study achievement in higher education (Frey & Detterman, 2004; Poole et al., 2012). Such measures (e.g., high school GPA) assess former cognitive functioning, and thus correlate greatly with cognitive ability or intelligence (Hodara & Lewis, 2017; Roth et al., 2015). The present study assesses the relation between Latin education and later academic

achievement in a very large sample, while controlling for an extensive range of cognitive measures.

Attitudinal Factors

The second category consists of attitudinal measures, which refer to socio-emotional skills that are developed and socially determined over the course of our life (Pierre et al., 2014). Various attitudinal factors explain incremental variance in academic achievement, on top of what is already explained by the cognitive predictors. Motivation for instance, has proven to be a valuable predictor of academic achievement (Spinath et al., 2014; Vansteenkiste et al., 2005). The Self Determination Theory proposes two types of motivation that drive students' behavior: a student either displays autonomous (driven by internal factors) or controlled (driven by external factors) motivation (Deci & Ryan, 2008). A myriad of studies demonstrate that motivation is able to predict study achievement, with positive effects specifically for autonomous motivation (e.g., Kriegbaum et al., 2018; Vansteenkiste et al., 2005).

Several aspects of personality have also been put forward as predictors of academic achievement. Various studies have shown a link with the personality trait conscientiousness, which can be defined as the tendency to be organized, achievement-focused, disciplined, and industrious (MacCann et al., 2009; Poropat, 2009; Schneider & Preckel, 2017). We include one facet of conscientiousness that is especially predictive of outcomes such as academic achievement and retention, namely grit, which is defined as the perseverance to work towards long-term goals and maintaining effort and interest, regardless of contingent obstacles (Duckworth et al., 2007, 2019).

Vocational interests have valuable predictive impact on study achievement too (Nye et al., 2012; Schelfhout et al., 2019). Holland's (1997) theory of vocational personalities and environments is typically used to depict vocational interests. This theory proposes a

hexagonal model with six interest dimensions: realistic, investigative, artistic, social, enterprising and conventional (abbreviated as RIASEC) (Nauta, 2010). A review by Rounds and Su (2014) has shown that interests can explain up to 5% of the variance in college grades.

Other attitudinal predictors of academic achievement are traits such as academic self-efficacy and metacognition (Richardson et al., 2012). Academic self-efficacy is defined as the confidence in one's ability to attain the desired academic goals (Bandura, 1993).

Metacognition can be described as the knowledge of one's own motivation and ability to use self-regulatory techniques during studying (Kitsantas et al., 2008). Both constructs are positively associated with academic performance and/or persistence (Richardson et al., 2012; Robbins et al., 2004; Spada & Moneta, 2014). A trait that is negatively correlated with academic achievement is test anxiety, which is described as feeling anxious in settings related to learning and evaluating (Credé & Kuncel, 2008). In the present study, we control for a wide range of attitudinal variables when assessing the relation between Latin education and academic achievement.

Demographic Factors

Finally, the last category is made up of demographic predictors (Richardson et al., 2012), that are not supposed to influence achievement, but often do in reality. In the present study, we include the two most common demographic predictors, namely gender and SES (socio-economic status). First, gender is a prominent demographic predictor of academic achievement, as literature has a longstanding history of demonstrating a pervasive female advantage on school performance, starting at the elementary level, and ending at the university level (Carvalho, 2016; Su et al., 2009; Voyer & Voyer, 2014). Second, SES is associated with academic achievement, as the meta-analyses by White (1982) and Sirin (2005) reported a medium to strong correlation between SES and academic achievement, depending on the way SES is defined (as income, education and/or occupation of the

household head). However, studies by Marks & O'Connell (2021a, 2021b) demonstrate that it is important to separate SES from other variables (e.g., mother's cognitive abilities) when making such claims. Nevertheless, as literature has also suggested that the education of Latin is more common for children from higher socioeconomic communities (Bennett, 2021; Sussman, 1978), controlling for SES is particularly important in the present study.

Furthermore, Bracke and Bradshaw (2020) noticed that possible confounds like social background were typically not considered in most studies on the benefits of studying Latin, even though social background is confounded with study choice in secondary education for instance (van de Werfhorst et al., 2003). Bracke and Bradshaw (2020) state that the research field would benefit from new studies that pay close attention to the role of gender, race, socioeconomic background, and teaching approach. The remarks about gender and SES are addressed in the present study, as we control for the impact of these two demographic covariates.

Method and Materials

The SIMON Project in an Open Access Study Environment

For the present study, we performed analyses on secondary data gathered within the longitudinal SIMON project of Ghent University (ARWU top 100 of the Shanghai ranking of worldwide universities). This study orientation project exists in an open access study system: every student with a high-school degree has the opportunity to start any program in higher education, except for performance arts, medicine, dentistry and veterinary medicine (Flemish Agency for Higher Education - Adult Education - Qualifications and Scholarships, 2023). However, data show that success rates in open access (Belgian) higher education are generally low (OECD, 2017). Consequently, the aim of the SIMON project is to help improve timely degree attainment by providing pupils with an internet-based self-assessment tool that generates non-binding study (re)orientation advice. As such, an extensive historical

dataset (with more than 70,000 entries as of 2021) was used to develop an algorithm that could generate study advice. The dataset includes both former students' exam scores and their scores on various tests measuring predictors of academic achievement, as discussed in the introduction. In order to deliver program-specific advice to new students, these test results are fed into the algorithm and compared to previous scores. If this comparison shows that the student has a very low likelihood of succeeding, he or she is advised to improve their basic skills or to reorient towards a more attainable or suitable study program. High response rates are acquired, as participation in the SIMON project is strongly encouraged among students at the start of their first academic year (Fonteyne, Duyck, et al., 2017). After the students finish their first year, their exam results are linked to their original data, which ensures a continued improvement of the prediction models.

Data

The dataset used in the present study includes test results from the SIMON project collected in 2018, and the subsequent exam results of first year students (mean age = 18, $SD = 0.42$) at Ghent University. Data from 1,898 students across 12 bachelor programs was considered (an overview is presented in Table 1). The gender distribution was different for each program, with the proportion of male students ranging from 17% to 89%. Importantly, both Latin and non-Latin students regularly engaged with foreign languages throughout primary and secondary school. From the age of 10, all Flemish students study French, followed by English from 12-13 years. Depending on their study program, pupils may also study a third foreign language, such as German or Spanish, later on in their curriculum (European Commission / EACEA / Eurydice, 2023). As such, it is reasonable to assume all students within the sample had (some) knowledge of at least 2 foreign languages (i.e., French and English).

Besides exploring each program specifically, we also considered 2 overarching program groups, namely STEM and non-STEM. The former is defined by UNESCO as a field that incorporates life and physical Sciences, Technology, Engineering, and Mathematics (UNESCO, 2016). Intuitively, one may not expect a relation between academic achievement and studying Latin in secondary school for the STEM study field. Such a relation would be more likely for the latter however, as the non-STEM programs encompass the arts and humanities. By distinguishing between STEM and non-STEM programs in our analyses, we were able to evaluate whether the predictive ability of Latin on academic achievement was equally large for these two groupings. The UNESCO definition of the STEM field was used to divide study programs into either STEM or non-STEM programs (UNESCO, 2016).

<Insert Table 1 here>

Ethics Statement

The Ethical Commission of the Faculty of Psychology and Pedagogical Sciences of Ghent University has granted approval to the SIMON project of which the present study is an integral part. The study was carried out in accordance with the recommendations of the Ethical Commission of Ghent University. All subjects gave their online informed consent in accordance with the Declaration of Helsinki.

Measures

An overview of the set of variables used to construct the predictive models is given in Table 2. We provide a full description of the included variables and their reliability. Extra information on the confidence intervals around the means of these measures is reported in Appendix S1, Table S1-1.

Dependent Variable

Our measure of academic achievement is GPA, which indicates the global result of the student in his or her first year on a scale from 0 to 1,000. The inclusion of this measure

allows us to compare our findings with the results from the international literature, where this is a common performance outcome measure (Schelfhout et al., 2019).

Cognitive Predictors

We included data from five tests to assess students' cognitive skills. The tests used are all valid predictors of academic achievement (Fonteyne, Duyck, et al., 2017; Fonteyne et al., 2015; Schelfhout et al., 2022). First, mathematic skills were estimated through a normal or advanced test. The administered test depends on the study program a student is in. Both tests included 25 questions, both multiple choice (MC) and open-ended. The normal test ($M = 16.91$, $SD = 2.97$, Chronbach's $\alpha = .72$) was administered in programs 1-5 and 10-11, and the advanced test ($M = 12.31$, $SD = 3.74$, Chronbach's $\alpha = .78$) in programs 6-8 and 12. No mathematics test was administered in program 9. An example of a question from the normal test is: "A book that is on a 40% discount costs €18. How much did it cost prior to the discount?". An example of an item from the advanced test is "Present the general equation of a circle with center $(-2,1)$ and radius 3". Second, the LexTALE test (Lemhöfer & Broersma, 2012) was used to test vocabulary ($M = 17.50$, $SD = 1.93$, Chronbach's $\alpha = .83$) in all programs. Here, students were presented with 60 items, and they had to indicate whether the stimulus was a word or not (i.e. lexical decision). Third, we tested comprehensive reading ($M = 15.02$, $SD = 4.45$, Chronbach's $\alpha = .78$). Students had to read an English text of medium length and were tested with 5 MC questions afterwards. This test was administered in all programs, except in programs 10 and 12. Fourth, a chemistry test ($M = 15.17$, $SD = 3.24$, Chronbach's $\alpha = .71$) was given to students in programs 8 and 11-13. This test included 25 items such as "What is the total number of valence electrons of a sulfur atom?". Finally, in programs 10-12 a physics test ($M = 11.52$, $SD = 3.54$, Chronbach's $\alpha = .68$) was given. An example of one of the 25 items is "What is Newton's first law?".

Four variables were used to depict study antecedents. First, we included self-reported high school GPA ($M = 72.41$, $SD = 6.60$). Second, we included the high school mathematics package ($M = 5.39$, $SD = 1.78$), high school Latin package ($M = 1.07$, $SD = 1.80$) and high school Dutch package ($M = 4.01$, $SD = 0.89$). These last three variables comprised the number of hours that particular subject was instructed in the students' final year of secondary education.

Attitudinal Predictors

The Cognitive Test Anxiety Scale (Cassady & Johnson, 2002) was used to assess test anxiety ($M = 9.93$, $SD = 2.46$, Chronbach's $\alpha = .92$). Students indicated on a Likert-scale from 1 to 4 how characteristic they found 25 items such as "I do not perform well on exams".

Motivation was assessed through the Self-Regulation Questionnaire (Vansteenkiste et al., 2009). Respondents had to indicate how characteristic different statements were for them. Controlled motivation ($M = 8.24$, $SD = 3.19$, Chronbach's $\alpha = .88$) was measured using 8 items (e.g., "I study because I'm supposed to do this"). Autonomous motivation ($M = 14.95$, $SD = 2.52$, Chronbach's $\alpha = .86$) was also measured with 8 items (e.g., "I study because it interests me").

To assess grit ($M = 13.55$, $SD = 1.85$, Chronbach's $\alpha = .73$), the Grit Scale (Duckworth et al., 2007) was administered. This scale contains 20 items (e.g., "I finish whatever I begin"), that respondents rated on a scale from 1 (*not at all like me*) to 5 (*very much like me*).

Academic self-efficacy was measured with an adaption of the College Academic Self-Efficacy Scale (Owen & Froman, 1988). 14 items were administered to assess comprehension ($M = 14.827$, $SD = 1.66$, Chronbach's $\alpha = .76$), and 8 to assess effort ($M = 15.24$, $SD = 2.02$, Chronbach's $\alpha = .73$). Students used a 5-point Likert scale to estimate how well they would cope with certain situations or tasks (e.g., "Tutor another student").

The Metacognitive Awareness Inventory (Schraw & Dennison, 1994) was used to assess two subscales of metacognition: Knowledge of cognition ($M = 13.77$, $SD = 2.15$, Chronbach's $\alpha = .87$) and Regulation of cognition ($M = 13.09$, $SD = 2.07$, Chronbach's $\alpha = .87$). In total, 52 items (e.g., "I know my intellectual strengths and weaknesses") were presented to the respondents. For each item, the students had to respond with a 6-point Likert scale (1 = *completely disagree* to 6 = *completely agree*).

The SIMON-I questionnaire (172 yes-or-no items) was used to assess the students' vocational interest profile (Fonteyne, Wille, et al., 2017; Schelfhout et al., 2019). Scores between 0 and 100 were given to each student on each of the RIASEC scales: the R ($M = 20.77$, $SD = 25.37$, Chronbach's $\alpha = .93$), I ($M = 34.91$, $SD = 20.75$, Chronbach's $\alpha = .87$), A ($M = 27.77$, $SD = 24.44$, Chronbach's $\alpha = .92$), S ($M = 33.83$, $SD = 25.64$, Chronbach's $\alpha = .92$), E ($M = 33.20$, $SD = 27.49$, Chronbach's $\alpha = .93$) and C ($M = 22.31$, $SD = 23.47$, Chronbach's $\alpha = .91$) dimension.

Demographic Predictors

Dichotomous measures were used to assess both gender and SES. The categorization into a low SES-group depended on whether the student met any of the following criteria: receiving a scholarship or having a mother who did not obtain a degree from secondary education. This procedure is based on the practices of the Flemish Department of Education (Het Vlaams Ministerie van Onderwijs en Vorming [Flemish department of education], 2012) to award study grants.

<Insert Table 2 here>

Procedures and Analyses

We used $\alpha < 0.050$ to interpret statistical significance. To test our hypothesis, we developed regression models using an AIC (Akaike's Information Criterion) procedure. This technique allows for minimizing the model's prediction errors (Burnham & Anderson, 2002),

which is ideal in the context of predicting individual study achievement. Furthermore, these models are able to explain the sample variance of study results in their respective study programs (Schelfhout et al., 2022). However, because the sample sizes of the linguistic programs were rather small ($n < 100$), we included a correction in order to prevent overfitting (Shmueli, 2010). Indeed, research by Hurvich and Tsai (1989) has shown that a high degree of negative bias is likely to characterize an AIC model in case of small sample sizes. We therefore used a more conservative variant (AICc) that applies a correction for every predictor that joins the model, based on the sample size (Cavanaugh, 1997). This AICc-methodology contrasts all possible predictor combinations and chooses the predictor set with the smallest likelihood of information loss as the final model. Afterwards, the prediction of this final model is compared to the results of each student individually. Ultimately, the selected model displays the smallest prediction error across all students. By verifying whether the variable ‘high school Latin package’ was included in the final predictor combination, and thus added incremental predictive value to the other possible cognitive, attitudinal, and demographic predictors, we were able to develop conclusions for our hypothesis. We not only computed program-specific regression models, but also regression models for two overarching groupings of study programs (STEM and non-STEM). The dataset considered for the non-STEM study programs contains information from programs 1-6. For the STEM study programs, data was included from programs 7-12.

The predictor list of the models for the overarching groups of the (non-)STEM study programs does not include data on chemistry and physics, as most programs are not tested on these predictors. Furthermore, the predictor list for the STEM study programs did not include data on comprehensive reading, as the students from 2 STEM study programs did not need to complete the comprehensive reading test. Finally, for the STEM study programs,

mathematics was not included in the predictor list, as students from program 9 (engineering) did not complete a mathematics test.

Results

Before exploring whether studying Latin is included as a factor in the programs' predictive models of academic achievement, we explored the general association between the measures of study antecedents and GPA. The correlations between GPA and these measures are reported in Table 3 (for the full correlation matrix, see Appendix S2). Most importantly, we found a significant correlation between studying Latin and GPA of $r(1393) = .15$ ($t(1393) = 5.51, p < .001$), which is comparable to the correlation between the high school mathematics package and GPA ($r(1393) = .14, t(1393) = 5.23, p < .001$).

<Insert Table 3 here>

Second, to get a better indication of the relation between Latin and academic achievement, we compared the average GPA of Latin students with that of non-Latin students. As such, we performed independent t-tests on the full dataset, and on the data of the STEM and non-STEM groups separately. The results are reported in figure 1. For the full dataset, a significant difference was found in mean GPA, with a small to medium effect size ($t(639.62) = -5.96, p < .001, d_s = .36^1$). More specifically, the Latin group had a 16.67% higher mean GPA than the non-Latin group. This effect seems to be driven by the non-STEM study programs, as a significant 19.05% increase in mean GPA was found there ($t(507.20) = -5.57, p < .001, d_s = .40$). This was not the case for the STEM group, as the 5.80% increase in mean GPA was not significant ($t(379.52) = -1.89, p = .060, d_s = .14$). In sum, while Latin students exhibited higher GPA's in all cases, this increase was only significant in the full dataset and in the non-STEM groups.

<Insert Figure 1 here>

After this first indication towards a Latin education effect, we tested our hypothesis by exploring whether studying Latin in secondary education is able to predict study achievement in academic higher education, above and beyond to other cognitive, attitudinal, and demographic predictors. We therefore developed program-specific prediction models of GPA (for a full overview of these models, we refer to Appendix S3)². A summary of our results are reported in Table 4. First, in the non-STEM group, the variable ‘high school Latin package’ was included as a predictor and uniquely explained 1% of the sample variance in GPA. Second, when we specifically analyzed each program, the variable ‘high school Latin package’ was included as a predictor in the final prediction models of GPA in study programs 1, 2, 4, 5 and 9. For these 5 study programs, the variance uniquely explained by high school Latin ranged from 1% to 18%. In sum, these findings are in support of our hypothesis, as including ‘studying Latin’ as a variable results in a modest, but significant contribution to the prediction of academic achievement for some study programs, over and above the best predictors of academic achievement known in the literature.

<Insert Table 4 here>

Discussion

While the option to study Latin in secondary education is still present to a considerable extent across Europe (European Commission / EACEA / Eurydice, 2023), its popularity amongst students has declined in Flanders and across the world (Duyck et al., 2017; Katz et al., 2020). The availability of this study program is often justified based on the assumption that the study of Latin leads to several cognitive benefits, within and beyond the linguistic domain (Devane, 1997; Mavrogenes, 1977). The present study investigated whether studying Latin in secondary education is able to predict success rates in higher education. First, we explored differences in mean GPA for Latin in comparison to non-Latin students. Second, we developed prediction models of academic achievement and explored to what

extent studying Latin in high school was included as a predictor in these models, above and beyond a wide range of other cognitive, attitudinal, and demographic variables.

We found that Latin students tend to perform better in higher education, as they displayed a substantially higher mean GPA (a 16.67% increase) compared to non-Latin students, when we considered the full dataset³. This finding was largely driven by the non-STEM study programs, as Latin students in these programs especially demonstrated substantially higher GPA's. While we did observe a similar, but smaller, increase in academic achievement for Latin students in STEM study programs, this effect was not significant.

Subsequently, we examined the presence of 'high school Latin package' in program-specific prediction models of academic achievement. An important remark is that the analyses we used were conservative by design, as no less than 21 cognitive, attitudinal, and demographic predictors of academic achievement were included in the prediction models, many of them assessed with time-consuming tests. The results revealed that Latin was included as a predictor in two thirds of the non-STEM program-specific prediction models, and in the overarching non-STEM model, over and beyond 21 other predictors. Including 'high school Latin package' as a factor in the prediction models resulted in an increase in the explained variance ranging between 1% and 18% for GPA. We acknowledge that the reported magnitude of the predictive effect of studying Latin in secondary education might seem large, but it is important to consider these effects in the context of an open access environment. Given that a highly diverse population enters Flemish university education, the variables we included present a wider range of variance. This contrasts closed-access study environments typically reported in the literature, in which the student samples are much more restricted in range, and consequently, sample variances are generally smaller than the actual population variance (Franco-Martínez et al., 2023).

When we further scrutinize the programs that included Latin in their prediction models, we find that ‘high school Latin package’ was predictive of academic achievement in study programs related to linguistics, as well as in psychology, law, and engineering, which amounts to 57.5% of the total sample tested. However, it is important to note that the sample variance explained uniquely by ‘high school Latin package’ was much larger in programs related to linguistics in comparison to the other programs. Indeed, the variance in GPA uniquely explained by Latin was 18% for linguistics and literary studies, and 11% for applied linguistics. The finding that the predictive ability of Latin education is particularly large in linguistics programs is not surprising from the perspective of near transfer effects. Indeed, studying Latin is generally an analytical process, as it is a complex language. By exercising great mental effort in parsing Latin’s grammar, students could develop a deeper understanding of how languages are construed (Pelling & Morgan, 2010). Furthermore, Latin is the foundation of many modern foreign languages, thus resulting in many shared grammatical structures and vocabulary roots. This foundation could allow linguistics students to pick up new languages more quickly (Mavrogenes, 1977; Pelling & Morgan, 2010). In sum, our findings could potentially reflect near transfer effects resulting from studying Latin, but the design of the present study does not allow to draw conclusions on the precise working mechanism behind such effects.

A noteworthy aspect of the present study is the fact that the declared number of hours of Latin was only based on students’ last year in secondary education. However, students in secondary education in Flanders can opt to change their curriculum at any time. Because of this regulation, some students who indicated that they did not study Latin may still have studied Latin for up to five years. For instance, Flemish statistics show that after four years of secondary education, about one third of the Latin students change their study program and quit studying the classical language (Flemish Department of Education, 2021). In other

words, if classical languages yield cognitive benefits, a meaningful part of our control group will also have partially enjoyed these effects. Therefore, our study may be a conservative underestimation of how much the factor ‘high school Latin package’ can contribute to the prediction of academic achievement.

Limitations and Future Work

As we did not have data available on university college students, we could not include them in the present study. Hence, our study only concerns university students, which could lead to an under- or overestimation of the relation between studying Latin in secondary education and later academic achievement. Besides this, the students in the Latin group all stem from general secondary education, as this is the only educational track that offers Latin. In contrast, students from the non-Latin group could have studied in general, technical, vocational or artistic secondary education. As data on educational track was not available in our dataset, nor in official databases, we could not control for this factor. Nevertheless, we know that most university students come from general secondary education tracks (89.9% of all first-year university students at Ghent University in the academic year 2018-2019 (cf. sample) came from general secondary education; Department of Educational Policy, Ghent University, personal communication, September 7, 2023). Furthermore, this limitation is partially addressed by the fact that we control for a variety of cognitive measures in our prediction models of academic achievement. We encourage future work to make a distinction between secondary education tracks and programs, as this could possibly nuance our conclusions. Finally, it is possible that we were not able to detect the predictive ability of studying Latin for academic achievement in each individual study program. Indeed, in some study programs the percentage of Latin students was rather small (e.g., only 10% in criminology), which makes it hard to pick up any effects of the predictor. By also considering

overarching groupings of study programs (i.e., STEM and non-STEM) we were able to partially address this concern.

Our findings cautiously support the idea that the predictive effect of studying Latin in secondary school on academic achievement cannot be explained through preselectivity alone. Indeed, the factor ‘high school Latin package’ was able to predict academic achievement incremental to no less than 21 cognitive, attitudinal, and demographic factors in a rigorous design, thus rendering a firm preselectivity-only hypothesis less plausible. However, the present non-interventional design alone is not capable of settling this causality debate. Are the advantages observed in Latin students tied to the classical language itself or to other social or attitudinal factors that may have shaped the choice of studying Latin? Future research could explore the causality of the effects associated with studying Latin and contrast the two views by performing a longitudinal, more controlled study. Such a design could follow and compare students that either take or do not take Latin at the start of secondary education, in their cognitive progress over the years. By matching these students for other cognitive, attitudinal, and demographic predictors, such research could provide a more in-depth insight into the potential benefits of studying Latin, while being able to control for effects of preselectivity.

Conclusion

The present study demonstrated that Latin students exhibit increased levels of study achievement in academic higher education, especially in non-STEM study programs. Furthermore, we found that studying Latin in secondary education is a measurable predictor of academic achievement in non-STEM study programs, over and beyond other known cognitive, attitudinal, and demographic predictors. We also showed that this relation between studying Latin and academic achievement is not limited to, but particularly large in linguistic study programs. Future research should explore the causal mechanism behind these

associations, and address whether these effects are the consequence of either preselectivity or cognitive transfer.

Notes

¹ A Cohen's d_s was used to report effect sizes, with 0.01 = very small effect, 0.20 = small effect, 0.50 = medium effect, 0.80 = large effect, 1.20 = very large effect and 2.00 = huge effect (Sawilowsky, 2009). Information on the confidence intervals around these effect sizes is reported in Appendix S1, Table S1-2.

² Multicollinearity of the predictors was examined prior to the analyses, and Variance Inflation Factor (VIF) values were all below 10 (Stevens, 2012).

³ This is an unadjusted effect, i.e., the effect we find without taking into account any control variables.

Materials Statement

We hereby provide the link to the platform that holds all the tests that were used in the current manuscript: <https://www.vraaghet aansimon.be/login>. To access the tests on this platform, creating an account is mandatory due to legal reasons.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

- **Appendix S1:** Descriptive Statistics.
- **Appendix S2:** Correlations Between Variables.

- **Appendix S3.** Program-specific Models Predicting Academic Achievement.

Tables

Table 1

Number of Students and Proportion of Latin Students per Study Program

Number and Acronym	Program	<i>n</i>	% Latin students ^a
-	Full dataset ^b	1395	24%
	Non-STEM ^c	943	27%
1 – PSY	Psychology	239	16%
2 – LAW	Law	227	43%
3 – CRIM	Criminology	106	10%
4 – LING	Linguistics and Literary Studies	75	56%
5 – APL LING	Applied Linguistics	74	41%
6 – ECON	Economy	222	16%
	STEM ^d	978	22%
7 – BIO ENG	Bio-engineering Sciences ^e	131	15%
8 – ENG TECH	Engineering Technology ^e	190	14%
9 – ENG	Engineering ^e	187	27%
10 – REHAB SCI	Rehabilitation Sciences and Physiotherapy	199	27%
11 – PHARMA	Pharmaceutical Sciences	130	28%
12 – BIOMED	Biomedical Sciences	118	21%

Note. The sample sizes of the full dataset, the non-STEM and the STEM program group do not necessarily equal the sum of the sample sizes of the programs included in that grouping, due to changes in the predictor lists used for their prediction models (see ‘Procedures and Analyses’, page 13).

^a % Latin students indicates the percentage of students per study program who studied Latin in secondary education. ^b The full dataset is based on the data from all programs except programs

10 and 12, as these programs do not include data on comprehensive reading. Furthermore, the full dataset does not include data from program 9, as this program does not include results on the mathematics test. ^c The non-STEM program group includes programs 1-6. ^d The STEM program group includes programs 7-12. ^e Three distinct types of engineering study programs exist, which all completely differ from each other. First, engineering technology focusses on a strong foundation in scientific courses, and subsequent specialization in a technological domain. The acquired knowledge is application-oriented and focusses on problem solving. Second, the general engineering category (often referred to as civil engineering) has a predominant focus on mathematics, which is applied in more technical courses. Finally, bio-engineering focusses on living matter and provides a synthesis between chemistry and biology, with mathematics and physics providing the bridge to technological applications (Onderwijskieser, 2023).

Table 2*Overview of the Variables Used to Construct the Predictive Models*

Category	Variables
Dependent variable	GPA
Cognitive variables	Vocabulary Comprehensive reading ^a Mathematics (baseline/advanced) ^b Chemistry ^c Physics ^d High school Dutch package High school Latin package High school mathematics package High school GPA
Attitudinal variables	Grit Academic self-efficacy (comprehension and effort) Test anxiety Motivation (autonomous and controlled) Metacognition (knowledge and regulation) Realistic interest dimension Investigative interest dimension Artistic interest dimension Social interest dimension Enterprising interest dimension Conventional interest dimension
Demographic variables	Gender Socioeconomic status

Note. GPA = grade point average.

^a Not used in programs 10 and 12. ^b The normal mathematics test was used in programs 1- 5 and 10-11, whereas the advanced mathematics test was used in programs 6-8 and 12. ^c Only used in programs 8 and 11-13. ^d Only used in programs 10-12.

Table 3*Correlations Between GPA and Measures of Study Antecedents.*

	HS Dutch package	HS Latin package	HS Mathematics package	HS GPA	GPA
HS Dutch package	-				
HS Latin package	.02	-			
HS Mathematics package	.04	-.12	-		
HS GPA	-.01	.16	-.01	-	
GPA	.05	.15	.14	.29	

Note. This correlation matrix was based on the full dataset, namely data from programs 1-8

and 11 ($N = 1395$) (see 'Procedures and Analyses', page 13). HS = high school, GPA =

Grade Point Average.

Bold = $p < .05$.

Table 4*Presence of Latin in Program-Specific Prediction Models of Academic Achievement*

Program	Latin in model	R^2 ^a	Unique R^2 ^b	Individual R^2 ^c
Non-STEM	X	.19	.01	.03
1 – PSY	X	.14	.02	.03
2 – LAW	X	.29	.02	.05
3 – CRIM		.24	-	.00
4 – LING	X	.39	.18	.27
5 – APL LING	X	.43	.11	.10
6 – ECON		.20	-	.00
STEM		.18	-	.00
7 - BIO ENG		.16	-	.01
8 – ENG TECH		.20	-	.00
9 – ENG	X	.34	.01	.00
10 - REHAB SCI		.29	-	.00
11 - PHARMA		.28	-	.00
12 - BIOMED		.28	-	.00

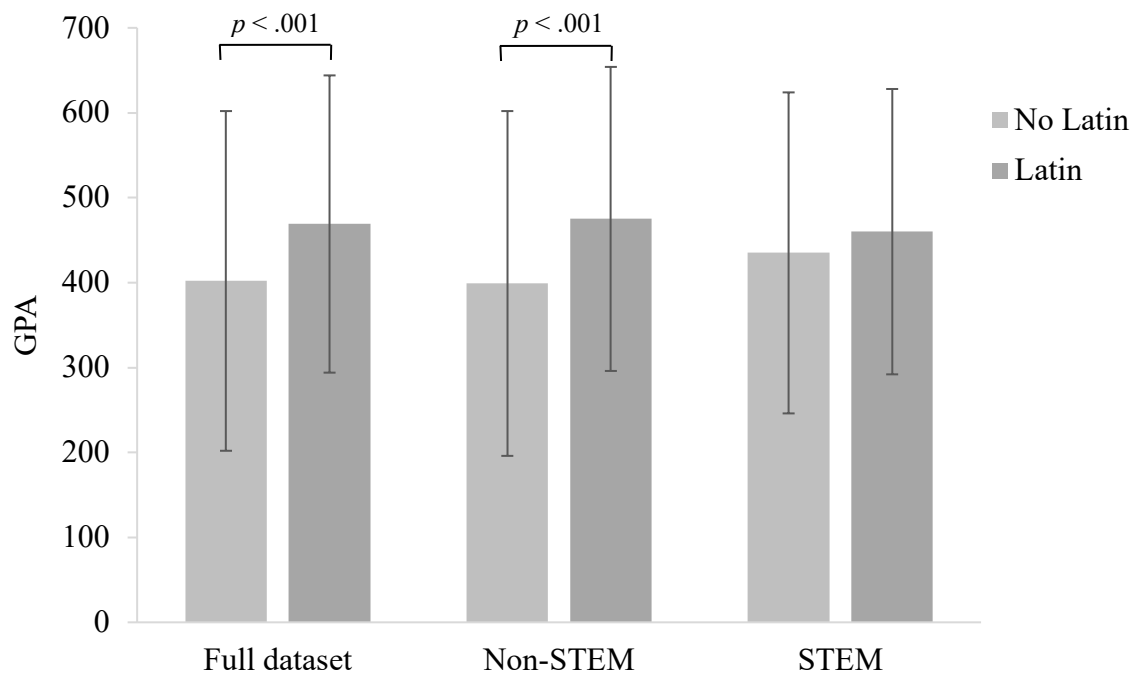
^a The explained sample variance is explained by Nagelkerke's adjusted R^2 . ^b Unique R^2

expresses the incremental amount of sample variance explained by 'high school Latin package'. A hyphen in this column indicates that 'high school Latin package' was not included as a factor in the prediction model. ^c Individual R^2 expresses the amount of sample variance explained by 'high school Latin package' when it is included as the only factor in the prediction model.

Figures

Figure 1

Comparison of mean GPA's



Note. The error bars indicate one standard deviation above and below the mean GPA. The full dataset is based on all data, but excluding data from programs 9, 10 and 12 (see 'Procedures and Analyses').

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Appendix S1: Descriptive Statistics

Table S1-1

Descriptive Statistics of the Included Variables

Variable	Mean	Confidence interval around mean	Standard deviation	Cronbach's alpha
Vocabulary	17.50	[17.42 – 17.56]	1.93	.83
Comprehensive reading	15.02	[14.85 – 15.19]	4.45	.78
Mathematics (baseline)	16.91	[16.77 – 17.05]	2.97	.72
Mathematics (advanced)	12.31	[12.10 – 12.53]	3.74	.78
Chemistry	15.17	[14.96 – 15.37]	3.24	.71
Physics	11.52	[11.27 – 11.77]	3.54	.68
High school Dutch package	4.01	[3.97 – 4.04]	0.89	-
High school Latin package	1.07	[1 – 1.13]	1.80	-
High school mathematics package	5.39	[5.33 – 5.46]	1.78	-
High school GPA	72.41	[72.17 – 72.66]	6.60	-
Grit	13.55	[13.49 – 13.61]	1.87	.73
Academic self-efficacy (comprehension)	14.87	[14.82 – 14.93]	1.66	.76
Academic self-efficacy (effort)	15.24	[15.18 – 15.31]	2.02	.73
Test anxiety	9.93	[9.85 – 10.01]	2.46	.92
Motivation (autonomous)	14.95	[14.87 – 15.04]	2.52	.86
Motivation (controlled)	8.24	[8.13 – 8.34]	3.19	.88
Metacognition (knowledge)	13.77	[13.70 – 13.84]	2.15	.87

Metacognition (regulation)	13.09	[13.02 – 13.16]	2.07	.87
Realistic interest dimension	20.77	[19.82 – 21.72]	25.37	.93
Investigative interest dimension	34.91	[34.12 – 35.69]	20.75	.87
Artistic interest dimension	27.77	[26.85 – 28.69]	24.44	.92
Social interest dimension	33.83	[32.86 – 34.80]	25.64	.92
Enterprising interest dimension	33.20	[32.18 – 34.23]	27.49	.93
Conventional interest dimension	22.31	[21.43 – 23.20]	23.47	.91

Note. GPA = Grade Point Average.

Table S1-2*Effect Sizes of GPA Comparisons*

Data	Effect size ^a	Confidence interval around effect size
Full dataset	.36	[.21 - .51]
Non-STEM dataset	.40	[.23 - .57]
STEM dataset	.14	[.00 - .33]

Note. ^a A Cohen's d_s was used to report effect sizes, with 0.01 = very small effect, 0.20 = small effect, 0.50 = medium effect, 0.80 = large effect, 1.20 = very large effect and 2.00 = huge effect (Sawilowsky, 2009).

Appendix S2: Correlations Between Variables**Table S2-1***Zero-order Correlations Between All Variables, Excluding Chemistry and Physics*

Variable	1	2	3	4	5	6	7	8
1. Grit	-							
2. Gender	.19	-						
3. SES	.08	.05	-					
4. Controlled motivation	-.20	-.10	-.04	-				
5. Autonomous motivation	.43	.25	.06	.02	-			
6. HS GPA	.18	.22	-.02	-.01	.24	-		
7. Metacognition (knowledge)	.43	.08	-.02	-.02	.49	.20	-	
8. Metacognition (regulation)	.44	.15	.02	.00	.52	.21	.78	-
9. Test anxiety	-.26	.11	.00	.22	-.14	-.18	-.27	-.11
10. HS mathematics package	-.13	-.35	-.12	.13	-.17	-.01	-.10	-.15
11. HS Dutch package	-.02	.01	.03	-.02	.01	-.01	.02	-.01
12. HS Latin package	.01	.12	-.04	.01	.05	.16	.01	.01
13. Academic SE (comprehension)	.27	-.12	-.04	.00	.36	.15	.53	.48
14. Academic SE (effort)	.50	.20	.03	-.08	.51	.29	.51	.54
15. Comprehensive reading	-.02	.00	-.01	-.08	.05	.09	.05	.01
16. Vocabulary	.05	.01	-.10	-.05	.02	.09	.05	.01
17. Mathematics ^a	.00 / .07	-.08 / .01	-.13 / .01	.02 / .03	.01 / .09	.09 / .16	.05 / .08	.06 / .12
18. R	-.16	-.50	-.04	.11	-.15	-.13	-.07	-.0
19. I	-.01	-.10	-.02	.07	.14	.08	.09	.12
20. A	-.13	.19	.02	.04	.09	.03	.07	.09

21. S	.07	.38	.07	-.04	.17	.02	.11	.16
22. E	.05	-.16	-.02	.06	.03	-.03	.07	.05
23. C	.08	-.18	.00	.09	-.01	-.04	.05	.04
24. GPA	.02	.08	-.14	.03	.07	.29	.06	.05
	9	10	11	12	13	14	15	16
9. Test anxiety	-							
10. HS mathematics package	-.05	-						
11. HS Dutch package	-.04	.04	1					
12. HS Latin package	-.04	-.12	.02	1				
13. Academic SE (comprehension)	-.34	.14	-.02	.00	1			
14. Academic SE (effort)	-.20	-.17	-.01	.01	.45	1		
15. Comprehensive reading	-.15	.03	.00	.08	.08	.17	1	
16. Vocabulary	-.11	.00	.04	.10	.06	.16	.16	1
17. Mathematics ^a	-.05 / -.24	.37 / .37	.14 / .00	.12 / -.03	.22 / .23	-.05 / .06	.10 / .26	.17 / .17
18. R	.01	.45	-.03	-.10	.12	.07	.00	.04
19. I	-.02	.25	-.03	-.04	.20	.06	.01	.11
20. A	.08	-.18	-.02	.16	.02		.01	.00
21. S	.12	-.36	-.01	.05	.01	.06	.00	.03
22. E	-.05	.02	-.01	.05	.10	-.07	-.07	-.03
23. C	-.01	.14	-.01	-.03	.08	-.03	.08	.06*
24. GPA	-.14	.14	.05	.15	.09	.10	.01	.00
	17 ^a	18	19	20	21	22	23	24
16. Vocabulary								
17. Mathematics ^a	1							
18. R	.11 / .11	1						
19. I	.18 / .10	.17	1					
20. A	.02 / -.06	-.24	.19	1				

21. S	.00 / -.12	.10	.05	.46	1			
22. E	.05 / -.20	.19	.18	.22	.21	1		
23. C	.05 / -.14	-.07	-.05	.02	.09	.73	1	
24. GPA	.23 / .22	-.24	.19	.04	.02	-.01	-.04	1

Note. This correlation matrix was based on the full dataset, namely data from programs 1-8 and 11 ($N = 1395$) (see ‘Procedures and Analyses’, page 13).

HS = high school, HE = higher education, Academic SE = Academic self-efficacy, GPA = Grade point average, R = realistic interest dimension, I = investigative interest dimension, A = artistic interest dimension, S = social interest dimension, E = enterprising interest dimension, C = conventional interest dimension. ^a Correlations reported before the slash are based on the normal mathematics test ($n = 852$). Correlations after the slash are based on the advanced mathematics test ($n = 543$).

Bold = $p < .05$.

Table S2-2*Zero-order Correlations with Chemistry and Physics*

Variable	Chemistry	Physics
1. Chemistry	-	.51
2. Physics	.51	-
3. Grit	.08	.01
4. Gender	.00	-.13
5. SES	-.09	-.11
6. Controlled motivation	.00	-.02
7. Autonomous motivation	.18	.09
8. HS GPA	.26	.18
9. Metacognition (knowledge)	.21	.15
10. Metacognition (regulation)	.14	.07
11. Test anxiety	-.15	-.21
12. HS mathematics package	.23	.26
13. HS Dutch package	.01	-.03
14. HS Latin package	-.04	-.11
15. Academic SE (comprehension)	.23	.18
16. Academic SE (effort)	.15	.04
17. Vocabulary	.20	.20
18. Mathematics	.41 / .49	.51 / .53
19. R	.04	.16
20. I	.06	.12
21. A	-.01	.02
22. S	.03	.00
23. E	.01	0.08
24. C	-.07	.03
25. GPA	.28	.32

Note. This correlation matrix was based on data from programs 10-12 ($N = 447$). We

excluded data from programs 1-9 as these programs did not include data on both chemistry

and physics. HS = high school, HE = higher education, Academic SE = Academic self-

efficacy, GPA = Grade point average, R = realistic interest dimension, I = investigative

interest dimension, A = artistic interest dimension, S = social interest dimension, E =

enterprising interest dimension, C = conventional interest dimension. ^a Correlations reported

before the slash are based on the normal mathematics test ($n = 329$). Correlations after the

slash are based on the advanced mathematics test ($n = 118$).

Bold = $p < .05$.

Appendix S3: Program-Specific Models Predicting Academic Achievement

Table S3-1

Program-specific Models Predicting GPA¹

Program(s)	Model	R^2 ^a	Unique R^2 ^b
Non-STEM ^c	-0.13 * SES + 0.25 * HS GPA – 0.10 * Test anxiety + 0.11 * HS Latin package + 0.10 * HS Dutch package + 0.26 * HS mathematics package – 0.01 * I + 0.13 * S – 0.11 * C	.19	.01
1 - PSY	0.15 * HS Latin package + 0.16 * HS Dutch package + 0.14 * HS mathematics package + 0.15 * Mathematics + 0.17 * Academic SE effort – 0.15 * I + 0.14 * S	.14	.02
2 - LAW	-0.14 * SES + 0.36 * HS GPA – 0.16 * Test anxiety + 0.15 * HS Latin package + 0.22 * HS mathematics package	.29	.02
3 - CRIM	- 0.21 * SES – 0.29 * Test anxiety + 0.29 * HS mathematics package + 0.26 * Vocabulary	.24	-
4 - LING	-0.19 * Grit + 0.28 * HS GPA + 0.22 * Metacognition knowledge + 0.47 * HS Latin package	.39	.18
5 - APL LING	0.25 * Controlled motivation + 0.37 * HS GPA + 0.35 * HS Latin package + 0.44 * HS mathematics package	.43	.11
6 - ECON	0.31 * HS GPA – 0.14 * Test anxiety + 0.23 * HS mathematics package – 0.12 * I	.20	-
STEM ^d	0.34 * HS GPA + 0.17 * HS mathematics package + 0.10 * Academic SE effort – 0.07 * I + 0.08 * S	.18	-
7 - BIO ENG	0.35 * HS GPA + 0.22 * HS mathematics package	.16	-

¹ We also tested interaction effects with high school Latin package in the program-specific models predicting GPA. Significant interactions were found in the non-STEM group ((1) between high school Latin package and high school GPA and (2) between high school Latin package and test anxiety), and in program 4 (between high school Latin package and metacognition (knowledge)).

8 – ENG TECH	0.18 * HS GPA + 0.15 * Metacognition regulation + 0.20 * HS mathematics package + 0.17 * Mathematics	.18	-
9 - ENG	0.53 * HS GPA – 0.17 * Metacognition knowledge – 0.13* HS Latin package + 0.21 * HS mathematics package + 0.17 * Academic SE comprehension – 0.13 * S	.34	.01
10 - REHAB SCI	0.28 * Physics + 0.32 * HS GPA + 0.21 * HS Dutch package + 0.23 * HS mathematics package – 0.19 * Academic SE comprehension + 0.15 * Academic SE effort	.29	-
11 - PHARMA	0.28 * HS GPA – 0.21 * Test anxiety + 0.25 * Mathematics – 0.20 * Academic SE comprehension + 0.17 * Academic SE effort + 0.29 * R – 0.29 * E	.28	-
12 - BIOMED	0.28* Chemistry + 0.23 * Autonomous motivation + 0.25 * HS GPA	.28	-

Note. Academic SE = Academic self-efficacy, GPA = grade point average, HS = high school, R = realistic interest dimension, I = investigative interest dimension, A = artistic interest dimension, S = social interest dimension, E = enterprising interest dimension, C = conventional interest dimension. All variables were standardized for ease of interpretation of the models.

^a The explained sample variance is explained by Nagelkerke's adjusted R^2 . ^b Unique R^2 expresses the incremental amount of sample variance explained by 'high school Latin package'. A hyphen in this column indicates that 'high school Latin package' was not included as a factor in the prediction model. ^c The non-STEM dataset is based on data from programs 1-6. ^d The STEM dataset is based on data from programs 7-12.