

DOCTORAL PROGRAMME

Information Management

UNDERSTANDING SCHOOL SUCCESS: DRIVERS OF ACADEMIC ACHIEVEMENT OF PORTUGUESE PUBLIC HIGH SCHOOL STUDENTS

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A thesis submitted in partial fulfillment of the requirements for the degree of Doctor in
Information Management

NOVA Information Management School
Instituto Superior de Estatística e Gestão de Informação
Universidade Nova de Lisboa

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by

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Doctoral Thesis presented as partial requirement for obtaining the PhD in Information Management

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May 2023

STATEMENT OF INTEGRITY

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration. I further declare that I have fully acknowledge the Rules of Conduct and Code of Honor from the NOVA Information Management School.

Catarina Neves Nunes

Lisbon, May 2023

ACKNOWLEDGEMENTS

Many contributions were of immense value to the completion of this work. I would like to acknowledge and thank:

- My supervisors, Professor Tiago Oliveira, Professor Frederico Cruz Jesus and Professor Mauro Castelli, for the opportunity to work in this important and rewarding project. Their guidance was essential throughout the last three years, and they have inspired me and motivated me to thrive. I am for sure a better researcher after having worked in this team.
- My other co-authors, Professor Fernando Santini and Dra. Ana Beatriz Afonso for their contributions to the studies of this thesis. I am looking forward to following Beatriz's work as she pursues this challenge of understanding what drives academic achievement.
- DGEEC, for all the chances to discuss our intermediate results, and for sharing valuable insights and knowledge. I'd like to thank Dra. Joana Duarte, in particular, whose help and guidance were essential to successfully complete the data collection in the schools.
- My research colleague, Dr. Ricardo Mendes, for all the support and sense-checking while we worked on this project together.
- The professors I have met in the NOVA IMS Doctoral Programme and my colleagues in the 2019 class.
- My family and friends for pulling me through.

ABSTRACT

Education plays a fundamental part in self-development since it capacitates individuals with cognitive, procedural, and attitudinal competences, thus promoting employment, earnings, and health. For societies, it drives economic growth, spurs innovation, and fosters social cohesion and poverty reduction. Research has increasingly dwelled on understanding the drivers of academic achievement to better inform decision-makers.

Educational policies in recent decades in Portugal have increased literacy rates, yet the number of dropouts before high school (compulsory education) completion is still a matter of concern when compared to the European graduation average rates.

The present thesis aims at shedding light on what are the main determinants of academic achievement in Portuguese public secondary education. By combining various data sources – literature review, primary and secondary data – and employing robust data analysis methods – structural equation modeling and machine learning techniques – this work identifies and classifies, by order of importance (i.e., which of them has a greater impact on students' grades), determinants pertaining to students, teachers, and parents.

Results allowed for a comprehensive overview of the determinants of academic achievement, highlighting the more significant ones. The two main drivers of success are previous retention and parental education level. Specifically, having failed a year in school impairs high school achievement, while having a legal guardian who holds a university degree promotes it. This result was found in both primary and secondary research, thus eliciting that combining multiple data sources and resorting to sophisticated analysis methods poses an advantage in this field of research. Moreover, it has significant practical implications, as it helps to advise policies in order to increase graduation rates.

KEYWORDS

Academic achievement; High school; Structural equation modeling; Machine learning

Sustainable Development Goals (SGD):



RESUMO

A educação desempenha um papel fundamental no autodesenvolvimento, pois capacita os indivíduos com competências cognitivas, procedimentais e atitudinais, promovendo assim o emprego, o rendimento e a saúde. Para as sociedades, impulsiona o crescimento económico, estimula a inovação e promove a coesão social e a redução da pobreza. Trabalhos de investigação académica nesta área têm-se concentrado cada vez mais na compreensão dos impulsionadores do desempenho académico para melhor informar os decisores públicos.

As políticas educativas em Portugal nas últimas décadas aumentaram as taxas de alfabetização, mas o número de abandonos antes da conclusão do ensino secundário (ensino obrigatório) ainda é motivo de preocupação, sobretudo quando comparado com as taxas médias de conclusão europeias.

A presente tese pretende esclarecer quais são os principais determinantes do desempenho académico no ensino secundário público português. Combinando várias fontes de dados – revisão de literatura, dados primários e secundários – e empregando métodos avançados de análise de dados – modelação de equações estruturais e técnicas de aprendizagem automática (*machine learning*) – este trabalho identifica e classifica, por ordem de importância (ou seja, qual deles tem maior impacto sobre o desempenho escolar dos alunos), determinantes pertencentes a alunos, professores e pais.

Os resultados permitiram uma visão abrangente dos determinantes do desempenho académico, destacando os mais impactantes. Os dois principais impulsionadores do desempenho académico são a retenção anterior e o nível de escolaridade dos pais. Mais especificamente, já ter reprovado anteriormente na escola prejudica o desempenho académico no ensino secundário, enquanto ter um encarregado de educação com um grau académico superior promove positivamente o mesmo. Este resultado foi encontrado tanto em análises que usam dados primários e secundários, evidenciando assim que combinar múltiplas fontes de dados e recorrer a métodos de análise sofisticados representa uma vantagem nesta área de investigação. Adicionalmente, esta combinação resulta em implicações práticas mais substantivas, pois ajuda a aconselhar políticas para aumentar as taxas de conclusão do ensino secundário.

PALAVRAS-CHAVE

Sucesso Escolar; Ensino Secundário; Modelos de Equações Estruturais; Aprendizagem Automática

OBJETIVOS DE DESENVOLVIMENTO SUSTENTÁVEL (ODS):



INDEX

1. INTRODUCTION.....	1
1.1. Research gap and objectives	3
1.2. Path of research and methodology	5
1.3. COVID-19 pandemic and AA	6
2. A weight and meta-analysis on academic achievement of high school students	9
2.1. Introduction	9
2.2. Method	12
2.2.1. Criteria for selection of studies.....	12
2.2.2. Data extraction	13
2.2.3. Merging of variables	14
2.2.4. Analysis procedures	14
2.3. Results.....	16
2.3.1. Descriptive statistics	16
2.3.2. Weight analysis	16
2.3.3. Meta-analysis correlation effects	18
2.3.4. Moderation effects	20
2.3.5. Major findings.....	22
2.4. Discussion	23
2.4.1. Theoretical implications.....	26
2.4.2. Practical implications	28
2.4.3. Limitations and future studies	29
2.5. Conclusions.....	30
3. Determinants of academic achievement: how parents and teachers influence high school students' performance.....	31
3.1. Introduction	31
3.2. Literature review and hypotheses.....	33
3.2.1. Students	34
3.2.2. Teachers.....	37
3.2.3. Parents	38
3.2.4. Conceptual model.....	40
3.3. Method	41
3.3.1. Participants and procedure	41

3.3.2. Data	42
3.4. Results.....	44
3.4.1. Measurement model	44
3.4.2. Structural model	47
3.5. Discussion	49
3.5.1. Theoretical implications.....	54
3.5.2. Practical implications	56
3.5.3. Limitations	58
3.6. Conclusions	58
4. Is academic self-efficacy really important? Assessing the determinants of academic self-perception and achievement	60
4.1 Introduction	60
4.2. Literature review	62
4.2.1. Mastery-approach goals	62
4.2.2. Parental expectations	63
4.2.3. Teacher involvement	64
4.2.4. Academic self-efficacy	66
4.2.5. Conceptual model.....	67
4.3. Method	68
4.3.1. Participants and procedure	68
4.3.2. Data.....	69
4.4 Results.....	70
4.4.1. Measurement model	71
4.4.2. Structural model	72
4.5. Discussion	75
4.5.1. Limitations and future research	79
4.6. Conclusions	79
5. Mathematics and Mother Tongue Academic Achievement: A Machine Learning Approach	80
5.1. Introduction	80
5.2. Theoretical background.....	81
5.2.1. AA Drivers	82
5.2.2. Application of Machine Learning on AA	85
5.3. Methodology	87
5.3.1. Machine Learning Methods.....	87
5.3.2. Feature Selection	88

5.3.3. Data.....	89
5.4. Results.....	90
5.4.1. Feature Importance	90
5.5. Discussion, implications, and limitations	92
5.5.1. Discussion of findings.....	92
5.5.2. Theoretical Implications	95
5.5.3. Implications for Practice	96
5.5.4. Limitations and Future Work	97
5.6. Conclusions.....	97
6. Overall Conclusion.....	99
6.1. Findings.....	100
6.2. Contributions	102
6.3. Limitations and recommendations for future works	103
References.....	105
APPENDIX I	144
APPENDIX II - Questionnaire – constructs table	147
APPENDIX III - Loadings and cross-loadings	149
APPENDIX IV	150
APPENDIX V – Instrument	151
APPENDIX VI – Loadings and cross-loadings	152
APPENDIX VII - Heterotrait-Monotrait Ratio (HTMT).....	153

LIST OF FIGURES

Figure 2.1 - Literature search, screening, and assessment process.....	13
Figure 2.2 - Final weight analysis and meta-analysis results model	23
Figure 3.1 - Conceptual model and hypotheses.....	41
Figure 3.2 - Results – structural model	48
Figure 4.1 - Conceptual model and hypotheses.....	68
Figure 4.2 - Results – structural model	73
Figure 4.3 - Moderation effect	74

LIST OF TABLES

Table 1.1 - Publications status of each article/section	6
Table 2.1 - Weight analysis results (ordered by frequency of use).....	17
Table 2.2 - Meta-analytic calculation (ordered by frequency of use).....	19
Table 2.3 - Meta-regression analysis.....	22
Table 3.1 - Sample characteristics.....	43
Table 3.2 - Descriptive statistics, composite reliability (CR), and average variance extracted (AVE).....	46
Table 3.3 - Formative measurement model evaluation.....	47
Table 3.4 - Research hypotheses results.....	51
Table 4.1 - Sample characteristics.....	70
Table 4.2 - Descriptive statistics, composite reliability (CR), and average variance extracted (AVE).....	72
Table 4.3 - Research hypotheses results.....	76
Table 5.1 – Predicted impacts of the changing a unit in each variable, ceteris paribus, using prototypes	92

LIST OF ABBREVIATIONS AND ACRONYMS

AA	Academic achievement
AVE	Average variance extracted
CR	Composite reliability
DGEEC	Directorate-General for Statistics of Education and Science
GPA	Grade point average
HTMT	Heterotrait-monotrait ratio
ICT	Information and communication technologies
MLP	Multilayer perceptron
NN	Artificial neural networks
RFE	Recursive feature elimination
SEM	Structural equation modelling
SES	Socioeconomic status
VIF	Variance inflation factor

1. INTRODUCTION

Academic achievement (AA) reflects the extent to which students are successful in school and have acquired knowledge and competences defined in the school curricula. It is typically assessed through performance evaluations, and data like individual students' grades each year, school achievement exams, standardized test scores, or grade point average informs whether students have accomplished the desired learning goals (Steinmayr et al., 2014) allowing for the monitorization of teaching quality.

AA is a vast topic that researchers of several domains have consistently investigated. Its relevance has increasingly been proven since education is related to crucial socioeconomic aspects such as the development of countries and higher productivity indexes (Spinath, 2012), and is the foremost tool to diminish inequalities, conveying important individual and collective outcomes. Societies are continually faced with economic and social transformations which bring about new demands in order for individuals to cope and successfully adapt. In addition, the technological innovations of recent decades have caused increasing competition in the job market (OECD, 2019), urging people to acquire higher and more differentiated skills. This scenario highlights the importance of thoroughly understanding the drivers of AA, as this knowledge is pivotal to providing policymakers, school leaders, and teachers with adequate strategies to promote success in school. Struggling students with an unsuccessful academic path are more at risk of dropping out and face challenges to pursuing a successful career in adulthood (Koc et al., 2020), which may result in hardship and social exclusion (European Commission, 2017). Adolescence and high school years are critical periods for achievement (Leeson et al., 2008), and while high school graduation is necessary to complete compulsory education in most developed countries, including Portugal, it is the period when most students drop out (Dupéré et al., 2015; Janosz et al., 2000). In order to counteract this scenario, policies to reduce dropout and minimize the consequent deleterious effects have been a part of the strategic agenda of the European Commission for 2020 and 2030 (European Commission, 2021).

Most of the research done in AA has identified a vast number of drivers that have an impact on student performance. These drivers are understandably, for the most part, characteristics of the students, yet social capital theory states that relations with other persons are also at play, as students have better results in environments where parents, teachers, and the local community interact (Coleman, 1988). Therefore, AA results from reciprocal relationships between students, parents, teachers, and peers (Hattie, 2015). This integrated perspective has evolved throughout decades of research.

Early education research in the late 19th and early 20th centuries focused particularly on student cognitive ability (Mertler, 2018), due to the development of the first IQ tests to discern cognitively impaired students from underachieving yet cognizant peers. However, the primacy of cognitive ability as a driver of AA has been challenged (e.g., Taub et al., 2008) after the development of psychometric instruments to study individual differences, such as personality (Cattell, 1949; Cattell & P. Cattell, 1995) or motivation (Mayer et al., 2007; Vallerand et al., 1992). This line of research has demonstrated that these individual student traits, and attributes drive school performance. Student gender is likewise one of the most researched drivers of AA. Literature shows that girls typically outperform male peers (Mensah & Kiernan, 2010; Steinmayr & Spinath, 2008); however, boys achieve higher in specific math abilities (Brunner et al., 2008) while girls excel in reading (Brunner et al., 2013). To fully understand AA, and perhaps as important as individual student traits are the characteristics of their familiar background, namely the social and cultural capital of the family (Tan et al., 2019), their socioeconomic status, parental education (Chesters & Daly, 2017) and involvement (Fan & Chen, 2001). All of these drivers have been shown to positively impact AA. Finally, teacher influence is also commonly addressed in AA research: the Pygmalion effect, i.e., how teacher expectations influence student academic progress, has been widely described in the literature (e.g., Friedrich et al., 2015). Positive student-teacher relationships show consistent, direct predictive effects on graduation (Zaff et al., 2017), and teacher training and quality (Harris & Sass, 2011) also impact AA.

This thesis was developed in the scope of a research project aimed at understanding the drivers of academic achievement in the Portuguese public high school system. The project was proposed in 2018, kicked off in 2019, and had as its main goals to engender AA by:

- providing decision-makers a better understanding of its drivers;
- contribute with insights to achieve the Europe 2020 strategic goals for AA;
- contribute to extending the literature of AA's antecedents, resorting to primary and secondary data sources, and combining classical statistical methods with advanced data science techniques.

1.1. RESEARCH GAP AND OBJECTIVES

With this work, we intend to explore the main determinants of AA in Portuguese public high schools. Portuguese high school completion rates have risen dramatically in the past decades due to significant improvements and investment in the Education sector. Scores in the Program for International Student Assessment (PISA), a triennial evaluation of 15-year-old student performance in math, reading, and science, show Portugal is the only OECD country with consistent growth, having started in the bottom of the ranking in 2000 and reaching OECD average in 2018 (Marôco, 2021). In fact, by 1998, only 17% of Portuguese adults had completed secondary education, a number that rose to 50% in 2021 (Pordata, 2022). Education policies that were enacted following the first PISA assessment, such as the extension of pre-school education, differentiation of pedagogical practices, improvement of schools' infrastructures, reinforcement of curricula aligned with international frameworks, high-stake exams, and development of a vocational track for high school students less interested in science-humanistic courses have all contributed significantly to increase AA in Portugal. Despite this, high school dropout rates were still above the European average in 2018, which hints at a need for a more specific outlook on the high school period in the scope of this work. The gap between generations of parents and students concerning high school completion and learning also makes Portugal a particularly unique case to analyze more deeply.

In this work, both primary data sources (collected from students) and secondary data sources (institutional data collected by schools) were analyzed in order to achieve a more comprehensive overview of the drivers of high school success. AA research has mostly relied on a classical approach, resorting to qualitative and quantitative data collection methods, in particular self-report measures. These studies have allowed for the development of a vast research field as they allow for the collection of perceptions and intrinsic variables, only accessed through self-reports. However, survey-based research studies may have some limitations, such as lack of generalized applicability and constraints in time and costliness of administering at a large scale (Delen, 2010), and therefore recent studies have analyzed secondary educational data with advanced data science methods to research AA (Costa-Mendes et al., 2021a; Cruz-Jesus et al., 2020). Even though it is not widely ingrained in educational research (Fischer et al., 2020), this data-driven approach may be preferable in the face of said limitations, as vast amounts of data are available in institutional databases, and the use of machine learning techniques to extract insights from said data has demonstrated superiority compared to classical methods (Caison, 2007).

Given that AA is a complex topic, influenced by a multitude of factors, both intrinsic and extrinsic, to the student, combining various data sources and analyses seems to be of particular interest to address this research topic. Based on the existing literature, we: i) propose and test two conceptual models to explain AA, based on data collected through surveys, exploring the impact that drivers pertaining to students, their parents, and teachers have on high school grades, and ii) analyze institutional data using prototypes, i.e., “fictional” students scored with machine learning models, to measure how a standard deviation in each AA driver impacts a student's grade, keeping all other parameters fixed with mean values, as to quantify to what extent each AA driver impacts students' grades. Secondary data was collected from the MISI database of the Ministry of Education and Science, i.e., the information system in which Portuguese educational data is collected. It centralizes all educational data and provides information for educational statistics, generating insights that influence educational policies.

1.2. PATH OF RESEARCH AND METHODOLOGY

The first step conducted to develop this work was an extensive literature review on the antecedents of AA. In particular, we looked at studies that had a quantitative measure of achievement, such as final grades, exam grades, or GPA. This led to the first article of the present thesis, which identifies the most studied antecedents of high school AA in scientific literature and classifies their impact on grades through weight and meta-analysis.

After this step, we focused on the Portuguese high school context and proposed the first model based on literature and validated by a qualitative assessment done with high school students, teachers, and education experts. This model includes drivers pertaining to students (age, academic track record, ICT), parents (education, socioeconomic status, and expectations), and teachers (social and pedagogical involvement), and its effects on Portuguese (mother tongue) and Math grades; this study comprises the second article of the thesis. Results show academic track record is a strong determinant of AA and highlight the relevant role of parent-related drivers such as expectations, education, and socioeconomic status promoting mother tongue AA and, particularly, teacher involvement promoting Math AA.

The third article aims to explore further the findings of the previous one: given that parental expectations and teacher involvement impact AA directly, we explored if these drivers influence the pursuit of learning goals (mastery approach) and contribute to student self-efficacy, thus increasing AA.

Finally, our fourth article is a study done with a data-driven approach and based on the use of machine learning techniques to assess which drivers are relevant to AA and to what extent. AA measures were the national exam grades of 2019 for Portuguese and Math. Academic track record and parental education are, similar to the findings of the second article, the main drivers of high school AA.

Table 1.1 details the publication status of each article, which comprise four sections (2-5) of the thesis.

In terms of methodology, the type of this dissertation's objectives and conceptual background demand a mixture of several methodological approaches. Theoretically, this dissertation presents features entirely consistent with the positivist approach, as we use multiple quantitative techniques, which assume a proposition of underlying and quasi-absolute rules. Regarding the quantitative techniques, we use multivariate (classic) statistical methods, partial least squares structural equation modeling, and state-of-the-art data science and machine learning methods. Additional Detail can be found within each chapter about how these were employed.

Table 1.1 – Publications status of each article/section

Section	Title	Status
2	A weight and meta-analysis on academic achievement of high school students	Published in Education Sciences
3	Determinants of academic achievement: how parents and teachers influence high school students' performance	Published in HELIYON
4	Is academic self-efficacy really important? Assessing the determinants of academic self-perception and achievement	Submitted to a Scimago Q1 journal
5	Mathematics and Mother Tongue Academic Achievement: A Machine Learning Approach	Published in the Emerging Science Journal

1.3. COVID-19 PANDEMIC AND AA

During the development of this work, in mid-March 2020, the world came to an unprecedented scenario caused by the coronavirus (SARS-CoV-2) pandemic, which led most countries to implement lockdown measures to prevent the spreading of the virus and COVID-19 disease. This implicated the closing of schools and turning all classes into an online format via video conference applications. In presence, classes were replaced by online classes during most of the third term of the 2019/20 school year, and the year 2020/21 was still impacted by the pandemic, as a new period of lockdown took place in most of the second term and classes were again exclusively online. During the spring of 2021 ,presence classes were mandatory. However, isolation periods at home for those who tested positive for COVID-19 or had been in contact with someone positive.

This period was severely disruptive, with consequences that may span for years and that is still not totally accounted for. In the academic context, one of the most noteworthy immediate impacts was due to the digital divide, as students without an internet connection at home or without a computer or mobile device available to access classes were behind colleagues that could follow the curricular program and pursue their learning goals (Garcia & Weiss, 2020).

Research done during this period details some other impacts, namely for teachers, who generally felt poorly prepared for distant teaching (Steinmayr et al., 2021) due to technological difficulties and a lack of adequate class planning. They reported working longer hours and experiencing difficulties, despite their willingness to cooperate with their students. Most teachers provided distant teaching activities by sending out tasks and solutions every week. In general, students experienced less support and feedback from their teachers resulting in a decrease in the work efforts of struggling students and lower self-efficacy (Mælan et al., 2021), indicating that only assigning tasks is not enough to enhance students' learning processes. Students who reported having more support from their teachers during this period had higher levels of academic motivation (Camacho et al., 2021), an essential predictor of AA. The motivation was impacted by factors other than the teacher-student relationship, such as participation in extracurricular activities and student age: older students and those who maintained regular extracurricular activities had a lower decrease in motivation (Zaccoletti et al., 2020). ICT use escalated during the lockdown, as it was the tool for remote working and learning, indoor leisure activities to reduce social isolation, and maintaining contact with peers. Excessive time on social network sites was correlated with poorer sleep habits, absenteeism, and lower AA (Astatke et al., 2021). Adolescents reported experiencing sleep disturbances to manage academic demands during COVID-19, which impacted their mental health, and those who had greater severity of sleep disturbances (provoked by bedtime screentime) reported higher anxiety (Zhang et al., 2021). School closure brought to the attention another important social function, as students from lower-income families had most of their daily meals at school.

In Portugal, the evaluation criteria were changed in an attempt to minimize the impacts described. Students from previous years had to perform all exams of the disciplines they were enrolled in to graduate, whereas, in 2020 and 2021, students only had to take the exams they needed to apply to university. Because the evaluation conditions and criteria in this period were so particular, in our work, namely in study four, we did not compare the national exam grades of 2019 and 2020. Studies 2 and 3, however, report the internal grades that teachers attribute to students in 2021, and no particular changes in the evaluation criteria were at stake after the pandemic.

2. A WEIGHT AND META-ANALYSIS ON ACADEMIC ACHIEVEMENT OF HIGH SCHOOL STUDENTS

2.1. INTRODUCTION

Academic achievement (AA) has been a key topic of interest in many areas of knowledge, namely education, psychology, sociology, and economics (Koch et al., 2015), and involves one's family, community, and school experiences (Rivkin et al., 2005). It is usually measured through performance, namely individual students' grades in a given year, school achievement exams or standardized test scores in core subjects, grade point average (GPA), and teacher rating scales (Chowa et al., 2015).

The impact that students' AA has on individuals and overall society is a matter that has increasingly concerned researchers, mainly because of the positive effects that it has demonstrated on key aspects of society, such as improvements in development and productivity (Spinath, 2012). Research shows that international scores on mathematics and science tests are strongly related to national development and economic growth, namely because mathematics, science, and reading skills are important for the labor force (Wößmann & Hanushek, 2007).

Academic difficulties may lead to long-term patterns of school dropout, academic failure, and problems achieving a successful career in adulthood (Alexander et al., 2001). Struggling in school can also lead to externalizing problems (Ansary & Luthar, 2009; Bishop et al., 2020), especially during adolescence and high school years, which are understood to be a critical period with important implications for school achievement (Leeson et al., 2008). Given all the rapid societal transformations and the need to handle and adapt to the economic, technological, and cultural changes of societies and the competition in the job market (OECD, 2019), one can understand the importance of understanding the drivers of AA, as it is a topic that has considerable personal and social impacts. School dropout is one of the most common outcomes of school failure (Janosz et al., 2000) and is also an obstacle to economic growth and employment, as dropout harms productivity and competitiveness, and fuels poverty and social exclusion. For these reasons the Europe 2020 Strategy seeks to reduce

dropout rates and increase the number of students that complete their compulsory education, and simultaneously increasing the number of students who continue to the university level (European Commission et al., 2016). This concern is still ongoing as it is a fundamental concern in the 2030 Strategy, according to which all young people should receive better education and training, regardless of their socio-economic background, thereby leading to more and better skills.

Research in this topic is therefore of critical importance to provide decision makers with quality information to increase school success (Crain-Dorough & Elder, 2021). The interconnectedness between researchers and practitioners also enriches the range of knowledge gained, improving theory building and allowing more applicable results (Ming & Goldenberg, 2021). Most of the research done in AA has identified many factors that impact students' performance, namely characteristics of the students (Steinmayr, Ricarda; Spinath, 2008; Watts et al., 2014), of parents (Ali et al., 2020; Fan & Chen, 2001), of teachers (Akiba et al., 2007; Kalogrides & Loeb, 2013), and of the schools (Rockoff, 2004) — the four main agents related to the education process. However, most studies and reviews on this topic explore the contributions of each of these factors individually or in clusters of factors that are more related to each other. Another concern is that the literature in AA reports conflicting findings. For example, some authors show that internet access is to be highly correlated with low academic achievement (Kubey, 2001), although other studies have proved that these conclusions are not so clear since children who use the internet with more often attain higher scores (Liebert & Chou, 2001). In this line, a quantitative meta-analysis serves as a useful tool for synthesizing the results of numerous studies on a particular topic (Bowman, 2012). With our weight analysis and meta-analysis, we perform a quantitative synthesis of the findings in this area of research, identifying some of the determinants that have been more scrutinized in the literature, those that are the best predictors of success, and shed light on the contributions of each construct to AA. This meta-analysis will also promote a generalization analysis of each relationship tested with AA, thereby providing evidence regarding the conflicting results found in the academic literature (Fern & Monroe, 1996).

We will perform a weight and meta-analysis of factors that impact AA, including high school students. Although it may seem reasonable to assume that some drivers of AA may be shared across different school levels, certainly each has its own, and more importantly, with different impacts. High school was chosen because even though this particular period of school life is a part of compulsory education in most developed countries, it is the one during which most students drop out (Janosz et al., 2000). The high school period is characterized by significant changes on a personal level, namely on identity and personal and social development (Nakkula, M & Toshalis, 2006), and research shows that in adolescence, cognitive-affective variables become crucial in accounting for academic behavior, comparing to earlier years (Gonzalez-pianda et al., 2002). High school also presents changes at a curricular level, as secondary education is more narrowed down to the student's interests regarding preparation for tertiary education or pursuit of a professional career (Julien & Barker, 2009). High school success is also linked to better results in university (Kleemola & Hyytinen, 2019), thus the importance of understanding AA, to enhance social and personal development.

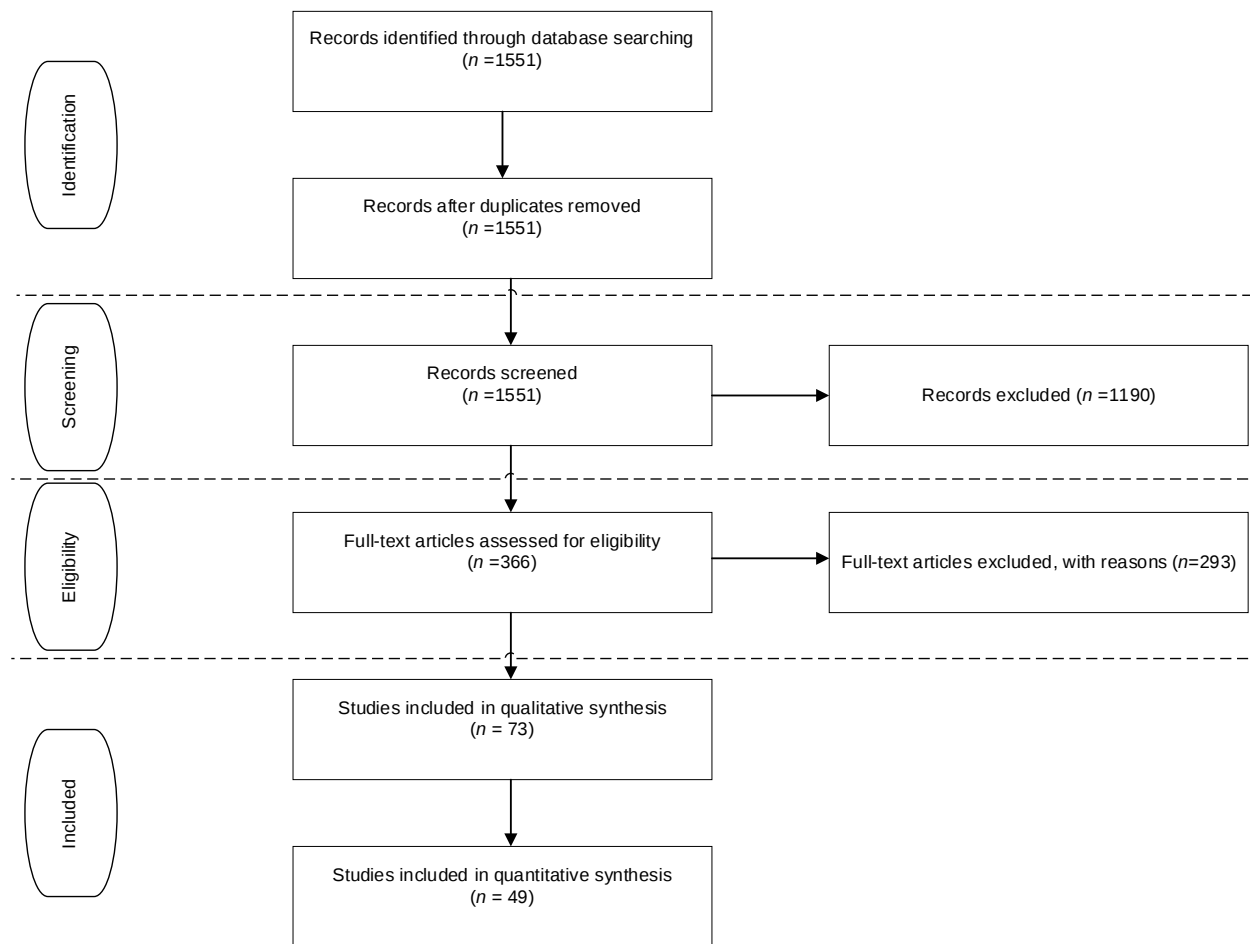
This paper's contributions are threefold. First, we contribute to a broader understanding about which of the determinants of AA have received more attention from researchers in this period of education. Second, we characterize the impact and relevance of those determinants on high school achievement. Finally, we identify the best determinants of AA, based on weight analysis and meta-analysis results.

The next section describes the research methodology. Subsequently, we present this study's results, including descriptive statistics, weight analysis, and the meta-analysis. Finally, we discuss the findings and their implications for theory and practice, and our conclusions, limitations of the study, and avenues for future research.

2.2. METHOD

2.2.1. Criteria for selection of studies

The first step in a weight and meta-analysis investigation is to formulate the problem (Cooper, 2010). We are interested in determining which factors are most studied when trying to explain the academic performance of high school students. The second step concerns how to conduct a systematic review (Cooper, 2010). For this we follow the PRISMA protocol (Moher et al., 2009) as applied in other researchers' meta-analyses (Guraya & Barr, 2018). Following the PRISMA protocol and in order to identify the factors or variables of AA, we selected studies that examined this topic as broadly as possible. Accordingly, we conducted the search on an online scientific database (Web of Science core collection) through a query combining the following terms in the title or abstract (topic): "academic achievement", "school dropout", and "academic performance", AND "drivers", "model", "research model", "conceptual model", "quantitative", "regression", and "correlation", AND "PLS", "SEM", "OLS", and "ordinary least squares", AND "student", "high school", and "secondary". The papers were peer reviewed and in English and the systematic search included all papers published until the end of 2019. This query returned 1,551 results, screened according to the following exclusion criteria: a) school year (only secondary school years were included, and we excluded studies made in elementary/primary school, junior high, or university); b) clinical population (e.g., students with dyslexia; studies that addressed drug or alcohol use); c) studies in which the dependent variable was not AA, expressed by GPA or another quantitative score (e.g., test or exam score, previous term grade, previous year grade); d) qualitative studies, scale development studies, or meta-analyses; e) training development program studies. This screening excluded 1,190 papers by reading the title and abstract only, and 293 excluded after full text reading. Following the screening, 73 papers remained for inclusion in the meta-analysis (Figure 2.1).



Note: *n* refers to the number of papers.

Figure 2.1 - Literature search, screening, and assessment process

2.2.2. Data extraction

To extract the data we applied the Rust and Cooil (Rust & Cooil, 1994) suggestion. These tasks were made by two research assistants. Before starting the data extraction process, the classification criteria were discussed among three researchers. As mentioned, two researchers performed the coding of all valid articles separately. At the end of these procedures the results were compared, and the level of agreement was 80%. For those cases of disagreement, the third researcher analyzed the differences. The procedure used for the data extraction followed that of earlier research in meta-analyses (Rosario et al., 2016).

The following items were extracted from each article: year of publication, type of relationship found with AA (e.g., independent-dependent variable), name of relational constructs, coefficient of relationships between constructs, significance (yes or no), quantitative method, sample size, school year, school subject (when available), and nationality of the sample. We identified 363 relationships between explanatory variables and AA. Figure 2.1 illustrates each step applied to identify the valid studies used in this meta-analysis.

2.2.3. Merging of variables

The analysis of the extracted data revealed that in some cases different authors gave different names to variables that measure the same construct and therefore have the same meaning. Hence, after careful theoretical review, we merged variables found in these studies that were synonyms (e.g., gender and sex), were described with different phrasing (e.g., performance approach and performance approach goals, absence and absenteeism), or were related to the same construct (e.g., cognitive confidence and academic self-efficacy).

Following the merging of variables we identified twenty relationships between variables that have been studied in our sample's papers at least three times or more (Hunter & Schmidt, 2015). In nineteen of those relationships the dependent variable was AA; the other relationship between variables present at least three times was between academic self-efficacy and performance goals. From in the initial pool of 73 papers, 24 studied only variables that did not merge with the others, i.e., were not used at least three times in explaining AA. We therefore excluded those 24 papers from the analysis. The final sample included in the weight and meta-analysis comprises 49 papers (Appendix I).

2.2.4. Analysis procedures

2.2.4.1. Weight analysis

Weight is an indicator of the predictive power of independent variables (Kline, 2013). The weight for a variable was calculated by dividing the number of times an independent variable was reported to be

significant by the number of times the independent variable was examined. In this study, we analyze the constructs' relationship strength, i.e., the influence of an independent variable over a dependent variable (AA). A weight of 1 indicates that the relationship was significant in all papers, and a weight of zero indicates that the relationship was nonsignificant in all studies.

2.2.4.2. Meta-analysis

We follow the traditional analysis used in meta-analytical studies (Santini et al., 2017) whereby the direct analysis was performed considering the Pearson's correlation coefficient (r). When studies did not report the correlation effects (e.g., Beta; t-test; F-ratio; χ^2), we used the conversion procedure suggestions of Hunter & Schmidt (2015). The effect-sizes were corrected by scales reliability and sample size (Hunter & Schmidt, 2015). As suggested by those authors, we applied the random effects model of the effect-size and considered the confidence interval index at the 95% level.

Our analysis also presented the level of heterogeneity among the studies by the Q and I² tests. Cochran's Q calculates the weighted sum of squared differences between the individual effects of the study and the combined effect of the studies (Lau et al., 1998). The I² statistic is obtained through the Q statistic. I² of 25% or lower presents low heterogeneity; I² index of 26%-50% shows moderate heterogeneity, and studies that present I² greater than 75% have high heterogeneity (Higgins et al., 2003).

We also investigated possible moderators on the significant relationships that had more than ten effects (Hunter & Schmidt, 2015). This analysis was made by a meta-regression test in which we used raw effect sizes from primary studies as a dependent variable in weighted regression analysis. The moderators coded were used as independent variables (Combs et al., 2019). All analyses were conducted by metafor R package (Viechtbauer, 2010).

2.3. RESULTS

2.3.1. Descriptive statistics

In the 49 selected papers, published between 1992 and 2019, we identified 120 relationships (independent-dependent variable) that were included in the meta and weight analyses. Table in Appendix I synthesizes the list of papers selected for our study, also indicating the school years and subjects each study refers to (when this information is available), the sample size, country, and the statistical analysis used. The total sample is 610,522 students, from 25 different countries in Europe (10), Asia (9), North America (2), Africa (2), and Australia (1). South Korea is the country with the largest sample size (487,077), and the United Kingdom (UK) the smallest (120). Although many studies choose to assess AA considering global performance in a given year (e.g., GPA), Math, Sciences, and English (either as a native or foreign language) are the main subjects considered in these studies. Few of the articles found were published before 2012, but from that year on we observe a more regular number of publications per year, showing an increasing interest in this topic.

2.3.2. Weight analysis

Table 2.1 presents the results of the weight analysis ordered by frequency of use of the independent variables. According to the weight analysis, the variables that can be considered to be the leading determinants of AA (as their weight is equal to or greater than 0.8 and are examined at least five times) are academic self-efficacy (1), conscientiousness (0.88), cognitive ability (0.88), socioeconomic status (SES) (0.86), gender (0.81), and performance avoidance (0.80). Some variables are significant in all studies, and therefore have a weight of 1, but because they are present fewer than five times are considered “promising determinants”. These include sleep habits, motivation (both present four times), absenteeism, work avoidance, and mastery avoidance (present three times).

Table 2.1 - Weight analysis results (ordered by frequency of use)

Independent variable	Dependent variable	Non-significant	Significant	Frequency of use	Weight (Sig/Freq)
Gender	AA	4	17	21	0.81
Socioeconomic status (SES)	AA	2	12	14	0.86
Academic self-efficacy	AA	0	11	11	1.00
Performance approach	AA	2	7	9	0.78
Conscientiousness	AA	1	7	8	0.88
Cognitive ability	AA	1	7	8	0.88
Agreeableness	AA	4	2	6	0.33
Performance avoidance	AA	1	4	5	0.80
Motivation	AA	0	4	4	1.00
Sleep habits	AA	0	4	4	1.00
ICT leisure use	AA	1	3	4	0.75
Extraversion	AA	3	1	4	0.25
Openness	AA	3	1	4	0.25
Absenteeism	AA	0	3	3	1.00
Mastery avoidance	AA	0	3	3	1.00
Work avoidance	AA	0	3	3	1.00
Parental involvement	AA	1	2	3	0.67
Emotional stability	AA	2	1	3	0.33
Mastery approach	AA	2	1	3	0.33

Note: Variables in bold represent best predictors (weight ≥ 0.80 and examined at least five times).

2.3.3. Meta-analysis correlation effects

We first present the results pertaining to direct relationships (Table 2.2). This table presents: (a) the effect-sizes (r) adjusted by sample size and reliability of measurement; (b) the correlations transformed by Fisher's Z-distribution; (c) the upper and lower confidence interval index (95% level), which comprises an estimate of the mean range of corrected weighted correlations (Hunter & Schmidt, 2015), and (d) the heterogeneity test of the effects by Cochran's Q test and I^2 .

Table 2.2 - Meta-analytic calculation (ordered by frequency of use)

Variables	(k)	(o)	N	r	Z	Sig	LCI (95%)	UCI (95%)	Q	I ²
Gender	20	21	571462	-0.021	-0.470	0.636	-0.109	0.067	5220.200	99.600%
SES	13	13	117088	0.183	3.420	.000***	0.079	0.284	1748.680	99.300%
Academic self-efficacy	11	11	27705	0.347	3.970	.000***	0.181	.493	969.220	98.900%
Performance approach	9	9	8930	0.147	2.620	.008**	0.037	0.254	90.780	91.200%
Conscientiousness	9	9	10981	0.119	1.390	0.165	-0.049	0.281	416.340	98.100%
Cognitive ability	8	8	50844	0.249	1.210	0.225	-0.156	0.583	7732.000	99.900%
Agreeableness	6	6	5654	-0.024	-0.391	0.697	-0.14	0.1	78.870	92.400%
Performance avoidance	4	5	3244	-0.099	-1.140	0.253	-0.263	0.07	73.220	94.500%
Motivation	4	4	21054	0.22	11.690	.001***	0.184	0.255	12.090	75.200%
Sleep habits	3	3	11799	-0.192	-2.010	0.044*	-0.366	-0.004	134.860	98.500%
ICT leisure use	4	4	8777	-0.216	-2.590	.009**	-0.368	-0.053	84.330	96.400%
Extraversion	4	4	4572	-0.044	-2.680	.007**	-0.076	-0.019	3.31^{ns}	4.200%
Openness	4	4	4617	0.075	1.340	0.179	-0.034	0.184	11.690	74.300%
Absenteeism	3	3	9271	-0.177	-1.680	0.095	-0.369	0.029	54.150	96.300%
Mastery avoidance	2	3	1908	-0.271	-2.440	.014*	-0.464	-0.055	39.570	94.900%
Work avoidance	3	3	3325	-0.219	-2.720	.006**	-0.366	-0.062	23.040	91.300%
Parental involvement	3	3	23846	0.113	2.250	.024*	0.017	0.245	122.150	98.400%
Emotional Stability	4	4	1316	0.056	1.260	0.207	-0.031	0.142	5.20 ^{ns}	42.400%
Mastery approach	3	3	4286	0.221	2.000	.004**	0.004	0.418	49.510	96.000%

Note: * p<0.05; ** p<0.01; ***p<0.001; ns=non-significant; k = number of studies used in the analysis; o=number of observations tested; r =weighted average effect and corrected from the sample obtained in studies; Z = Fisher Z effects; Sig = degree of significance of the effect size, LCI lower confidence interval; UCI upper confidence interval; Q: test of heterogeneity; I² = test of heterogeneity.

We evaluated 19 constructs that were related to AA. Eleven of these presented significant effects. Academic self-efficacy had the strongest positive effect-size ($r = .347$; $p < .001$). This analysis was obtained from 12 studies and a sample of 27,705 students. Extraversion was negatively related with achievement ($r = -.044$; $p < .01$). In this case we also observed that the effects produced by four primary studies that analyzed the relationship produced consistent findings, since the heterogeneity index was not significant ($Q = 3.31$; $p > .05$; $I^2 = 4.2\%$). In the same line, we also found a negative and significant effect on the relationship between ICT leisure use and AA ($r = -.216$; $p < .05$).

Other significant effects were related to mastery assumptions. While the relationship between mastery approach and AA was positive ($r = .221$; $p < .05$), the effect of mastery avoidance on AA was negative ($r = -.217$; $p < .05$). Both were obtained from three effect-sizes. We also noted positive and significant effects of student motivation and AA ($r = .220$; $p < .01$). These results are derived from a sample of 21,054 students distributed among four studies. Parental involvement also presented positive and significant effects on student achievement ($r = .113$; $p < .05$). About the other four significant relationships, we found that performance approach and SES socio-economic status showed positive effects on AA ($r = .147$; $r = .183$; respectively), while sleep habits and work avoidance produced negative effects ($r = -.192$; $r = -.219$; respectively).

Finally, the results also showed that eight of the relationships tested do not yield a significant effect on the students' AA. These are absenteeism, agreeableness, cognitive ability, conscientiousness, emotional stability, gender, openness, and performance avoidance. One can argue that although these features appear in some research as antecedents of AA, they can work as such in specific contexts.

2.3.4. Moderation effects

We also investigated possible moderators that could explain some heterogeneity on direct relationships found (Lipsey & Wilson, 2001). The analysis was made on the relationships between (1) academic self-efficacy and AA and (2) SES and AA. Both relationships were significant and produced

more than 10 effect-sizes. Lower numbers would be insufficient to analyze effect size changes through moderators (Hunter & Schmidt, 2015).

In this line, we analyzed the possible moderation of 1) the scores of the 2018 Program for International Student Assessment (PISA), an international assessment that measures 15-year-old students' reading, math, and science literacy every three years, 2) the Human Development Index (HDI), a statistic composite index of life expectancy, education, and per capita income indicators, and 3) Education Index (EI), a component of the HDI, measured by combining average adult years of schooling with expected years of schooling for children in each country. The PISA index was obtained by the National Center for Education Statistics (2018), the EI from the United Nations Human Development Report (2016), and the HDI from the United Nations Human Development Report (2019). The classification of each of the moderators was based on the country of origin of the data collections applied in each research. The PISA index raw scores are scaled to allow meaningful comparisons: the OECD average in each domain (mathematics, reading, and science) is 500 and the standard deviation is 100; the EI and HDI scores vary from .001 to .999. Table 2.3 presents the moderation analysis results.

As seen in Table 2.3, none of the moderators obtained significant effects. This may indicate that the impact of the variables academic self-efficacy and SES in the studies present in this meta-analysis is relatively stable across countries, regardless of being a developed or developing country, as none of the possible moderator variables explored explain variance in our results.

Table 2.3 - Meta-regression analysis

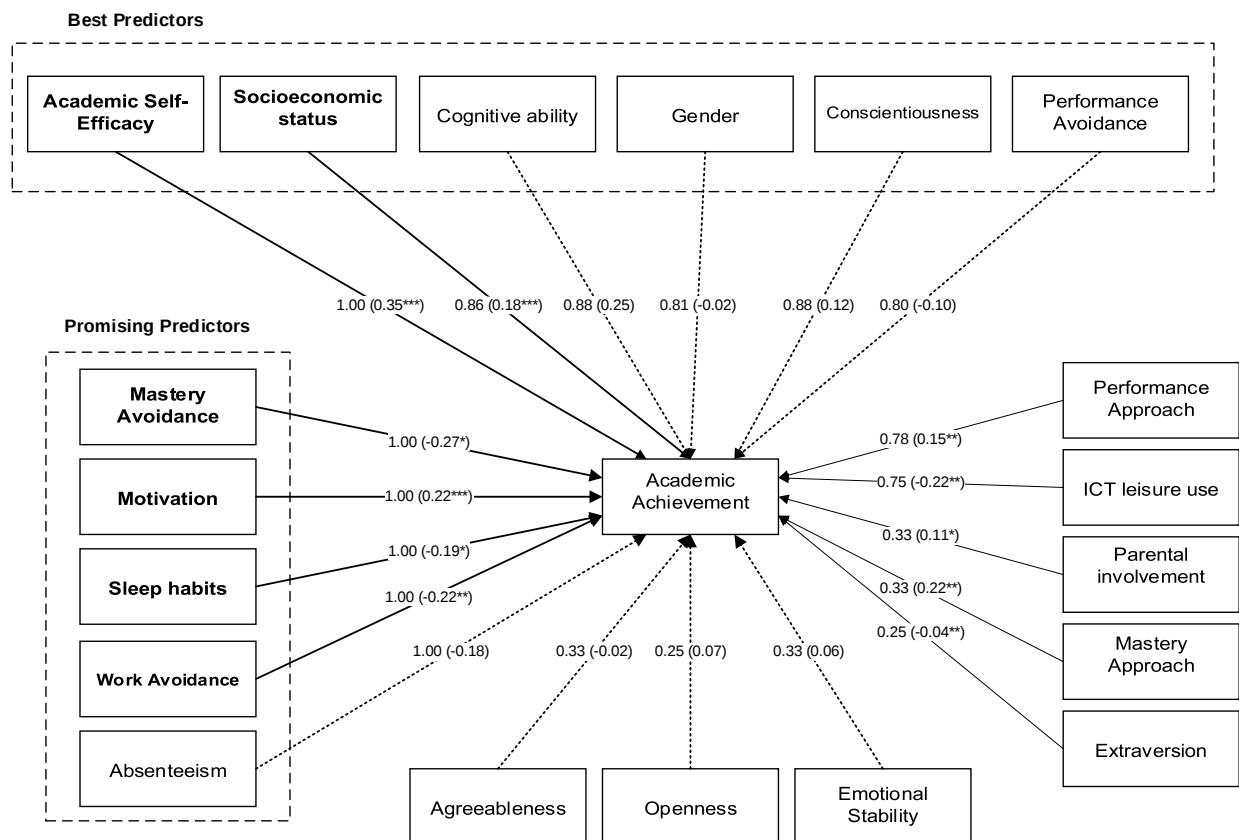
Academic self-efficacy and AA					
Moderator	β	z	CI(L)	CI(U)	p
Intercept	0.897	0.911	-0.890	-2.680	0.325
PISA x ASE	-0.002	0.001	-0.004	0.001	0.208
HDI x ASE	0.375	1.560	-2.690	3.440	0.811
EI x ASE	-0.124	0.933	-1.950	1.700	0.089
Socioeconomic status (SES) and AA					
	β	z	CI(L)	CI(U)	p
Intercept	1.267	1.530	-1.730	4.260	0.408
PISA x SES	-0.001	0.002	-0.005	0.003	0.587
HDI x SES	-1.900	4.090	-9.910	6.110	0.642
EI x SES	1.310	2.730	-4.050	6.740	0.632

2.3.5. Major findings

Figure 2.2 presents the combined results of the weight and meta-analysis. Values represent the weights obtained by weight analysis, and in parentheses are the weighted average effect values obtained in the meta-analysis. Best and promising predictors as determined from the weight analysis are represented: best predictors have a weight of at least 0.80 and are present five or more times in the analysis, and promising predictors have a weight of 1 but are examined fewer than five times.

The results show that the best predictors of AA are academic self-efficacy, socioeconomic status, cognitive ability, gender, conscientiousness, and performance avoidance. Of these best predictors, the ones that are statistically significant in the meta-analysis are academic self-efficacy and socioeconomic status. The promising predictors that are statistically significant are motivation, sleep habits, mastery avoidance, and work avoidance. Absenteeism is also a promising determinant (weight of 1, but present only four times in the analysis), but it showed to be not significant in the meta-analysis. The

determinants found to be least important are agreeableness, openness, and emotional stability, as they were all non-significant and have low weight values.



Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. Values represent weight and the effect-sizes (r) adjusted by sample size, and reliabilities of measurement are in parentheses. Full lines represent significant paths.

Figure 2.2 - Final weight analysis and meta-analysis results model.

2.4. DISCUSSION

The results of this paper show that AA is a widely studied topic that interests researchers from different areas and is a topic that has become increasingly prominent in the literature, with a growing number of published papers in the last decade. Paradoxically, there is a plethora of studies with apparently contradictory findings, and there is a lack of studies summarizing the literature with the goal of shedding light on such an important topic, as is AA. Our goal is to contribute to this synthesis of the drivers that are the best and most significant predictors of AA.

From the weight analysis the following variables emerged as best predictors of students' success in high school (independent variables that were examined five or more times and with a weight of at least 0.80): academic self-efficacy, socioeconomic status, conscientiousness, cognitive ability, gender, and performance avoidance. All of these variables except performance avoidance have a positive impact on AA, but only academic self-efficacy and socioeconomic status are statistically significant in the meta-analysis.

Academic self-efficacy refers to an individual's belief that (s)he can successfully achieve a specific academic goal at a designated level on an academic task (Bandura, 1997). Socioeconomic status (SES) measures in this analysis derive from self-reported or self-perceived values and school record information. Students' SES background depends upon family income, level of education, and occupation status and, not surprisingly, is a significant determinant of AA, as social and economic conditions may influence youngsters' functioning and development (Conger et al., 2002).

Conscientiousness is a personality trait present in the Big Five Model related to self-control, ability to plan, and being efficient and organized (Digman, 1997), and cognitive ability, as operationalized in the papers in this meta-analysis, is a quantitative measure of general intelligence (g factor), i.e., the ability for reasoning, problem solving, complex idea comprehension, and learning from experience (Gottfredson, 1997).

Cognitive ability is one of the most studied predictors of AA, and research has consistently demonstrated it to be an important predictor of success in school (Rohde & Thompson, 2007) and in adult life (Furnham & Cheng, 2016). Concerning gender, our results are consistent with literature: females tend to perform better than males. However, some authors have shown that males outperform females in specific mathematics abilities (Brunner et al., 2008), so this analysis could be useful for clarifying gender impact on AA. The only determinant identified in the weight analysis as one of the best predictors of AA that has a negative impact is performance avoidance, i.e., the desire to

avoid performing more poorly than others do (Darnon et al., 2007). Performance avoidance is consistently linked to a number of negative outcomes, such as anxiety and decreased performance (Baranik et al., 2010), thus explaining its negative impact on AA.

Other relationships between variables evaluated five or more times in this study were found to be significant in the meta-analysis but obtained a weight slightly below 0.80. This is the case for performance approach (weight = 0.78), for which further research could help to assess the actual impact on AA. The AA determinants that have the lowest weight value (0.25) are extraversion and openness, personality traits that are part of the Big Five Personality Model (McCrae & Costa, 2008), suggesting they probably are not among the most relevant for AA research.

Our weight analysis and meta-analysis results allow us to draw a model of the predictors of high school achievement across countries, the best being academic self-efficacy and social economic status, and to identify other seemingly important antecedents of AA (weight of 1, but present fewer than five times in this analysis), which are motivation, sleep habits, work avoidance, and mastery avoidance. These last three antecedents have a significant negative impact on AA and should continue to be considered in future research in order to clarify their importance in student achievement. Absenteeism, although not statistically significant in the meta-analysis, is also a promising predictor of AA. These results highlight the importance of the students' habits outside school, and further conclusions can help parents, teachers, and other educational agents in promoting better conditions to enhance AA.

We analyzed the possible effect of moderators in two relationships found in this meta-analysis: academic self-efficacy and AA, and SES and AA. The data samples used in this study belong to countries that have different classifications in terms of social and economic development, such as Norway, USA, Dominican Republic, and Iran. No significant results were found for the moderators (PISA index score, Human Development Index, and Education Index score of each country), which seems to indicate that

both of these determinants (academic self-efficacy and SES) influence AA in a manner that is independent of the students' country of origin.

Survey driven measures, such as the ones in most studies presented in this work, have been widely used in AA research. Recent research (Bernardo et al., 2021) has suggested that data-driven research using machine learning techniques could complement the more traditional research approach and produce more accurate results, capitalizing on the great amount of information available to educational institutions (Fischer et al., 2020). Cruz-Jesus et al (Cruz-Jesus et al., 2020), for example, employed artificial intelligence techniques to assess AA drivers in high school, using a database from all public high schools in Portugal, containing demographic information, financial information of students' families, and information about the school and the area in which the school is located. These authors found that the students' previous academic record (namely if the student had failed previously) and gender (females outperforming males) are the variables that impact AA the most, whereas, and contrary to what previous research had suggested (Bosworth, 2014), class size does not significantly affect students' achievement. Apart from gender, none of the other variables identified by these authors emerged in our analysis, suggesting that the use of AI methods could bring new valuable insights for this area of research.

2.4.1. Theoretical implications

This paper contributes to theory by assessing, through an analysis of relevant literature, what the main drivers of AA are. To the best of our knowledge, no research addresses meta-analysis combined with weight analysis in the context of AA. Using these analytical methods, we contribute to research by identifying the most used determinants, their significance, and their impact, and what the best predictors of AA are, thus allowing us to synthesize knowledge from a very broad area of research.

According to our results, one of the most important drivers of AA is academic self-efficacy, a variable that impacts AA positively. Students who have a high level of academic self-efficacy tend to have a

greater level of participation in class and exert greater effort studying, which will increase their final score (Galyon et al., 2012). Research also that academic self-efficacy moderates the relationship between future orientation (i.e., students' expectations about the outcomes of their academic path) and AA (Mazzetti et al., 2020). Our study also allowed us to assess the impact of all four dimensions of the achievement goals framework (Elliot & Murayama, 2008) on high school students' AA. According to this framework, individuals who have a strong mastery orientation feel competent at a task when they have mastered the task itself or when they have improved relative to their own past performance, whereas individuals who have a strong performance orientation feel competent at a task when they have performed well on the task relative to others.

Considering the impact of performance approach (i.e., the desire to outperform others), previous research findings are not consistent, showing that although it is a driver of success, it is also related to negative outcomes, namely because of increased levels of performance anxiety (Hulleman et al., 2010). Our results, however, highlight a positive significant impact of performance approach on AA, suggesting that at the secondary education level, the motivation to perform better compared to others can be more beneficial than detrimental. Our results also reveal a positive impact of mastery approach on AA, which is consistent with earlier empirical research reporting that this driver is linked to several positive achievement outcomes through increased self-efficacy, adaptive learning strategies, and feedback-seeking behaviors (Payne et al., 2007). Performance avoidance and mastery avoidance are both determinants with a negative impact on AA, and the impact is significant for mastery avoidance, suggesting that when preventing failure, it is the self-evaluation of past performance rather than comparing with other students that matters the most, although from earlier research we would have expected a stronger relationship between performance avoidance and AA (Baranik et al., 2010).

Some predictors in this study did not have a significant impact on AA, namely conscientiousness, a contrasting result compared with recent findings (Dumfart & Neubauer, 2016) indicating conscientiousness is a crucial noncognitive predictor for school achievement when compared to other

predictors such as self-efficacy, grit, and anxiety, and should be focused on when supporting students and improve their performance. Our results, however, highlight context specific determinants such as academic self-efficacy as more relevant and more worthy of such focus.

2.4.2. Practical implications

Academic success has important personal and societal outcomes. Findings from this study raise implications that could be of interest to policy makers, schools, and teachers. Specifically, understanding which among the variables studied herein are the ones that are the best predictors of AA, yields valuable information highlighting new policies or interventions could be directed to enhance academic results.

Considering academic self-efficacy is one of the most important determinants of AA, school management and teachers could implement academic self-efficacy enhancing interventions such as teaching study methods and test-taking skills in order to reduce performance anxiety (Schunk & Ertmer, 2000), thus increasing students' belief that they will succeed academically. These interventions would convey benefits for students with low academic self-efficacy, who are usually less motivated to thrive (Bakadorova & Raufelder, 2016). Our results also suggest other ways of improving AA, such as interventions designed to minimize the negative impact of mastery avoidance and work avoidance – specifically discussing with students the influence of previous academic failure on their performance and helping them to set personalized and attainable achievement goals. Combined with school environment interventions, such as the ones discussed, others involving families and schools seem to convey good results: parental involvement is a strong predictor of student AA (Wilder, 2014) and our results demonstrate a positive relationship between parents' involvement in school life and AA. Previous research has highlighted that the combination of strong school–family relationships and high levels of parental satisfaction with school lead to better results (Hampden-Thompson & Galindo, 2017). Therefore, facilitating ways to engage parents in their children's academic path, and enhance communication with schools are seemingly beneficial to increase performance. Parental involvement

can be contingent on the family's SES, as not all families have the same availability or social capital to participate in students' school life. Although SES is a relatively stable condition and difficult to change, research suggests that social inequalities can be attenuated by interventions based on the sociocultural-self model, as targeting individual attributes can help underprivileged students form and sustain a positive self-concept, increasing AA (Li et al., 2020). Research also shows hope is a significant mediator between SES and AA (Dixon et al., 2018), meaning that SES gaps can be overcome if students' hope is increased.

Our results show that ICT leisure use impairs AA, thus policy changes in schools to minimize the impact of this variable, such as the restraint of mobile phone use in the classroom or monitoring of students' time spent on internet (on social media, gaming, etc.) could increase AA. The concern with ICT leisure use should also be considered outside school. Internet and technology use play an immense part in everyday activities of human life, and are also considered an asset for learning, yet their excessive use has been linked to addiction behaviors (Toozaandehjani et al., 2021; Xu et al., 2012). Research has shown that parental monitoring of students' internet usage should be done carefully, as mere dissuasion may not be an effective strategy, and some authors suggest alternative means such as rationalization, and communication should be preferential (Venkatesh et al., 2019).

Poor sleep habits, although a common characteristic in adolescence, also diminish AA, and are antecedents of other problems such as smoking, alcohol usage, and high anxiety and depression scores. Seemingly, high school students would benefit from more guidance from parents, school authorities, and health professionals when it comes to sleep and sleep habits (Saxvig et al., 2012).

2.4.3. Limitations and future studies

As stated above, AA is a vast topic that interests researchers from different areas of knowledge. We present an analysis based on a small number of papers, which are only a small portion of the existing literature on this topic. The fact that we selected only papers written in English can also mean we left

out relevant literature in other languages and, for the type of analysis conducted, we also left out qualitative studies.

2.5. CONCLUSIONS

This paper performs a meta-analysis and weight analysis on the determinants of AA in high school of 49 papers published across 27 years (1992-2019). We identify some of the best and most promising predictors of high school AA and their significance, thus contributing to an integrated and synthesized view of an extensive topic of research such as AA. The results show that academic self-efficacy and socioeconomic status are the variables with the greatest impact on AA, while motivation, sleep habits, absenteeism, work avoidance, and mastery avoidance are promising determinants that should be further explored in research. We critically discuss these results, framing them in the findings reported in the existing literature, and propose a model of the synthesized determinants of AA that could be of use for researchers, by providing information about the main constructs to be included in AA research models, and for parents, teachers, and other stakeholders to support policies and interventions aimed at helping students achieve better results.

3. DETERMINANTS OF ACADEMIC ACHIEVEMENT: HOW PARENTS AND TEACHERS INFLUENCE HIGH SCHOOL STUDENTS' PERFORMANCE

3.1. INTRODUCTION

Education is the base of countries' economic prosperity and development (Hanushek & Woessmann, 2020). High-ranking countries in the OECD's Program for International Student Assessment (PISA), a triennial evaluation of student skills in Math, reading, and science, are also the countries with a higher Gross domestic product (GDP). Economic prediction models have shown that an increase in PISA scores can yield significant economic gains (Hanushek & Woessmann, 2010). Work and education play a central role in establishing social status, security, and income (Robertson, 2014). The profuse technology advances in the past decades have made the skills required for career success evolve quickly and require an ever-higher degree of specialization. Highly educated people are better equipped to deal with these challenges, as they are more skilled and able to adapt, thus accomplishing individual growth, better jobs, higher socioeconomic status (SES), and cultural capital, and at the same time contributing to social and economic development (Power, 2015).

Research has focused on understanding the determinants of academic achievement (AA), i.e., why some students succeed while others struggle to achieve (Koch et al., 2015). This research string is of particular interest to policymakers as it informs on how to promote AA and develop educational strategic plans, which are essential to granting equity in access and opportunities for every student to complete their education, reducing the impact of any prior factors that may lead to inequality (European Commission, 2016). Students are understandably the leading agents in their learning and achievement, yet teachers and parents also greatly influence school progress (Hughes & Kwok, 2007). During high school, student-teacher and parent-children relationships are pertinently relevant, as this school period overlaps with adolescence, in which identity, autonomy development, and concerns about the future can be emotionally challenging for teenagers, increasing the chance to exhibit externalizing behavior (Ansary & Luthar, 2009; Bishop et al., 2020). Research shows that the quality of

relationships students maintain with teachers, and parents can help them stay engaged in high school to a greater extent than the quality of relationships with peers (M. Te Wang & Eccles, 2012).

In this study, we intend to explore the determinants of AA considering this student, parent, and teacher interaction in Portuguese high schools. Portugal has been seen as a particular case concerning PISA scores. Starting from an unfavorable position compared to the OECD average, the country has shown consistent growth in ranking since 2000, unlike any other OECD country, primarily due to significant changes in educational policies (Marôco, 2021). However, 2018 results show there are still striking discrepancies that account for inequality in education. For example, the score difference in Math between the top 10% of students with the highest scores and the bottom 10% of students with the lowest scores is one of the largest among PISA-participating countries and economies. The average difference in the reading scores of advantaged and disadvantaged students is also above average, with disadvantaged students showing higher retention rates (OECD, 2022). The fact that such progress in PISA results has been made highlights the importance of changing policies; however, the results also show a gap not only within this generation but between these students and high schoolers from previous generations.

In Portugal, all high school students must attend Math and Portuguese (native language) classes, regardless of the vocational course in which they are enrolled. These are considered crucial subjects in compulsory learning that are important to establish competencies and gain access to post-secondary education. Portuguese language skills in high school are oriented to further developing literacy development, interpretation, and linguistic reflection (Buescu et al., 2015). High school Math goals aim to assimilate reasoning and abstract thinking further. Math has the reputation of being one of the most challenging subjects in school, and many students suffer from Math anxiety (Leshem & Markovitz, 2013). This issue is not so common in reading-related subjects (native or foreign language, for example). We propose a conceptual model exploring how determinants related to students, teachers, and parents influence secondary school level Portuguese and Math scores. Student determinants are

previous retention (i.e., having failed at least a year in school), previous achievement, ICT use, and age; as for teachers, we assess the influence of their (pedagogical and social) involvement on AA; parents' expectations, parental education, and educational allowance (SES measure) are the determinants concerning parents. We aim to shed light on the importance of each determinant to student performance in two subjects essential for a successful career. Career choice and preparedness for adult life is a significant matter in high school as it is associated with both positive and harmful psychological, physical, and socioeconomic inequalities that persist beyond youth (Robertson, 2014); thus, the importance of understanding AA in secondary school.

The main contributions of this study are twofold. First, we intend to develop and test a comprehensive model of AA in high school, comparing students', teachers', and parents' contributions to achieving better grades, informing opportunities for AA improvement, and producing reliable insights for decision-makers in education. Second, because this investigation also compares the determinants for AA in Portuguese and Math in the same model, it allows for a critical overview of the similarities and differences between AA in these two core subjects, which are mandatory for graduation, as they are common to all high schoolers' curricula, regardless of the area of studies in which they are enrolled. The paper is organized as follows: Section 3.2 consists of a relevant literature review and hypotheses development, Section 3.3 details the applied method, Section 3.4 focuses on the results, and finally, Section 3.5 discusses the results and implications of the research.

3.2. LITERATURE REVIEW AND HYPOTHESES

AA is measured through performance outcomes such as individual students' grades, school achievement exam grades, standardized test scores, or grade point averages (Chowa et al., 2015). These outcomes are an expression of the extent of accomplishment of students' learning goals and represent the results of the learning developed during all school years. Understanding what determines AA is essential, particularly for the benefit of low achievers with enduring academic difficulties, who tend to be at risk of dropping out and suffering problems in adulthood (Gottfried &

Plasman, 2018). School dropout is linked to poverty, social exclusion, and obstacles to pursuing a prosperous professional career (Koc et al., 2020). High school completion is fundamental to achieving a successful professional career or university education, as it is mandatory in most developed countries, including Portugal. Nevertheless, despite having decreased in the past decades, high school dropout rates are still a concern.

AA determinants have been extensively described in the literature, namely determinants pertaining to students (Steinmayr et al., 2018a) but also teachers (Ober et al., 2021) and parents (Castro et al., 2015; Situmorang & Salim, 2021) who play a pivotal role in student life, education, and ability to make good career decisions.

3.2.1. Students

Students' cognitive ability, measured by psychometric tests, has been considered a major determinant of AA (Deary et al., 2007). General intelligence and other cognitive abilities correlate with Math scores (Taub et al., 2008); however, research has shown that a much wider number of factors interact to explain AA (Galindo-Rueda et al., 2005). In fact, individual psychological attributes such as personality traits, motivation, academic engagement, self-efficacy beliefs, and grit are positive determinants of AA, as they influence students' pursuit of learning goals, work efforts, and performance (Steinmayr et al., 2018a). Abstractedness and perfectionism also predict better educational results (Mateus et al., 2021), while anxiety due to self-esteem issues impairs AA (X. Liu et al., 2019, 2022). Recent research found that motivational and personal predictors at the high school level are more critical to explaining AA than cognitive abilities. In fact, the importance of cognitive abilities decreases significantly as students advance to graduation (Tikhomirova et al., 2020). The motivational and personal predictors are linked to students' academic track records, i.e., the progress students have made during their school years and their achieved academic results. Previous achievement is a positive predictor of AA (Cruz-Jesus et al., 2020; Phan, 2012) due to the cumulative nature of learning and knowledge acquisition throughout all school years. Past achievement encompasses students' history of successes

and failures that impact AA and motivation (Gareau et al., 2019). For students with persistent academic difficulties, failing a year can impair AA significantly. Research shows that not only does grade retention not provide significant benefits (Jimerson, 2001), there is evidence that there is a higher probability for a previously retained student to fail a year again (Cruz-Jesus et al., 2020). A recent study in Portugal on elementary school retention shows meager retention benefits before 4th-grade completion on 6th-grade exam scores (Nunes et al., 2018). These benefits tend to fade at later stages, as failing 8th grade affects the likelihood of high school completion (Jacob & Legfren, 2009). Grade retention negatively impacts self-esteem, academic self-concept, and homework completion and contributes to higher maladaptive motivation and absenteeism (Martin, 2011). Retention has been linked to stigmatization by peers, particularly during early adolescence, aggravating behavioral and socioemotional adjustment problems (Anderson et al., 2011). Considering the impact of student track records, we propose the following hypotheses:

- H1a Previous retention negatively impacts Portuguese AA.
- H1b Previous retention negatively impacts Math AA.

Academic track records are part of the information teachers have about their students at the beginning of every school year. Research shows teacher behavior toward students who have failed is contingent upon their perception of student capabilities and effort. In some cases, teachers show a tendency to give up on the efforts to help the student improve (Georgiou et al., 2002). However, according to Anderson et al.(2011), one of the principal explanations for the negative impacts of retention is the absence of specific remedial strategies, which we believe can be implemented by teachers directly, fostering a positive cycle of interaction where higher involvement from teachers will produce better results. Thus, we propose the following:

- H1c Previous retention moderates the relationship between teacher involvement and Portuguese AA in such a way that the effect is more positively significant than for non-retained students.
- H1d Previous retention moderates the relationship between teacher involvement and Math AA in such a way that the effect is more positively significant than for non-retained students.
- H2a Previous achievement positively impacts Portuguese AA.
- H2b Previous achievement positively impacts Math AA.

AA also depends on students' demographic factors, such as age, nationality, and gender. Older students typically perform worse (Tolen & Quinlin, 2017). The AA of non-national students or those whose parents are immigrants is contingent on how well they have adapted to school (Portes & Rumbaut, 2005). Girls typically achieve higher than boys (Mensah & Kiernan, 2010), yet boys score better in specific Math skills (Brunner et al., 2008).

Over the past few years, high schoolers have increasingly become avid internet users, mainly due to the massification of ICT access. There are striking benefits of ICT use in many areas, yet the impact on AA is still controversial, as both gains and losses for learning have been identified. Although ICT is an essential tool for education, ICT use for leisure has escalated, especially among teenagers. Excessive internet use for hedonic purposes (for instance, spending too much time on social media, online games, etc.) elicits lower academic results due to sleep disturbances and neglect of study time (Kubey, 2001), lower general health, and a higher chance to develop internet addiction, and engaging in risky behaviors (Toozandehjani et al., 2021). However, moderate computer use and video gaming have positively influenced high school AA (Bowers & Berland, 2013; Simões et al., 2022). Research has also demonstrated that students who have a higher internet usage frequency tend to perform better (Torres-Díaz et al., 2016) and students with computer access, i.e., who do not only rely on a cell phone for internet access, and students with better digital skills typically outperform their peers (Hampton et al., 2021). We therefore propose:

- H3a ICT Use positively impacts Portuguese AA.
- H3b ICT Use positively impacts Math AA.

A framework of ICT usage's impact on adolescents has considered demographic factors such as gender, socioeconomic attributes, perceived academic achievement, and relevant use type (Judi et al., 2013). According to UTAUT (Venkatesh et al., 2003), age is a moderator of technology usage behavior. We propose that age is another demographic factor that may be important in assessing the impact of ICT use. Older teenagers are not only more expert users of ICT, as they tend to have more autonomy and less parental guidance compared to younger peers. Therefore, older teens are probably more likely to engage in excessive ICT use, thus suffering from the negative consequences that, according to the literature, impact AA, suggesting the following hypotheses:

- H4a Age moderates the relationship between ICT use and Portuguese AA in such a way that for older students, ICT use impairs Portuguese AA.
- H4b Age moderates the relationship between ICT use and Math AA in such a way that ICT use impairs Math AA for older students.

3.2.2. Teachers

Teachers' influence is also a significant determinant in explaining students' AA (Rockoff, 2004). Previous research in Portuguese high schools assessed the impact of teacher gender, employment situation, education level, and experience on student AA. The results revealed that classes with female teachers and those with more experienced teaching staff typically achieve higher AA. In contrast, negative impacts were found for teachers who work away from home. Younger teachers who are less experienced have less stable contracts and are more likely to work away from home, which can account for these differences. The education level effect (BSc vs. MSc or Ph.D.) was insignificant (aaa et al., 2016). Teachers who communicate higher expectations about student performance help improve students' academic self-concept and AA (de Boer et al., 2018).

Besides pedagogical involvement, student perception of teacher social involvement and emotional support increase engagement and academic resilience (Romano et al., 2021), leading to better results. Teenagers' urge for independence from their parents may strengthen student-teacher relationships in high school: students rely on teachers for help in planning their careers and even for support in their decision-making process (Wong et al., 2021). Student perceived support of their teachers is a strong positive predictor of AA (Chen, 2005), leading us to propose:

- H5a Teacher involvement positively impacts Portuguese AA.
- H5b Teacher involvement positively impacts Math AA.

3.2.3. Parents

AA is determined by the specificities of the student's family, such as parental expectations, education level, SES, and cultural capital. Family background is critical for student development and adjusting to school life and demands. In fact, parents from lower educational backgrounds struggle to value education, give the necessary support in school matters, and provide the resources needed to improve AA (Sirin, 2005). Most research found that parental involvement in their children's academic path positively influences AA (Castro et al., 2015; Fan & Chen, 2001). Parents' participation in school matters builds students' coping mechanisms and develops appropriate behavioral attitudes that lead to success (Hill & Taylor, 2004). Parents who are more involved tend to have higher expectations regarding their children's academic path and professional future, and these high expectations improve motivation for school work and yield better results (Lee & Bowen, 2006). The benefits of parental involvement are more noticeable for disadvantaged families (Benner et al., 2016; Poon, 2020), who participate less actively. Schools and teachers play an essential role in promoting expectations and developing parental involvement skills (Ali et al., 2020). In Portugal, there is a public discussion about future living conditions and employment of young adults, emphasizing the importance of education to achieve more steady jobs. This aspect leads us to believe parental expectations about their children's

academic path and professional future are a critical dimension of parental involvement, so we developed the following hypotheses:

- H6a Parental expectations positively impact Portuguese AA.
- H6b Parental expectations positively impact Math AA.

AA is positively linked to higher parental income, higher education levels, and the parents' occupation type (Steinmayr, Dinger, et al., 2010; Tomul & Savasci, 2012a). In fact, middle school students with university-educated parents achieve much higher levels than their peers whose parents did not pursue post-secondary education (Chesters & Daly, 2017). Students with highly educated parents usually have better results, as parents are typically more involved and supportive of school matters. They can help students in a way that parents with less cultural capital cannot, for instance, by engaging in academic discussions with their children (Tan et al., 2019). Regarding parental education, we propose the following:

- H7a Parental university education positively impacts Portuguese AA.
- H7b Parental university education positively impacts Math AA.

Students from socio-economically challenged families typically attain lower levels of development in communication, language, literacy, and mathematical skills. Children who receive financial support for educational purposes (i.e., state-granted educational allowances) tend to perform worse than their peers (Archibald, 2006; Delen, 2010). Likewise, early motherhood, low maternal qualifications, low family income, and unemployment predict lower scores at school (Mensah & Kiernan, 2010). In Portugal, lower-income families can apply for state-granted educational allowances to help bear education costs. Lower-level SES predicts low scores, so considering educational allowances as a proxy for lower-income, we propose:

- H8a Receiving educational allowances (due to lower SES) negatively impacts Portuguese AA.

- H8b Receiving educational allowances (due to lower SES) negatively impacts Math AA.

3.2.4. Conceptual model

Figure 3.1 illustrates our proposed model based on previous AA literature. We defined which constructs to include in our model according to the student-teacher-parent interaction in high school life. Constructs related to the student were previous retention, previous achievement, ICT use, and age. As for teachers, we measured student perception of teacher involvement. Constructs pertaining to parents are student-perceived parental expectations, parental education, and educational allowance. Gender and legal guardian mother were control variables, and age was only present as a moderator between ICT Use and AA. For each construct, at least two research hypotheses were developed, one relating to Portuguese AA and the other to Math AA, thus allowing to compare the impact of each determinant in these two subjects, mandatory for all students to conclude high school in Portugal.

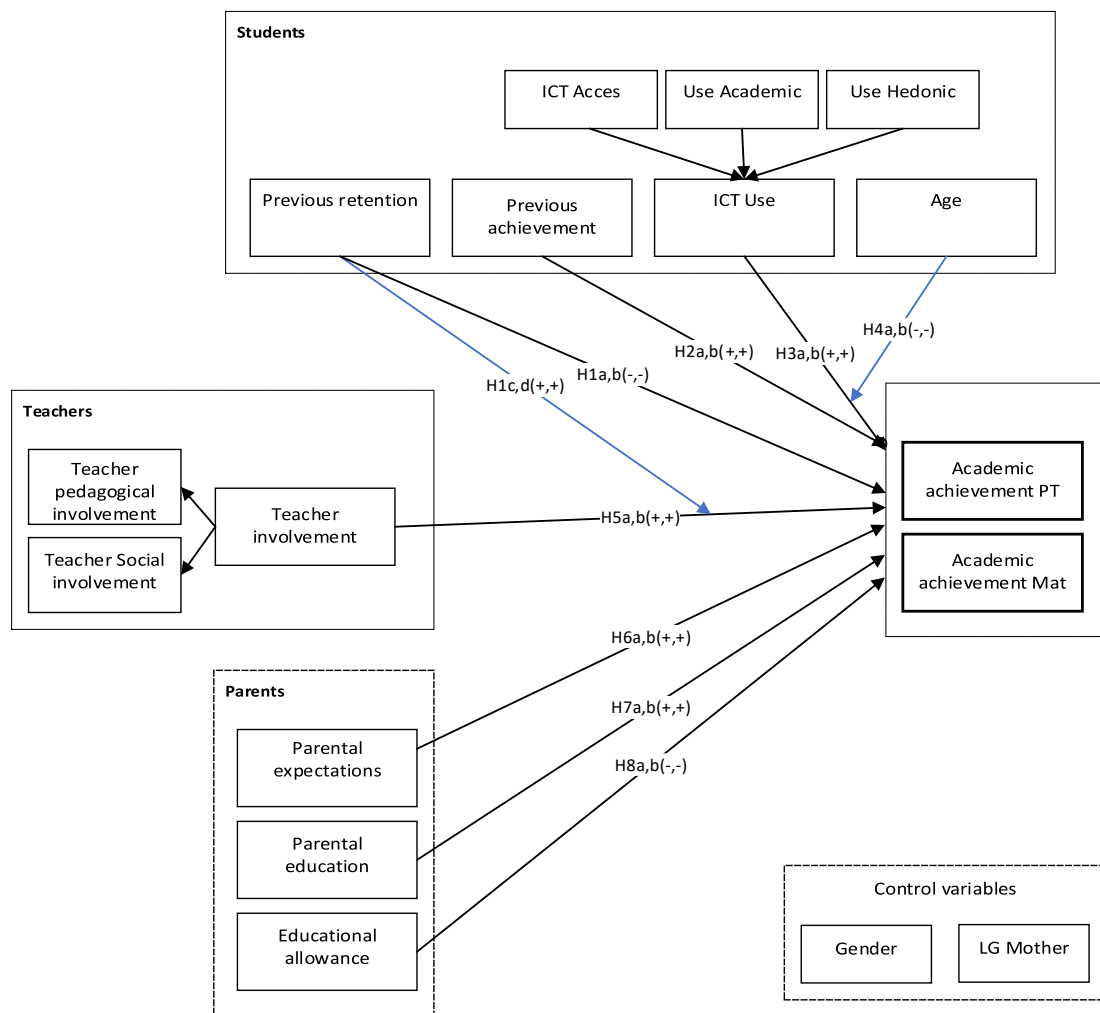


Figure 3.1 - Conceptual model and hypotheses

3.3. METHOD

3.3.1. Participants and procedure

We surveyed public high school students in the 10th, 11th, and 12th grades. The public sector was chosen because around 80% of all students in Portugal attend the public education system. Therefore, it is more representative than the private education sector, which is typically an option only accessible to more privileged families. The survey had an estimated completion time of ten minutes. It was designed online (Qualtrics XM) and was e-mailed to 44 schools across the country, along with an invitation and presentation of the study. Data were collected online due to the government's

restrictive measures and school directions imposed during the COVID-19 pandemic. As compensation for schools' participation, a short report with the main findings was sent to school directors.

The questionnaire was answered online and was comprised of closed questions about the constructs included in the conceptual model (please see Appendix II): previous student retention, previous achievement (Day et al., 2010), ICT use, including academic and hedonic use (Tang & Patrick, 2018), student perception of teacher (social and pedagogical) involvement (Johnson & Johnson, 1983), student perception of parental expectations towards their academic path (Veas et al., 2015), and sociodemographic information (parental education (Chesters & Daly, 2017), educational allowance, gender, age, legal guardian). AA measures were the self-reported students' grades in the core subjects Portuguese and Math in the current school year. It is worth mentioning that both these subjects are compulsory in all three years of high school, regardless of the course students are enrolled in, and their completion is necessary for secondary education graduation.

Participants were informed of the voluntary condition of their participation and the use of their data (anonymous, confidential, and strictly for the purposes of this research). The survey was approved by the NOVA IMS Ethics Committee, the MagIC Research Centre, and the Directorate-General for Education of the Portuguese Ministry of Education. This approval meant students could consent to their participation in the study, dismissing the need for their legal guardians' consent.

3.3.2. Data

A pilot study with 37 students was conducted to help assess the instrument, allowing us to ensure the viability of the measurement scales and the appropriateness of the instrument to fulfill our research goals.

Data collection took place between April and November 2021. The final survey data, which only considered the fully completed responses, amounted to 220 valid responses from 404 answers. AA was measured through self-reported grades on a scale of 0-20 for Portuguese ($M= 14.67$, $SD=2.39$) and

Math ($M=13.97$, $SD=3.49$) of the current school year. Participant ages varied from 16 to 23 years old; students aged 18 or over can become their own legal guardians, meaning they make all decisions regarding their schooling. Sample demographics are detailed in Table 3.1.

Table 3.1 - Sample characteristics

Measure	Value	%	Frequency
Gender	F	62.7	138
	M	35.0	77
	Other	2.3	5
School year	10	13.2	29
	11	38.2	84
	12	48.6	107
Age	16	44.5	98
	17	43.2	95
	18	10.9	24
	>18	1.4	3
Legal guardian	Mother	77.3	170
	Father	20.9	46
	Self	0.9	2
	Other	0.9	2
Parent education level	Less than 12 years (high school not complete)	14.5	32
	12 years (high school graduate)	35.5	78
	More than 12 years (tertiary education)	45.9	101
	Don't know/Don't want to answer	4.1	9
School allowance	Yes	13.6	30
	No	71.8	158
	Don't know/Don't want to answer	14.5	32
Parents nationality	Portuguese	85.9	189
	Other	14.1	31

3.4. RESULTS

Structural equation modelling (SEM) was used to test the relations estimated in our theoretical model and its effects. We opted for partial least squares (PLS-SEM), a variance-based SEM technique due to this research's exploratory nature, to identify key driver constructs of AA. It is a method that works better than covariance-based SEM on complex models, allowing for smaller sample sizes and less restrictive assumptions on data while incorporating reflective and formative constructs (Henseler et al., 2009a).

We used the PLS-SEM method as the recommended two-step approach that first tests the reliability and validity of the measurement model and then assessed the structural model (Anderson & Gerbing, 1988) with the SmartPLS 3 software (Ringle et al., 2015).

3.4.1. Measurement model

Measurement models measure the relation between the latent variables and their indicators for both reflective and formative constructs. In this study, all constructs are reflective except ICT use, which is formative.

Table 3.2 shows that the composite reliability (CR) is higher than 0.7 in all constructs, reflecting internal consistency (McIntosh et al., 2014). Analyzing the items' loadings, all above 0.6, we can verify indicator reliability (Appendix III). To demonstrate convergent validity, we verified the average variance extracted (AVE) values of constructs, and they are all higher than 0.5 (see Table 3.2), confirming convergent validity (Sarstedt et al., 2017).

Three methods were used to analyze discriminant validity - the Fornell-Larcker criterion, the loadings, and cross-loadings analysis, and the heterotrait-monotrait ratio (HTMT) methodology. The Fornell-Larcker criterion states that the AVE square root of each construct should be higher than the correlation between constructs (Fornell & Larcker, 1981), as shown in Table 3.2. However, assessing the higher-order construct of teacher involvement's discriminant validity requires additional scrutiny.

The lower-order components (TSInv and TPIInv) must exhibit discriminant validity among each other and to all other constructs in the model—except for their own higher-order component of which they are a part (Sarstedt et al., 2017). The second criterion states that the loadings should be higher than the respective cross-loadings (Hair et al., 2014), which is observed in Appendix III. As for the HTMT criteria, HTMT values (please see Appendix IV) should be lower than 0.9 (Sarstedt et al., 2017). Thus, all the constructs have discriminant validity.

Table 3.2 - Descriptive statistics, composite reliability (CR), and average variance extracted (AVE)

	Mean	SD	CR	PRet	PAch	ICTA	ICTAc	ICTHe	Age	TSInv	TPInv	PExp	PEdu	EAllo	AAPT	AAMat
PRet	0.132	0.339	1.000	1.000												
PAch	14.702	2.541	0.866	-0.060	0.829											
ICTA	5.936	1.538	0.783	0.177	-0.104	0.802										
ICTAc	4.825	1.726	0.826	0.015	0.023	0.307	0.839									
ICTHe	6.036	1.422	0.803	0.047	-0.099	0.569	0.245	0.820								
Age	16.673	0.872	1.000	0.317	-0.021	0.009	0.015	-0.044	1.000							
TSInv	3.784	1.865	0.921	0.099	0.099	-0.037	0.224	-0.049	-0.134	0.864						
TPInv	5.181	1.685	0.918	0.058	0.137	-0.069	0.265	-0.090	-0.188	0.638	0.858					
PExp	6.368	1.274	0.926	-0.222	0.165	-0.002	0.229	0.045	-0.264	0.132	0.275	0.846				
PEdu	3.536	1.088	1.000	-0.196	0.128	0.006	-0.015	0.071	-0.158	0.039	0.043	0.241	1.000			
EAllo	0.160	0.367	1.000	-0.220	0.227	-0.129	-0.045	-0.085	0.037	-0.039	0.023	0.228	0.306	1.000		
AAPT	14.671	2.393	1.000	-0.268	0.418	-0.084	-0.039	-0.055	-0.132	0.082	0.064	0.396	0.349	0.230	1.000	
AAMat	13.967	3.490	1.000	-0.197	0.333	-0.109	-0.019	-0.086	-0.129	0.200	0.238	0.136	0.114	0.039	0.422	1.000

Notes: Values in bold are the AVE square root. PRet=previous retention; PAch=previous achievement; ICTA=ICT access; ICTAc=ICT academic use; ICTHe=ICT hedonic use; TSInv=teacher social involvement; TPInv=teacher pedagogical involvement; PExp=parental expectations; PEdu=parental education; EAllo=educational allowance; AAPT=academic achievement Portuguese; AAMat=academic achievement Math.

We checked the model for multicollinearity by analyzing the variance inflation factor (VIF) to assess the validity of the formative construct ICT use. Table 3.3 shows the VIF values are all under five (Hair et al., 2017), as the threshold indicates, thus indicating no multicollinearity issues. In terms of significance, the three items are statistically significant ($p < 0.01$). We, therefore, verify the reliability of the formative construct. We can conclude that both reflective and formative constructs present a good measurement model and confirm the structural model results.

Table 3.3 - Formative measurement model evaluation

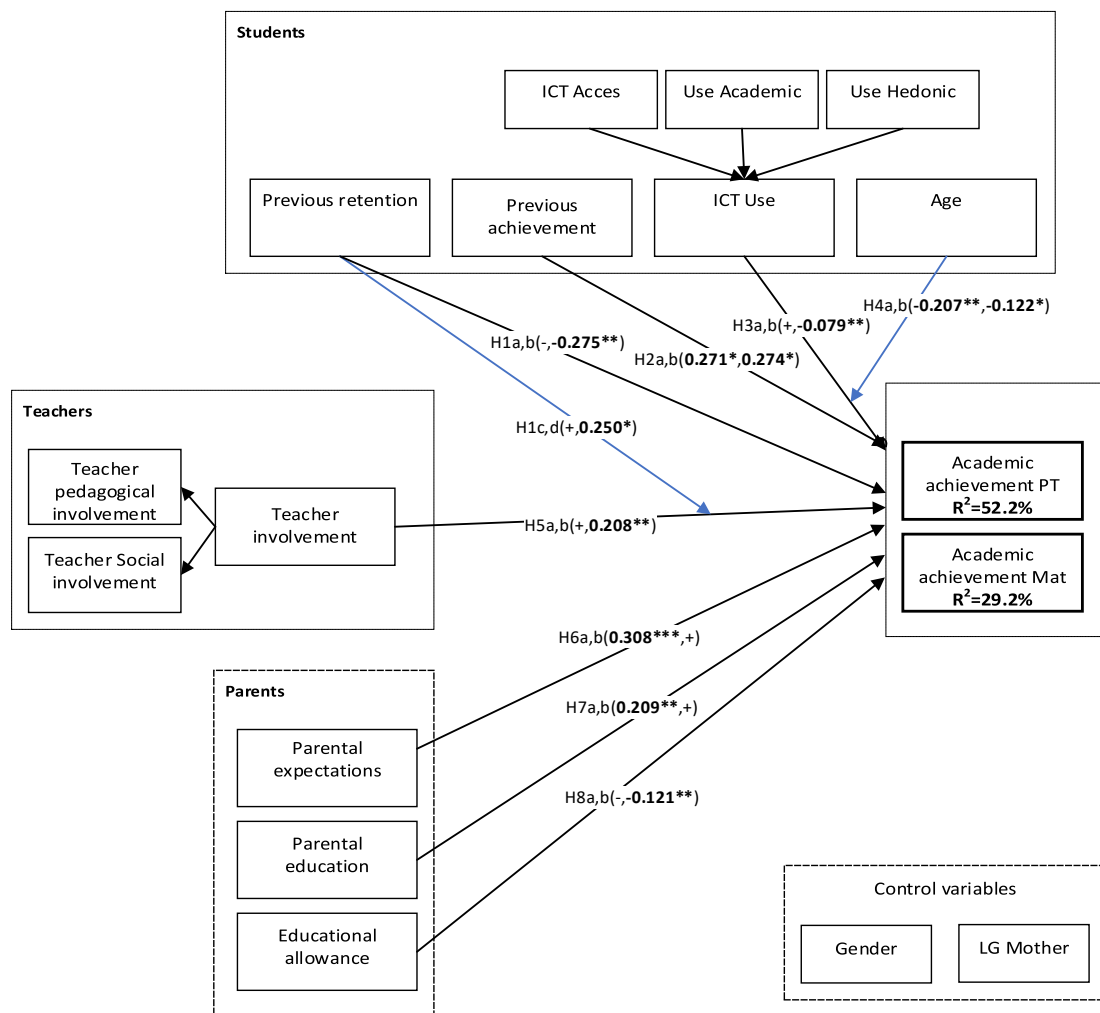
Items	VIF	Weights
ICTA	1.548	0.461***
ICTAc	1.113	0.372***
ICTHe	1.492	0.465***

Note: *** $p < 0.001$ ICTA=ICT access; ICTAc=ICT academic use; ICTHe=ICT hedonic use.

3.4.2. Structural model

First, we assessed the VIF to check the model for multicollinearity issues to estimate the structural model. The VIF values are below the threshold of five (Sarstedt et al., 2017), so the model does not have multicollinearity problems. We performed bootstrapping with 5,000 resamples to evaluate the statistical significance of the path coefficients. The results are presented in Figure 3.2.

Previous achievement is the only determinant that has a significant impact on both Portuguese AA ($\beta = 0.271$, $p < 0.10$) and Math AA ($\beta = 0.274$, $p < 0.10$), meaning that previous grades predict current grades. Previous retention only significantly negatively affects Math AA ($\beta = -0.275$, $p < 0.05$). Likewise, ICT use only significantly affects Math AA, revealing a negative value ($\beta = -0.079$, $p < 0.05$). When considering age as a moderator, ICT use impairs both Portuguese and Math grades ($\beta = -0.207$, $p < 0.05$; $\beta = -0.122$, $p < 0.10$).



Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Figure 3.2 - Results – structural model

Teacher involvement only affects Math AA ($\beta = 0.208$, $p < 0.05$), the effect on Portuguese AA is not statistically significant. With previous retention as a moderator of teacher involvement and AA, the pattern is the same: for previously retained students, teacher involvement is only significant in Math grades ($\beta = 0.250$, $p < 0.10$), as for all students.

Parental expectations and education are significant positive predictors of Portuguese AA ($\beta = -0.308$, $p < 0.01$; $\beta = 0.209$, $p < 0.05$) and non-significant for Math. While educational allowance only affects Math AA by impairing it ($\beta = -0.121$, $p < 0.05$), i.e., students from lower SES who receive educational allowances tend to score worse in Math.

3.5. DISCUSSION

In this study, we proposed to compare the contribution of students-, teachers-, and parents-related determinants for high school AA in Math and Portuguese, two core subjects that all students must complete to graduate secondary education in Portugal. Although there are differences in the individual traits and skills necessary to succeed in language and Math at the high school level, considering most findings in previous literature, we did not anticipate differences in the relevance of each determinant for each of the subjects' AA. The results, however, show otherwise, as there are determinants that are only significant for one of them. Table 3.4 details our proposed hypotheses and the results of this research.

Looking into the constructs pertaining to students, we found that previous retention is only a significant determinant of Math AA, with a negative effect. This means that having failed a year previously impairs Math AA but not Portuguese AA. We hypothesized that both grades would be impaired by previous retention. However, we only confirmed the hypothesis regarding Math AA, hinting that the deleterious effects of retention affect Math performance specifically. Possible explanations may be that students perceive Math as a more difficult subject, eliciting higher performance anxiety levels. Math AA requires high levels of self-efficacy and perceived Math competence (Vizek Vidović, 1999), and students who have previously failed are likelier to have lower perceived competence levels. Students' past learning and composite achievement contribute to current learning and performance. Our results show that previous achievement is a significant positive predictor of current achievement in both Portuguese and Math. These results are consistent with previous literature (Benner et al., 2016; Zhao & Kuo, 2015) and confirm both our hypotheses regarding previous achievements.

As for student ICT use, we found a significant negative effect for Math AA and a negligible effect for Portuguese AA. This disputes our initial assumption that ICT use would promote AA in both subjects. Contradictory effects have been found in previous research regarding ICT use and AA (Bowers &

Berland, 2013; Türel & Toraman, 2015), so we analysed the impact of both academic and hedonic usages of ICT on AA, aiming to clarify these results. Descriptive statistics show the mean value of self-reported frequency of use, indicating heavy usage for hedonic purposes ($M=6.04$, $SD=1.42$, on a scale from 1 – never to 7 – multiple times a day), which can explain the negative effect on AA. Such an adverse effect may likely be due to the disruption of work and poorer study habits that have been shown to particularly affect Math performance (Rozgonjuk et al., 2021). With age as a moderator, ICT use is a significant prejudicial driver of both Portuguese and Math AA.

Table 3.4 - Research hypotheses results

	Independent variable		Dependent variable	Moderator	β	Findings	Conclusion
H1a	Previous retention	→	AA - Portuguese	n.a.	-0.140	non sign.	not supported
H1b	Previous retention	→	AA - Math	n.a.	-0.275	**	supported
H1c	Teacher involvement *	→	AA - Portuguese	Previous retention	0.101	non sign.	not supported
H1d	Teacher involvement *	→	AA - Math	Previous retention	0.250	*	supported
H2a	Previous retention	→	AA - Portuguese	n.a.	0.271	*	supported
H2b	Previous achievement	→	AA - Math	n.a.	0.274	*	supported
H3a	ICT Use	→	AA - Portuguese	n.a.	-0.044	non sign.	not supported
H3b	ICT Use	→	AA - Math	n.a.	-0.079	**	supported
H4a	ICT Use * Age	→	AA - Portuguese	Age	-0.207	**	supported
H4b	ICT Use * Age	→	AA - Math	Age	-0.122	*	supported
H5a	Teacher involvement	→	AA - Portuguese	n.a.	-0.021	non sign.	not supported
H5b	Teacher involvement	→	AA - Math	n.a.	0.208	**	supported
H6a	Parental expectations	→	AA - Portuguese	n.a.	0.308	***	supported
H6b	Parental expectations	→	AA - Math	n.a.	0.052	non sign.	not supported
H7a	Parental education	→	AA - Portuguese	n.a.	0.209	**	supported
H7b	Parental education	→	AA - Math	n.a.	0.020	non sign.	not supported
H8a	Educational allowance	→	AA - Portuguese	n.a.	-0.044	non sign.	not supported
H8b	Educational allowance	→	AA - Math	n.a.	-0.121	**	supported

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Along with these student determinants, we also analyzed teacher-related determinants. We predicted higher levels of teacher involvement indicate higher AA, based on previous research assumptions (Chen, 2005; Keith et al., 1998), according to which teachers' involvement strengthens academic engagement and student performance. However, this effect was only significant for Math. A moderation effect of previous retention on teacher involvement and AA is significant for Math but not

Portuguese, thus strengthening the assumption that Portuguese AA is somewhat independent of perceptions of teacher involvement. At the same time, Math AA improves with higher levels of teacher-social and pedagogical collaboration, an effect proven even for struggling students who have failed in the past.

Finally, regarding parental traits as determinants of AA, contributions are in the direction we had predicted: parents' expectations and education increase AA, while educational allowance (a proxy for lower SES) impair AA, and these findings are consistent with the literature (Altschul, 2012; Poon, 2020). However, the results also show differences in Portuguese and Math AA: Portuguese grades are significantly better for students whose parents communicate higher expectations about children's school path and who have post-secondary education. In contrast, educational allowances impair Math AA but not Portuguese.

From these results, we conclude that the only predictors of academic achievement in both language and Math are previous achievement and ICT use, with age as a moderator. All other determinants only explain one of the current grades. Considering Math, previous retention, ICT use, and educational allowance contribute to lower AA, while teacher involvement promotes it. Portuguese grades are positively determined by parental involvement and parental higher education level. This finding seems to show that the path to AA in Math and language is different and highlights the different roles that teachers and parents have in promoting success. Notwithstanding, previous literature has found that higher parent and Math teacher expectations combined in the 10th grade are associated with better 12th-grade Math AA and higher educational attainment two years after high school completion (Benner et al., 2021).

Looking into why such differences in parents' and teachers' roles in AA have emerged, we propose some possible explanations considering specifics of the Portuguese context that can account for the results. Cultural capital, i.e., familiarity with the dominant cultural codes in a society, can determine

educational success because it can be misinterpreted by teachers as academic excellence and rewarded as such. Because children from high socioeconomic status (SES) backgrounds, on average, possess more cultural capital than those from low-SES backgrounds, they have a comparative advantage in the educational system, which helps them reproduce their privileged social position (Bourdieu & Passeron, 1990).

Parents with higher education levels and a higher cultural capital are better equipped to help their children thrive intellectually by promoting academic discussions and reading habits (Tan et al., 2019), as well as granting the development of skills necessary for language AA, such as interpretation and critical thinking. Nearly half of the students in our sample reported that their legal guardian (which in most cases is the mother) had completed tertiary education. In recent decades, graduation rates have increased significantly in Portugal: according to national statistics data, in 2021, the percentage of women between 35-64 years who completed university was 31.7%, twice the value of 2011 (15.7%). Although tertiary education rates are increasing, most of the generation who are now high school student parents, despite having completed an upper secondary degree or higher, seem not to be particularly savvy in Math, as suggested by a previous study that demonstrated the low Math literacy skills of the adult population in Portugal in general (Ponte, 2003). Therefore, it seems the extent of parent contribution is more evident in language achievement than in Math. Likewise, parental expectations are only significant for Portuguese AA. This result contradicts the Benner et al. (2021) findings that show Math AA of American students is significantly driven by parents' expectations. According to Chen (2005), perceived parental support and expectations impaired global AA (combined scores of Math, English, and native language Chinese), suggesting that the stronger students perceive the support from parents, the worse they tend to perform, which is explained by a reactive strategy toward parents and difficulties in emotional regulation that is typical in teenagers. Other authors highlight that in Chinese culture, societal expectations are associated with "high-achieving" stereotypes, meaning students feel more stressed when facing school problems (Qu et al., 2020) and

pressure to achieve. Seemingly, the effect of parents' expectations can differ according to cultural aspects or more or less disruption in parent-teenager relationship quality. Wang et al. (2013) found that positive relationships between students and teachers moderated the effect of effortful control and parent-adolescent conflict on emotional and behavioral adjustment at age 18.

As for Math AA, our results show the relevance of perceived teacher involvement as a positive predictor and receiving an educational allowance as a negative one. Gregory and Weinstein (2004) found that U.S. adolescents' perceptions regarding connection with and regulation from parents and teachers were the strongest predictors of growth in their Math AA from 8th to 12th grades, with teacher connection being the strongest predictor, particularly for adolescents from low SES families. High school students in Portugal commonly attend private tutoring, as a complement to their high school classes, particularly for STEM subjects. However, this tutoring is contingent on family income, and one of the reasons why lower SES predicts lower Math AA.

These results highlight relevant aspects of theory and practice, comparing achievement in two fundamental subjects in pursuing tertiary education or a career.

3.5.1. Theoretical implications

From a theoretical perspective, these results have consolidated previous findings, such as the relevance of previous AA for current AA (Benner et al., 2016; Cerdeira et al., 2018; Phan, 2012), a consequence of the cumulative nature of education and learning. We have also contributed to the debate on ICT use and its effect on AA, as self-reported high levels of ICT use predicted lower AA in Math, particularly for older students, for whom the negative effect was significant for both subjects. Research has shown that students consider ICT is an essential tool for their daily life and that usage improves their academic and cognitive skills, as well as IT skills that they consider essential for career growth (Joshi & Rose, 2018). Our sample reported using ICT on average daily, for both academic and hedonic purposes, although more often (several times a day) for hedonic purposes such as browsing

social networks, gaming, videos, etc. Previous studies have found seemingly different effects of using ICT: recreational use at moderate levels (one to two hours a day) predicted positive scores in language and Math (Bowers & Berland, 2013), while students who reported higher levels of ICT usage, both at home and at school tended to have, on average, lower Math AA (Rozgonjuk et al., 2021), hinting that the time spent online plays an important role in AA.

The burden of previous retention for AA also corroborates earlier findings from the literature (Goos & Belfi, 2013; Jacob & Legfren, 2009). This observation was only proven for Math, suggesting that, at least in Portugal, the negative outcomes of being retained have worse consequences on subsequent performance in this subject. This result is in line with most studies on retention and AA and high school completion. Most evidence supports the negative impact that retention has on current performance (Jimerson, 2001). It is justified mainly by the psychological impacts that being retained has on students (Tolen & Quinlin, 2017). However, few studies did find there may be benefits in repeating a year for some students, able to catch up to younger peers (Schwerdt et al., 2017). Our results did not find benefits in retention other than the non-significant effect on Portuguese AA in contrast to Math. Seemingly, the impacts of failing a year, such as a decrease in self-efficacy and motivation, for example, only impair Math performance. It may be the case that Math AA is more reliant on previous learnings compared to language subjects or that Portuguese high school students have an anxious approach to Math in particular. Academic self-efficacy may be more relevant to success if the latter is the case. Further research could help clarify these hypotheses.

Parents with university education significantly impact AA, a finding that is consistent with previous literature (Chesters & Daly, 2017), although the effect was only significant for high school Portuguese AA and not Math. University education has been demonstrated as a significant driver of AA for kindergarteners, middle school students, and university students (Stephens et al., 2014). The low average mathematical literacy in Portugal can account for the fact that highly educated parents' contribution was negligible to Math AA. Parental expectations also only promoted Portuguese AA,

which is an unexpected result according to the literature. Previous research states that parental expectations about AA help shape students' own expectations for success (Aceves et al., 2020) and positively predict achievement (Veas et al., 2015). The fact that parental expectations do not explain Math AA may be due to higher expectations regarding Math AA, thereby placing some degree of pressure on students (Jeynes, 2003), or that Math AA has particular features boosted by teachers and not Portuguese parents.

Among all the parental determinants we assessed, only low SES (receiving an educational allowance) predicted Math AA, which is also consistent with former findings (Altschul, 2012). Higher teacher involvement also predicted Math AA, but not Portuguese, and the effects of teacher expectations and involvement are variable, as previous results demonstrate (de Boer et al., 2018).

3.5.2. Practical implications

In the late decades of the 20th century, the level of adult education in Portugal was significantly lower than in other developed nations. This scenario has changed as Portuguese PISA scores have increased drastically in recent years, accounting for the higher skills and knowledge inherent to younger generations. This improvement is a consequence of strategic efforts to grant universal access to education and learning, thus increasing competencies as well as graduation rates. Policies such as establishing universal access to preschool, increasing compulsory education years, a significant quality improvement of teaching programs, and introducing assessment exams at the end of each educational cycle have all contributed to higher AA (Crato, 2020). Even though the current scenario is much more favorable, high school dropout rates in Portugal still surpass the European average. The present study's findings shed light on some practical implications that can still improve secondary school AA.

One of the drivers that impair AA is ICT use – high use, particularly for hedonic purposes, means students perform worse in Math. This factor highlights the need for more adult supervision to monitor the time spent on computers or smartphones or provide students with tools to self-regulate screen

time by promoting other leisure activities. School curricula could also be updated to include more engaging pedagogical ICT activities.

Given the current high demand for STEM jobs, there is a more pressing need for students to develop and master Math skills. Our results suggest that Math achievement may be incremented by promoting teacher social and pedagogical involvement. Teacher training could focus on pedagogical and social competencies, as teachers' roles are more relevant than parents' for Math AA and particularly for disadvantaged students. Teachers play a crucial role in capacitating students and may be very influential in potentiating hope for a better future (particularly when parents fail to do so) and the possibility of breaking the disadvantage cycle. Recent research shows that when adolescents believe their SES conditions can be changed, they achieve more, highlighting the importance of focusing on a growth mindset, hopefulness, and school engagement to enhance AA (Zhao et al., 2021).

Since previous retention is detrimental to Math grades, our results support the need to revise the criteria for failing a student. Retention policies have been under debate in Portugal in recent years. In fact, retention rates have been decreasing, but further work at the student level (such as individual tutoring at school for students at risk of failing), as previously suggested by Choi et al. (2018), and also at the institutional level, by for example updating retention criteria seems beneficial. Research has found a prevalent culture of retention in some European countries. The dominant belief shared by teachers is that year repetition benefits learning (Eurydice, 2011), even though it has been repeatedly disputed in previous research. It may be useful to question such assumptions before implementing legislative changes. Our results show that higher teacher involvement promotes Math AA, particularly for students with at least retention. This factor is an important result that highlights the importance of teachers for AA. It should be focused on to increase society's perceptions of the relevance of high school teachers.

3.5.3. Limitations

Some limitations must be considered when interpreting the findings of this study. One of them is regarding sampling, as our sample is a relatively small portion of high school students considering the total of students enrolled in Portuguese public high schools. Due to constraints in data collection provoked by the Covid-19 pandemic and public health measures in schools, data collection was done online. Contacts with schools were done solely by e-mail or phone, which we believe has had an impact and explains our low response rates, thus suffering from self-selection bias. Further research with a larger sample that is more representative of public secondary schools could be useful to improve the generalization of findings. It would also allow for performing more comprehensive analyses according to school region/district, including statistics such as population density, average monthly income, and unemployment rate, among others.

3.6. CONCLUSIONS

This paper highlights the interaction between students, teachers, and parents as contributors to high school Portuguese and Math AA in Portugal. We showed that in high school, apart from the academic track record, student perceptions about significant adults in their school life – parents and teachers – are important to achieve better grades in two core subjects. Student previous achievement predicted current Portuguese and Math AA, yet significant differences in determinants according to the subject were found. Parents' influence was more significant in Portuguese than in Math, namely through expectations and higher education levels. Teacher influence on Portuguese grades was not significant. In fact, only Math grades were positively affected by higher perceptions of teacher involvement, particularly for students who have failed a year. Math grades are impaired by previous retention, higher self-reported ICT use, and receiving an educational allowance, a proxy for lower socioeconomic status. We discussed these findings and proposed possible explanations for these differences in light of the current Portuguese high school context. Further research may help clarify if sociocultural

attributes are indeed at stake or if there are consistent differences in parent and teacher roles in language and Math AA.

4. IS ACADEMIC SELF-EFFICACY REALLY IMPORTANT? ASSESSING THE DETERMINANTS OF ACADEMIC SELF-PERCEPTION AND ACHIEVEMENT

4.1 INTRODUCTION

Understanding what drives student academic achievement (AA) has concerned researchers and educators for decades, as failing in school is one of the main predictors of social exclusion in adulthood (Jahnukainen, 2001a). AA is a product of the interaction of diverse drivers extensively reported in the literature (Dupéré et al., 2015; Hattie, 2015; Hattie & Clarke, 2018; Zaff et al., 2017). Research has explored the contributions of students' traits (Galindo-Rueda & Vignoles, 2005; Steinmayr et al., 2018; Wirthwein et al., 2013), their academic track record (Cruz-Jesus et al., 2020; Gareau et al., 2019; Jimerson, 2001), the familiar background (Chesters & Daly, 2017; Liu et al., 2021; Poon, 2020), and the school (Egalite & Kisida, 2016) and classroom environment as well as the relationship with teachers and peers (Chen, 2005; Gregory & Weinstein, 2004).

High school successful completion is a path to a more prosperous adult life, with both individual and social benefits, as highly educated citizens have the chance to foster community development (Zaff et al., 2017). Conversely, low completion rates maintain a cycle of social disadvantage, considering that the children of high school dropouts are likely to have poorer health, economic, and educational outcomes than children of parents who have graduated from high school (Hernandez & Napierala, 2013). Such impacts show that studying AA drivers is crucial to providing policymakers and educators with the appropriate knowledge to develop effective strategies to promote school success, thus contributing to social and economic growth.

Early education research focused mainly on student cognitive abilities (Boake, 2002; Mertler, 2018) yet, other individual constructs such as motivation (Mayer et al., 2007), academic self-efficacy (Stajkovic et al., 2018) or achievement goals (Dompnier et al., 2009) have also shown consistently across literature significant impacts on AA, as they determine the effort students exert in their learning

and school work. Research also shows that students whose parents and teachers are more involved in school affairs have better results (Poon, 2020; Zhao et al., 2021).

AA can be defined as the result of learning accomplishments measured in performance assessments, such as exam grades, final term grades, or grade point averages. This quantitative expression of AA classifies student success and, in many countries, is used to select high school graduates when applying for higher education institutions (Silva et al., 2020). However, achievement can also be assessed by student academic self-perception, a subjective measure of the extent to which students believe they are successful in school.

In this paper, we intend to explore the drivers that determine AA (expressed in grades and academic self-perception), considering the importance of mastery achievement learning goals, teachers' involvement, and parents' expectations in promoting academic self-efficacy and high school success. Literature shows that parents who communicate expectations for their children's future (Castro et al., 2015) and teachers' career advice promote student academic self-efficacy (Wong et al., 2021), thus promoting AA. Using a sample of Portuguese high school students, we intend to test whether academic self-efficacy, i.e., the confidence students have in their ability to perform and achieve their goals, is a promotor of grades and academic self-perception. A second contribution is to clarify the impact on academic self-efficacy and AA of the relationships that students establish with parents and teachers, by assessing student perceptions of parental expectations about their academic career, and teacher social and pedagogical involvement. The paper is organized as follows: Section 4.2 presents a relevant literature review and development of hypotheses, Section 4.3 details the method, Section 4.4 the results and finally, in Section 4.5 results and implications are discussed.

4.2. LITERATURE REVIEW

Teenagers' daily life is spent mostly at school or engaging in school-related activities. However, they are developing more than mere academic competencies, as adolescence is a period characterized by physical, emotional, and social maturing, with implications on school achievement (Leeson et al., 2008). Feelings of connectedness and adjustment in school are important to prevent dropout (Dupéré et al., 2015), a phenomenon most common during high school years, linked to hardships in adult life and obstacles to a successful professional career (Alexander et al., 2001). Establishing trustful and warm relationships with parents and teachers helps teenagers regulate behaviour, preventing emotional distress and misconduct (M.-T. Wang et al., 2013). Teacher-student positive relationships positively affect AA and well-being across all school years and have long-term effects on subsequent achievement (Kiuru et al., 2020). The perceptions that these significant adults (parents and teachers) emphasize about student goals predict students' motivation (Vedder-Weiss & Fortus, 2013) and help to plan for their future (Wong et al., 2021; S. Zhao et al., 2021) developing strategies to achieve.

4.2.1. Mastery-approach goals

Achievement goals refer to the reasons and ways people choose when facing achievement situations (Elliot et al., 2005). In an academic setting a 2x2 mastery-performance goals framework has been widely studied (Midgley et al., 1998), with different implications on achievement. In particular, students who score higher on mastery approach goals scales are concerned with excelling on the task they are working on and motivated to learn to gain knowledge and abilities. Their goal is on learning and self-improvement. Mastery approach goals are associated with enjoyment, higher self-efficacy, perceived success and deeper processing of material (Elliot et al., 1999) and support deep conceptual processing and engagement. Research also shows these students are more likely to transfer knowledge to new settings, regardless of an explicit instruction being given (Belenky & Nokes-Malach, 2012). Even though each goal may facilitate achievement in different circumstances as some contexts may favor a performance approach rather than a mastery approach (Senko, 2019), mastery driven students are

likely to achieve, as their orientation is for a more thorough learning, and their prevalent effect on AA is consistent in literature (Wirthwein et al., 2013). We therefore propose the following hypotheses:

- H1: Mastery-approach goals have a positive impact on academic self-efficacy.
- H2: Mastery-approach goals have a positive impact on AA.
- H3: Mastery-approach goals have a positive impact on academic self-perception.

4.2.2. Parental expectations

In literature, parental expectations are characterized as faiths or judgments that parents have about their children's future attainment as reflected in grades, school achievement, or university attendance (Glick & White, 2004; Goldenberg et al., 2001). The foundation of parental expectations is the family's resources and their children's academic capabilities (Yamamoto & Holloway, 2010).

Parental involvement in school affairs has a favorable impact on AA from early years (Castro et al., 2015; Fan & Chen, 2001), in particular by engaging in activities such as promoting reading habits at home, academic discussions, giving support for learning, and communicating aspirations and expectations about students' future (Boonk et al., 2018). More committed and involved parents typically manifest higher expectations of student academic progress, improving motivation for school work and confidence and yielding better results (Juang & Silbereisen, 2002; Lee & Bowen, 2006). Additionally, parents' expectations influence the ability to develop self-concepts and self-perceptions (Schunk & Pajares, 2002). (Cross et al., 2019) showed parental expectations also promote academic self-efficacy, in particular for students whose parents reported transmitting few messages of shame, pressure and academic effort.

In previous research, parental expectations have been proven to influence both AA and perceptions of success. Among others, Yamamoto & Holloway (2010) found that parental expectations are strongly related to the students' performance among European American families. Ma et al. (2018) used a sample of 872 adolescents in Hong Kong and revealed that high parental expectations were positively

associated with adolescents' academic performance. Neuenschwander et al. (2007) proved, by studying a sample of US and Swiss sixth and seventh graders, that high parent expectations predicted increased performance and low parent expectations predicted lowered performance. Following Davis-Kean (2005), parental expectations are directly and powerfully related to children's academic success, even in financially impoverished contexts. In fact, the benefits of parental involvement are more noticeable for disadvantaged families (Benner et al., 2016; Poon, 2020), who typically participate less in school life. Juang & Silbereisen (2002), using a sample of 641 German adolescents, demonstrated that higher expectations, caring, and involvement in 6th grade yielded better grades in the 9th grade. In contrast, adolescents who were characterized by below-average ability, parental school involvement and capability beliefs demonstrated the worst AA.

We therefore propose:

- H4: Parental expectations have a positive impact on academic self-efficacy.
- H5: Parental expectations have a positive impact on AA.
- H6: Parental expectations have a positive impact on academic self-perception.

4.2.3. Teacher involvement

Teachers' involvement concerns the desire to form and maintain a solid and stable interpersonal relationship with the students. Four major components of teacher involvement can be perceived: showing affection, showing that they understand the students, providing resources and being available (Stroet et al., 2013).

The impact of teachers has been pinpointed as a main driver of AA (Rockoff, 2004). Students tend to have higher scores when they believe their teachers are reliable and available to offer resources (Ayllón et al., 2019), and higher teacher expectations about student achievement increase students' academic self-concept and AA (de Boer et al., 2018). The perceived teacher's social involvement and emotional support boost academic resilience and engagement, which results in improved outcomes

(Romano et al., 2021). There is a need for supportive teaching for early adolescents' motivation and engagement (Stroet et al., 2013), as high school students depend on their teachers for assistance in career planning and even for support in their decision-making, which may be strengthened by their desire for independence from their parents (Wong et al., 2021).

Students' perceptions of teacher academic involvement can even be seen as similar to parental monitoring. Students may even be especially motivated to demonstrate their competence to their teachers or, at least, to avoid demonstrating incompetence (Régner et al., 2009).

Research on high school teachers' impact on AA evaluated different characteristics, such as the effects of teacher gender, employment status, educational attainment, and experience on student performance in Portugal. Results showed that classes led by female teachers with more years of teaching experience often outperform others. The fact that younger, less experienced instructors are more likely to work away from home in a more precarious work situation poses challenges that can account for these differences. The influence of education level (BSc vs MSc or PhD) was not significant (Sousa et al., 2016).

In previous research, the positive effect of teacher involvement was already established. Among others, Akiba & Liang (2016) used four years using longitudinal survey data collected from 467 middle school mathematics teachers in 91 schools merged with 11,192 middle school students' mathematics in Missouri and concluded that the teachers' collaboration and informal communication are effective ways of improving AA. Ayllón et al. (2019), using 86,000 records of teaching evaluations by students at the University of Girona (Spain), presented evidence that teachers' involvement and students' self-efficacy are the two most powerful elements regarding AA. Sharma (2016) used a sample of 646 students and, in accordance, concluded that there is a positive effect on AA from teachers' support. Lee (2012) shows that there is an advantage of a supportive relationship between the teacher and the student.

In sum, student perception of their teachers' support is a significant positive predictor of AA, which leads us to hypothesize:

- H7: Teacher involvement has a positive impact on academic self-efficacy.
- H8: Teacher involvement has a positive impact on AA.
- H9: Teacher involvement has a positive impact on academic self-perception.

To deeper explore how the influence of parents and teachers on achievement takes place, we propose two additional moderation hypotheses, considering their role is essential in the development of student learning goals:

- H10: Parental expectations will moderate the effect of the mastery approach on AA such that the relationship will be stronger among students with higher parents' expectations.
- H11: Teacher involvement will moderate the effect of the mastery approach on AA such that the relationship will be stronger among students with higher perceived teacher involvement.

4.2.4. Academic self-efficacy

Academic self-efficacy is one of the most studied and significant AA drivers (Honicke & Broadbent, 2016). Self-efficacy relates to one's confidence in the ability to carry out the behaviors required to achieve a particular performance or goal (Bandura, 1997) through the belief that one can exert control over their motivation, behavior, and environment in social settings. Self-efficacy is mainly a cognitive evaluation of capabilities to fulfil a potential performance based on past performances (Choi, 2005). Self-efficiency influences the choice of tasks, the level of task performance and the amount of effort and perseverance for each task (Martin & Rimm-kaufman, 2015).

In an academic context, students with higher self-efficacy can achieve better results because they monitor and self-regulate impulses, persisting when faced with challenges or difficulties (Komarraju & Nadler, 2013). This confidence can be reliant on many factors, but as previously stated, parents and teachers are determined to help students maintain this regulation, increasing AA. Self-efficacy triggers

students' motivation and ability to learn (Dinther et al., 2011) and emotional engagement with subjects (Martin & Rimm-kaufman, 2015).

In previous research, self-efficacy already proved to play a role when predicting and mediating AA, motivation and learning (Dinther et al., 2011). Lane et al. (2004), operating on a sample of 205 postgraduate students, confirmed that high levels of self-efficacy lead to better results in all areas. Drawing on 250 high school students, Motlagh et al. (2011), validated that self-efficacy is an important factor in AA, with self-evaluation and self-regulation as the most important subfactors of self-efficacy. Furthermore, a systematic review of 12 years of research was performed, using 59 studies, which confirmed the importance of high levels of self-efficacy for academic performance (Honicke & Broadbent, 2016).

Thus, for the impact of academic self-efficacy, we propose:

- H12: Academic self-efficacy has a positive impact on AA.
- H13: Academic self-efficacy has a positive impact on academic self-perception.

4.2.5. Conceptual model

Figure 4.1 depicts our proposed AA model based on previous literature examining the influence of student learning goals, parent expectations, and teacher involvement on academic self-efficacy and subsequent achievement. Constructs included are mastery approach goals, parental expectations, and teacher involvement which we propose will positively impact academic self-efficacy. All constructs concur in developing student confidence in their ability to achieve. Achievement measures (our dependent variables) are AA - the grades in Math and Portuguese (mother tongue) and academic self-perception, a subjective measure of achievement, i.e., the extent to which students feel they are successful in their school career. The effect of the student mastery approach, parent expectations, and teacher involvement on AA is analyzed directly and via the mediation of academic self-efficacy.

Control variables included are student gender, parental education (a binary under/over 12 years of education, i.e., if the legal guardian has a university degree or not), and educational allowance, a proxy for socioeconomic status, assuming students receive an allowance and have a smaller income.

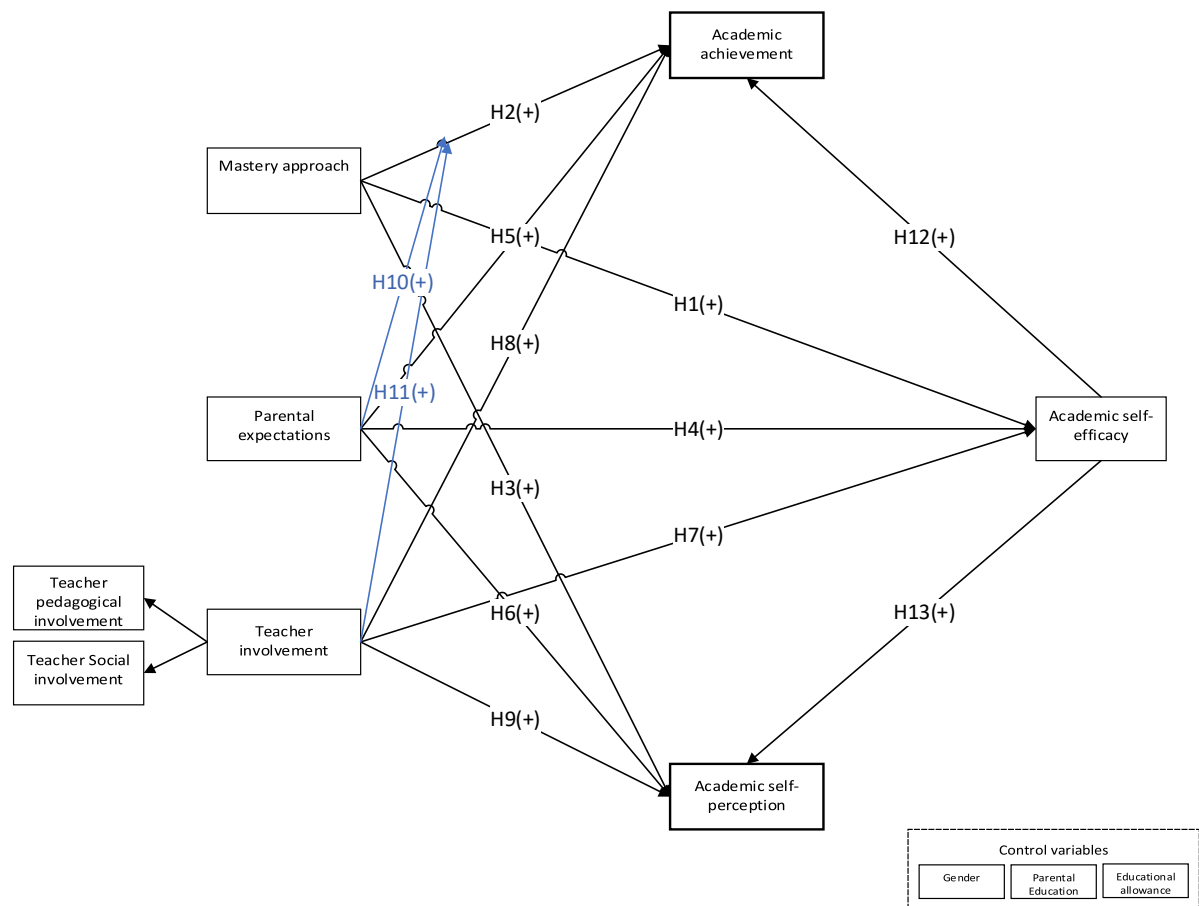


Figure 4.1 – Conceptual model and hypotheses

4.3. METHOD

4.3.1. Participants and procedure

We surveyed public high school students in the 10th, 11th, and 12th grades. Public high schools were chosen as most students in Portugal (around 80%) are in this system, meaning it is more representative than private education, an option that few privileged families often choose. The survey had an estimated completion time of ten minutes, was designed on Qualtrics XM, and was emailed to 44 schools in the country with an invitation to participate and a study presentation. Data was collected

online because of the restrictive measures ongoing during COVID-19, and a quick result report was shared with schools as compensation for participation.

Participants were informed that their response was voluntary and that their data was anonymous, confidential, and strictly for this research. The Ethics Committee approved the NOVA IMS and MagIC Research Centre survey and the Directorate-General for Education of the Portuguese Ministry of Education, meaning students could consent to their participation without the need for legal guardians' consent.

The questionnaire was answered online and was comprised of 31 closed questions about the constructs included in the conceptual model (Appendix V): mastery approach goals (Midgley et al., 1998), student perception of teacher (social and pedagogical) involvement (Johnson & Johnson, 1983), student perception of parental expectations towards their academic path (Veas et al., 2015) and academic self-efficacy (Midgley et al., 2000) AA measures were the self-reported students' grades in core subjects Portuguese and Math in the current school year (these subjects are compulsory in all three years of high school and their completion is necessary for secondary education graduation), and a subjective measure of success, i.e., academic self-perception (McCoach, 2002). Sociodemographic information was also collected: parental education (Chesters & Daly, 2017), educational allowance, and gender.

4.3.2. Data

We conducted a pilot study with 37 students to ensure the viability of the measurement scales and the instrument's appropriateness for our research goals.

Data collection took place between April and November 2021. Final data include 220 valid responses, from a total of 404 answers. AA was measured through self-reported grades on a scale of 0-20 of Portuguese ($M= 14.67$, $SD=2.39$) and Math ($M=13.97$, $SD=3.49$) of the current school year. Participant

ages varied from 16 to 23 years old; students aged 18 or over can become their legal guardians, meaning they make all school decisions. Sample demographics are detailed in Table 4.1.

Table 4.1 – Sample characteristics

Measure	Value	%	Frequency
Gender	F	62.7	138
	M	35.0	77
	Other	2.3	5
School year	10	13.2	29
	11	38.2	84
	12	48.6	107
Age	16	44.5	98
	17	43.2	95
	18	10.9	24
	>18	1.4	3
Legal guardian	Mother	77.3	170
	Father	20.9	46
	Self	0.9	2
	Other	0.9	2
Parent education level	Less than 12 years (high school not complete)	14.5	32
	12 years (high school graduate)	35.5	78
	More than 12 years (tertiary education)	45.9	101
	Don't know/Don't want to answer	4.1	9
School allowance	Yes	13.6	30
	No	71.8	158
	Don't know/Don't want to answer	14.5	32

4.4 RESULTS

Structural equation modelling (SEM) was used to test the relations estimated in our theoretical model and its effects. We opted for partially least squares (PLS-SEM), a variance-based SEM technique due to this research's exploratory nature, to identify key driver constructs of AA. It is a method that works better than covariance-based SEM on complex models, allowing for smaller sample sizes and less restrictive assumptions on data while incorporating reflective and formative constructs (Henseler et al., 2009b).

We used the PLS-SEM method as the recommended two-step approach that first tests the reliability and validity of the measurement model and then assesses the structural model (Anderson & Gerbing, 1988). Analyses were conducted using the SmartPLS 4 software (Ringle et al., 2022).

4.4.1. Measurement model

Measurement models assess the relationship between the latent variables and their indicators. In the proposed model, all constructs are reflective. Table 4.2 shows that the composite reliability (CR) is higher than 0.7 in all constructs, reflecting internal consistency (McIntosh et al., 2014). Analyzing the loadings of the items above 0.6, we verify that there is indicator reliability.

We used three methods to analyze discriminant validity: the Fornell-Larcker criterion, the loadings and cross-loadings analysis, and the heterotrait-monotrait ratio (HTMT) methodology. The Fornell-Larcker criterion states that the AVE square root of each construct should be higher than the correlation between constructs (Fornell & Larcker, 1981), as shown in Table 4.2. However, assessing the higher-order construct of Teacher involvement's discriminant validity requires additional scrutiny. The lower-order components (TSInv and TPInv) must exhibit discriminant validity among each other and to all other constructs in the model—except for their higher-order component of which they are a part (Sarstedt et al., 2017). According to the second criterion, loadings should be higher than the respective cross-loadings (Hair et al., 2011), which can be observed in Appendix VI. As for the HTMT criteria, HTMT values (Appendix VII) should be lower than 0.9 (Sarstedt et al., 2017). Thus, all the constructs have discriminant validity.

Table 4.2 – Descriptive statistics, composite reliability (CR), and average variance extracted (AVE)

	Mean	SD	CR	Mapp	Expe	TSInv	TPInv	ASEf	AA	ASPe
Mapp	5.655	0.318	0.884	0.818						
Expe	6.330	0.305	0.870	0.409	0.835					
TSInv	3.671	0.157	0.912	0.252	0.123	0.921				
TPInv	5.181	0.619	0.885	0.397	0.287	0.650	0.858			
ASEf	5.395	0.244	0.897	0.530	0.460	0.253	0.337	0.869		
AA	14.356	2.926	0.906	0.034	0.356	0.140	0.132	0.128	0.827	
ASPe	4.800	0.125	0.922	0.349	0.423	0.302	0.346	0.594	0.143	0.870

Note: Values in bold are the AVE square root. MApp=Mastery approach; Expe=Parental expectations; TSInv=Teacher social involvement, TPInv=Teacher pedagogical involvement; ASEf= Academic self-efficacy; AA=Academic achievement; AAchi1=Portuguese grade; AAchi2=Math grade; ASPe=Academic self-perception.

4.4.2. Structural model

To estimate the structural model, first, we assessed the VIF to check for multicollinearity issues. The VIF values are below the threshold of five (Hair et al., 2014), thus indicating there are no multicollinearity problems. To evaluate the statistical significance of the path coefficients, we performed bootstrapping with 5,000 resamples. Results are presented in Figure 4.2.

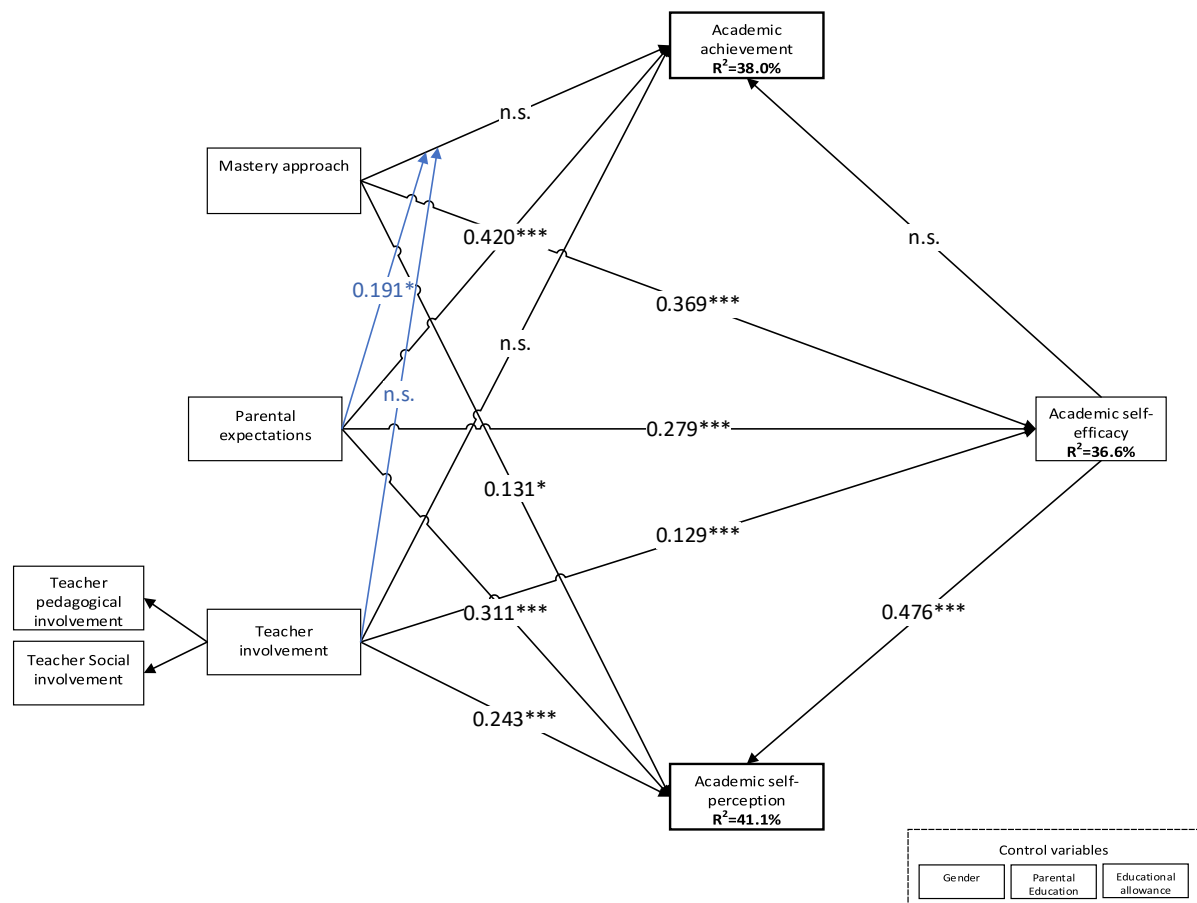


Figure 4.2 – Results – structural model

The three constructs explain academic self-efficacy in the model: mastery approach ($\beta=0.369$, $p<0.01$), parental expectations ($\beta=0.279$, $p<0.01$), and teacher involvement ($\beta=0.129$, $p<0.01$). Parental expectations also influence AA ($\beta=0.420$, $p<0.01$); in fact, student grades are only explained by parental expectations, as mastery approach goals, teacher involvement, and self-efficacy do not exert a direct effect on AA. The control variables' effect is negligible, except for the relationship between parental education – AA ($\beta=0.209$, $p<0.10$), which is natural as it is widely accepted that legal guardians' education is also a predictor of AA.

We also examined the moderation effect of parental expectations and teacher involvement on the relationship between mastery approach and AA, i.e., to what extent parents or teachers' influence

moderates the relationship between mastery goals and student grades. The effect was significant only with parental expectations as a moderator ($\beta=0.191$, $p<0.10$). This effect is detailed in Fig. 3, which shows that although the mastery approach is not significant in explaining AA, it becomes so once moderated by parental expectations. In fact, for students whose parents have low expectations, their mastery approach can actually be an AA inhibitor. On the contrary, for students whose parents have high expectations, the mastery approach is a driver of AA, i.e., it yields a positive effect. Hence, alone, the mastery approach is neutral and, therefore, not significant as an AA antecedent as its effect can be contradictory, depending upon parental expectations. This is, in our opinion, one key finding in our study.

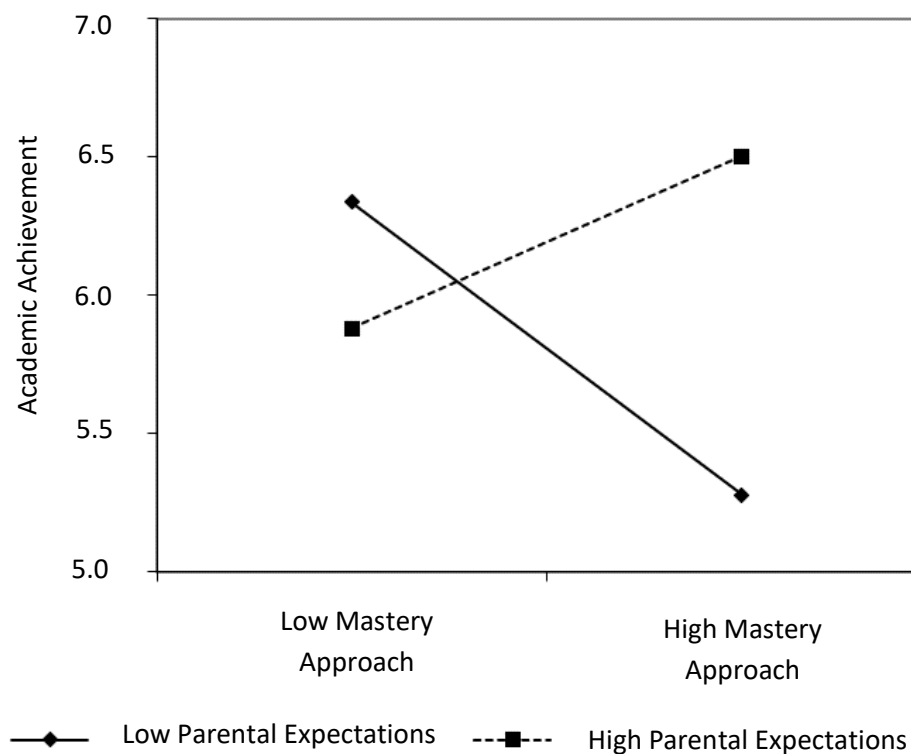


Figure 4.3 – Moderation Effect

Academic self-perception, the subjective measure of achievement, is explained by academic self-efficacy ($\beta=0.476$, $p<0.01$), parental expectations ($\beta=0.311$, $p<0.01$), teacher involvement ($\beta=0.243$, $p<0.01$), and mastery approach goals ($\beta=0.131$, $p<0.10$).

4.5. DISCUSSION

High school completion is essential for a teenager's future life, including career definition and success. In most western countries, secondary education is compulsory. Yet, students who struggle to perform well are more at risk of dropping out before graduation, which may imply adverse outcomes for themselves and, ultimately, to society and the community they belong to.

Research shows that academic self-efficacy and mastery approach goals are dynamic constructs, which evolve throughout all school life according to students' prior learning experiences and achievements, and in interaction with family, teachers, and peers. Establishing meaningful relationships with relevant education stakeholders (e.g., legal guardians and teachers) is essential for an adequate development, in particular during adolescence, to help regulate behaviors and reduce the feelings of anxiety stemming from planning for the future in an ever more competitive world. Hence, it is reasonable to assume these relationships are very significant for student AA, by fostering the motivation to pursue their learning goals and the adequate strategies to perform successfully. Parent and teacher involvement in students' life is essential to maintain feelings of connectedness with school and provide the necessary well-being to define career goals and perform to attain them. In this study, we intended to assess the contribution of student mastery approach goals, parental expectations, and teacher involvement for academic self-efficacy academic and high school AA. According to previous literature, we had anticipated that all of these relationships would be positive and significant. Results, however, show otherwise, particularly when explaining grades, as detailed in Table 4.3.

Table 4.3 – Research hypotheses results

Independent variable			Dependent variable	Moderator	β	Conclusion
H1	Mastery approach	→	Academic self-efficacy	n.a	0.369***	supported
H2	Mastery approach	→	AA	n.a	-0.109 ^{ns}	not supported
H3	Mastery approach	→	Academic self-perception	n.a	0.131*	supported
H4	Parental expectations	→	Academic self-efficacy	n.a	0.279***	supported
H5	Parental expectations	→	AA	n.a	0.420***	supported
H6	Parental expectations	→	Academic self-perception	n.a	0.311***	supported
H7	Teacher involvement	→	Academic self-efficacy	n.a	0.129***	supported
H8	Teacher involvement	→	AA	n.a	0.120 ^{ns}	not supported
H9	Teacher involvement	→	Academic self-perception	n.a	0.243***	supported
H10	Mastery approach	→	AA	Parental expectations	0.191*	supported
H11	Mastery approach	→	AA	Teacher involvement	0.016 ^{ns}	not supported
H12	Academic self-efficacy	→	AA	n.a	0.000 ^{ns}	not supported
H13	Academic self-efficacy	→	Academic self-perception	n.a	0.476***	supported

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

One unexpected result was that academic self-efficacy predicted student perception of success (academic self-perception) but not grades (AA). According to the literature, academic self-efficacy refers to the belief that students can perform well in schoolwork. The fact that self-efficacy impacts academic self-perception has grounds in academic research, as self-efficacy acts as an active driver of self-perception, even though there are evaluative differences among both constructs. Academic self-efficacy usually refers to a self-evaluation process where the individual develops a set of beliefs based

on his previous experience with a specific task. In contrast, academic self-perception can have a comparison component, such as the achievement of peers (Bong & Skaalvik, 2003).

According to previous studies, self-efficacy plays a vital role in predicting mathematics performance, leading to the conclusion that the beliefs that students possess about their ability to complete mathematics problems predict their mathematics performance, even when those beliefs might not match actual ability or levels of prior achievement (Stevens et al., 2004). Our results show, on the contrary, that the belief that one can perform well in school does not necessarily translate into high grades.

Mastery approach goals impacted academic self-efficacy, consistent with the literature (Bong, 2001), but did not impact grades or academic self-perception. This result seems inconsistent with previous research (Luo et al., 2011) that reports an effect of scoring higher on mastery approach goals scales on grades. Mastery approach goals help students develop behaviours directed at desirable outcomes, lead to positive learning experiences, and are related to a relatively high self-efficacy (Huang, 2016). When considering the moderating effect of parents' expectations, mastery approach (i.e., the desire to master or know the task one's working on; motivation to learn to improve knowledge and abilities with emphasis on learning and self-improvement), the effect on grades is positive and significant. This highlights how relevant parents' role in their children's education path is: communicating high expectations exerts an effect on students with higher mastery approach goals, which reflects on achievement. According to Dompnier et al. (2009), this effect may be due to our model's social desirability and utility derived from parents with higher expectations. According to these authors, students' perceptions of social desirability and social utility related to mastery goals moderated the relationship between mastery goals and achievement. In Portugal, university application rates are the highest, indicating that the "socially desirable" output after high school is pursuing tertiary education. Parents, therefore, seem to play a significant part in regulating the goal motivation towards AA and better results, particularly when we compare the moderator effect of teacher involvement on the

relationship between mastery approach and AA, which is not significant. In fact, parents' expectations have significant solid effects on grades, academic self-perception, and academic self-efficacy. However, previous studies have shown that parents with a university degree (control variable) also predict higher student grades (Chesters & Daly, 2017), although not academic self-perception or self-efficacy.

In line with previous findings, teacher involvement impacts academic self-efficacy and self-perception (Liu et al., 2018), yet its effect on grades is insignificant. This lack of effect was not anticipated since teachers' role in promoting AA has been widely studied and verified (e.g., Rockoff, 2004). It can be argued that in a model where parents and teachers concur to explain AA, the influence of parents is highlighted.

Perhaps the most important finding in this study is the moderation effect of parental expectations on the relationship between mastery approach and AA. While we found that the latter is not significant, it is only not so because parental expectations make it contradictory. Note that, as depicted in Fig. 3, for students whose parents' expectations are low, mastery approach is a significant AA inhibitor. On the other hand, when parental expectations are perceived by students as high, mastery approach is a significant AA driver. While at first sight, this fact may seem puzzling, we posit that this result actually makes sense. Note that students whose goal is to learn as much as possible (i.e., score high on mastery approach), but whose parents have low expectations towards their AA (and therefore likely give low support and confidence), may feel further demotivated, unsupported, and therefore feel more anxiety towards their AA, which ultimately ends up by affecting it negatively. On the other hand, students who want to learn (i.e., score high on the mastery approach) while benefit, at the same time, from their parents' high expectations, may feel extra motivated and be extra supported to overachieve in terms of AA. This result seems to highlight the importance of the familial relationships to regulate students' emotions and behaviors, providing the necessary structure to orient them towards AA.

4.5.1. Limitations and future research

Like in any work of this nature, ours entail some limitations that need to be acknowledged. First, given we analyzed self-reported data, i.e., student perceptions, it is possible there is some bias, due to social desirability, exaggeration, or shame. Additionally, there is a lack of observations due to difficulties in distributing the questionnaire during the COVID-19 pandemic and lockdown periods, as school directors would not answer the emails sent. It would be interesting for future work to have more observations and to connect this perceived information with primary data. A more extensive dataset would allow us to make more precise conclusions and use advanced analytics methods, which are proven more efficient.

Furthermore, our data is cross-sectional. Therefore, it would be noteworthy that future researchers used longitudinal data to understand how different drivers change from cycle to cycle of studies in the same student. Doing so would allow pointing different needs at the different stages of a student's life.

4.6. CONCLUSIONS

This study tested the importance of mastery approach goals, parental expectations, and teacher involvement on high school students' academic self-efficacy and AA (grades and academic self-perception). Our results highlight how significant parents are in students' life, as parental expectations are the primary driver of achievement directly and through enhancing academic self-efficacy. Higher parents' expectations moderate the relationship between mastery approach goals and grades, whereas teacher involvement's influence in this relationship is negligible.

5. MATHEMATICS AND MOTHER TONGUE ACADEMIC ACHIEVEMENT: A MACHINE LEARNING APPROACH

5.1. INTRODUCTION

Academic achievement (AA), the extent to which a student is successful in school, is a topic that has growingly interested researchers in several areas of knowledge (Koch et al., 2015b) as education has significant personal and social impacts. Among these are the positive effects on fundamental social aspects such as developing countries and productivity indexes (Spinath, 2012). Societies constantly face economic and social challenges, and education helps overcome these challenges by acquiring knowledge and high differentiated skills, thus contributing to socioeconomic development and more equality. High education rates allow individuals to be well-prepared and adapt to these changes and the competition in the job market (OECD, 2019). Therefore, it is of the utmost importance to understand AA drivers to provide policymakers with adequate strategies to promote academic success.

Traditionally, AA research has relied primarily on surveys and classical statistical analyses (Hattie & Clarke, 2018). Recent papers, however, have explored macrolevel institutional data collected by schools (Cruz-Jesus et al., 2020) using machine learning (ML) techniques to extract insights from the data. Institutional data encompasses decades of student information essential for educational research, such as demographics, academic background, and academic records. It is not typically used, as accessing, and analyzing big data in a school context poses some data availability and privacy issues (Fischer et al., 2020). However, it conveys significant benefits, such as a higher predictability power (Costa-Mendes et al., 2021b), that can complement traditional methods and contribute to research. In this paper, we use prototypes, i.e., fictional students that are scored with ML models, to measure how a standard deviation in each independent variable (i.e., AA driver) impacts a student's grade keeping all others fixed with mean values. By applying this methodology, we can quantify exactly how much each AA driver impacts students' grades. To the best of our knowledge, this is the first time a study can

achieve this goal with this detail and sample size. Theoretical and practical implications are then drawn from the results. In particular, we answer the following research questions:

- What are the main AA drivers at upper-secondary level?
- How do AA drivers differ between Mathematics and mother tongue?
- How can education researchers and practitioners engender AA?

In answering these questions, this paper is organized as follows: Section two presents the theoretical background; Section three details the methodology; Section four presents the results, whereas Section five has the discussion, implications, and future work. Finally, Section six closes with the conclusions.

5.2. THEORETICAL BACKGROUND

Academic achievement (AA), the extent to which students are successful in school, is usually measured quantitatively in terms of performance: individual students' grades, school achievement exams, standardized test scores, or grade point average (Chow et al., 2015). It is an expression of a cumulative learning experience across all school years. Understanding AA is crucial for educational decision-makers as academic difficulties may lead to long-term dropout patterns, academic failure, and problems achieving a successful career in adulthood (Gottfried & Plasman, 2018). Struggling in school can also lead to externalizing problems (Ansary & Luthar, 2009), especially during adolescence and high school, representing a critical period with significant implications for AA. Even though high school is a part of compulsory education in most developed countries, including Portugal, many students quit school. School dropout is linked to poverty and social exclusion (Jahnukainen, 2001b) and difficulties entering a successful career in adulthood (Alexander et al., 2001). Portugal's high school dropout rate currently surpasses the European average (12.6% vs 10.7%). Hence, a thorough understanding of the drivers of AA in high school can shed light on effective strategies to increase graduation rates and reduce dropouts.

Most of the research done in AA has identified diverse factors that impact students' performance, namely characteristics of the students (Steinmayr et al., 2018), parents (Castro et al., 2015), teachers (Ober et al., 2021), and the schools (Egalite & Kisida, 2016) – the primary agents related to the educational process. Other researchers described some influences that contribute to learning and achievement: the student, the home, the school, the classroom, the curricula, the teacher, and teaching and learning approaches (Hattie & Clarke, 2018).

5.2.1. AA Drivers

Students' characteristics

Students' characteristics are understandably a major factor in explaining AA. Students' cognitive ability has been identified as a major determinant of AA (Deary et al., 2007). However, this assumption has been questioned (Galindo-Rueda et al., 2005) as a much wider number of factors determining school success. Personal psychological attributes such as personality traits, motivation, academic engagement, self-efficacy beliefs, and grit also determine students' pursuit of learning goals and work efforts and are positive predictors of AA (Steinmayr et al., 2018).

The student's academic track record seems to play a crucial role in AA since not only grade retention does not provide greater benefits to students with academic difficulties than promotes the next grade (Jimerson, 2001), but it even means there is a higher chance of a previously retained student to fail a year again (Cruz-Jesus et al., 2020). Grade retention negatively impacts self-esteem, academic self-concept, and homework completion and contributes to higher maladaptive motivation and absenteeism (Martin, 2011). Retention has been linked to peer stigmatization during early adolescence and may aggravate behavioural and socioemotional adjustment problems (Anderson et al., 2011).

Research also shows significant differences in AA according to demographic characteristics of students, such as age (Cruz-Jesus et al., 2020), nationality (Portes & Rumbaut, 2005), and gender (Patterson & Pahlke, 2011). Older students, meaning they were likely previously retained, typically perform worse

(Tolen & Quinlin, 2017). In contrast, the AA of non-national students or those whose parents are immigrants is contingent on how well they have adapted to school (Portes & Rumbaut, 2005). Concerning gender, girls typically attain higher scores than boys (Mensah & Kiernan, 2010). However, boys have better results in specific mathematics abilities (Brunner et al., 2008), and girls outperform boys in reading (Brunner et al., 2013), particularly across OECD countries.

Computer usage and internet access have increased in the last decades, with noticeable benefits of its applicability in many areas. The impact on AA is still controversial as both benefits and losses have been identified. Although information and communication technologies (ICT) are an essential tool for education, its usage for leisure has escalated, especially among children and teenagers. Excessive internet leisure usage elicits lower academic results due to sleep disturbances and decreased study time (Kubey, 2001). However, moderate computer use and video gaming have positively influenced high school AA (Bowers & Berland, 2013). Concerning internet access, studies have shown that students who use the internet with a higher frequency tend to have higher scores (Torres-Díaz et al., 2016). Likewise, AA is higher for students who are not dependent solely on a cell phone (i.e., have computer access) for internet access and those with higher digital skills, mainly social media skills.

Parents' characteristics

AA is influenced by family characteristics such as socioeconomic status and cultural capital. A familiar background is crucial for children's development and to adjust to school life. Students with socioeconomic disadvantages show lower communication, language, literacy, and mathematical development. Likewise, early motherhood, low maternal qualifications, low family income, and unemployment predict lower scores at school (Mensah & Kiernan, 2010). Children whose families receive financial support for educational purposes are more likely to have lower grades (Archibald, 2006; Delen, 2010). AA is positively linked to higher parental income, high education levels, and the parents' occupation type (Steinmayr, C. Dinger, et al., 2010; Tomul & Savasci, 2012). Young people with highly educated parents are likelier to attain high AA levels than their peers with low-educated parents.

Middle school students with university-educated parents achieve at much higher levels than their peers whose parents did not pursue post-secondary education (Chesters & Daly, 2017), and parents from low educational backgrounds struggle to value education, give the necessary support, and provide the resources needed for improving AA (Coleman, 1968)

Parental involvement in school affairs has a noticeable relationship with AA (Castro et al., 2015; Fan & Chen, 2001). It enhances students' ability to cope with schooling activities and promotes appropriate behavioural attitudes that lead to success (Hill & Taylor, 2004). Parents who are more involved usually have higher expectations regarding their children's academic path, and these high expectations are linked to increased motivation for work and better results (Hill & Taylor, 2004). Participating in school activities seems to be more influential on AA for socioeconomically disadvantaged parents (Benner et al., 2016; Poon, 2020), and schools play an essential role in helping develop these parenting skills (Ali et al., 2020), helping to diminish the gap between normal pre-existing conditions.

Schools' characteristics

Research has also explored the role of schools' characteristics on student performance. Smaller schools benefit students with lower socioeconomic status and learning difficulties (Leithwood & Jantzi, 2009). Likewise, schools with an average number of students, a higher percentage of teachers on a permanent contract, and a lower proportion of economically disadvantaged students tend to yield better results (Hattie & Clarke, 2018). AA in Math and Reading declines as school size increases, and these adverse effects of large schools appear to be more salient in higher grades, which is also when schools tend to be the largest. Attending a school with a higher proportion of students from less-educated families hurts AA (Chesters & Daly, 2017).

Smaller classes have been frequently suggested as a way of enhancing academic success. In fact, smaller classes seem to improve AA, but they may also be more effective in diminishing the achievement gaps (Rivkin et al., 2005). Yet, it is not a consensual effect, as other studies demonstrate

that reducing class size is not directly linked to better AA (Costa-Mendes et al., 2020; Cruz-Jesus et al., 2020; Wößmann & West, 2006).

Teachers' characteristics

Teachers' influence is also among the most significant determinants explaining the students' AA (Rockoff, 2004). Previous research in Portuguese schools assessed the impact of teacher gender, teacher employment situation, education level, and experience and found that female teachers have a more substantial influence on students' AA than male teachers. Teachers working away from home have significant adverse effects on AA. Advanced degree teachers (with MSc or PhDs) seemed not to affect AA compared to those with a graduation degree. Teachers with more experience seem more effective increasing AA (Sousa et al., 2016). However, younger teachers typically work away from home in a more precarious work situation, which can account for this difference in teacher age and its influence on AA. Teacher involvement is crucial for developing student perceptions of academic, social, and emotional support and helping students' career planning and decision-making (Wong et al., 2021). Teachers with higher expectations about their students' AA help enhance their academic self-concept, which increases AA (Benner et al., 2016).

5.2.2. Application of Machine Learning on AA

Researchers and practitioners have resorted to novel data science and artificial intelligence techniques to shed light on AA drivers in recent years. It should be noted that most studies in this regard focus on classic, traditional methods. As more sophisticated data science methods tend to perform better than classic ones, our work uses the firsts to understand better what drives AA at the upper-secondary level.

One of the first studies using data science and artificial intelligence methods is Musso et al. (2020). These authors used data from 655 students from private universities in Buenos Aires to examine their AA using neural networks with error backpropagation. Despite its high performance, the ability of these authors to quantify each AA driver using neural networks is limited. Hence, to shed some light on AA drivers, some authors used more interpretable methods such as decision trees or random

forests. Among these is Şen et al. (2012) who examined data from 5,000 8th grade Turkish students to examine placement test scores. ML methods have been demonstrated to be highly effective, particularly decision trees. Abad and López (2017) also used decision trees to study the AA of 18,935 high school students from 99 Mexican schools, which proved to be extremely efficient thanks to its simplicity and high interpretability in understanding the underlying conditions that drive AA. Asif et al. (2017) provide another example of a study that used decision trees to examine study AA drivers, this time from 210 undergraduate Pakistan students. Even in cases where decision trees or random forests are not the best methods, for interpretation reasons, these end up being chosen for its advantages in terms of understanding the pattern between AA and its drivers. Delen (2010), for example, compared which ML methods better predict school dropout —using data from 16,066 first-year students from a public university in the United States. Likewise with other studies, although decision trees provided the second-best results, these methods were considered the most appropriate technique. Likewise, Miguéis et al. (2018) used random forests, decision trees, and other variants to examine the AA of 2,459 students attending public European universities.

In addition to the methodological issue regarding the trade-off between prediction power and interpretability discussed above, it should also be noted that most studies using sophisticated data science methods use sample data. In fact, every example mentioned earlier does this. Although using more sophisticated methods is proven worthwhile, it is still unquestionable that using sample data is an explicit limitation. There are a few studies using data that does not come from samples. One example is provided by Costa-Mendes et al. (Costa-Mendes et al., 2021b), who used neural networks, support vector machines, regression, random forests, and an extreme gradient boosting machine, discovering that the last yields the best performance. Another example is given by Cruz-Jesus et al. (2020), who compared the performance of a classical method with ML techniques to understand the factors leading to the failure or not of a school year, random forests proved to be the most accurate procedure.

5.3. METHODOLOGY

This section describes the methodology used in this work and is divided into three subsections. The first one presents a brief overview of the well-known machine learning method used in this paper - neural networks. The second focuses on a typical data science problem related to feature selection, i.e., choosing the essential variables. Finally, we present the data used in this work.

5.3.1. Machine Learning Methods

Artificial Neural Networks

Artificial neural networks, or just neural networks (NN), are biologically inspired methods mimicking the structure of a human brain (Jain & Mao, 1996).

Multilayer perceptron (MLP) is an architecture with an input layer, multiple hidden layers, and an output layer. All these layers are formed by neurons and connected through channels. First, a random weight is assigned to each channel, a bias for the neurons of the hidden layers, and all the nodes, except for the input node, receive an activation function. The algorithm starts with the feedforward process, sending the data from the input to the output layer, neuron-by-neuron. When reaching the output layer, the error is calculated using the following formula:

$$\delta_i^L = g'(h_i^L)[d_i^u - y_i^L]$$

Where h_i^L represents the input to the i th unit in the L th layer, and g' is the derivative of the activation function g .

The second step is the backpropagation, which follows the opposite direction, updating weights using a delta rule to minimize the cost function. The process now ends in the input layer. Using the following equation:

$$\delta_i^L = g'(h_i^L) \sum_j w_{ij}^{L+1} \delta_j^{L+1}$$

For $l = (L - 1), \dots, 1$.

The weights are updated by applying the following formula:

$$\Delta w_{ji}^l = \eta \delta_i^l y_j^{l-1}$$

This process can be repeated until the error is below a threshold or the maximum number of iterations is reached (Jain & Mao, 1996).

5.3.2. Feature Selection

Feature selection is a process of reducing the independent variables based on relevance. This process allows for the creation of simpler models, shorter the training times, increases precision and avoids the curse of dimensionality.

Recursive Feature Elimination (RFE) was used to set the optimal number for this project. RFE, Lasso, and Ridge regression voted for the essential features, and accordingly, with the optimal number selected on the first step, the most chosen variables were assigned.

Recursive Feature Elimination

RFE ranks the variables based on their performance on a model defined. Different measures can be applied. The features with the least importance are excluded (Guyon et al., 2002).

Ridge Regression

Ridge regression penalizes the coefficients of the features allowing for minimizing the error. The coefficients are shriveled toward zero (and each other), which grants the reduction of complexity and multicollinearity. The ridge estimate is specified as:

$$\hat{\beta} = \underset{\beta}{argmin} \sum_{i=1}^N \left(y_i - \beta_0 - \sum_{j=1}^p x_{ij} \beta_j \right) \text{ subject to } \sum_{j=1}^p \beta_j^2 \leq t$$

$t \geq 0$ is a complexity parameter that controls the amount of shrinkage: the larger the value of t , the greater the amount of shrinkage (Hastie et al., 2009). The features selected to be part of the model have higher coefficients.

Lasso Regression

Lasso is a form of linear regression that uses a shrinkage and minimizes the prediction error. The model shrinking process penalizes the regression coefficients, and the higher the penalty, the further the estimates are shrunk towards zero. After the shrinking process, the variables showed to be the weakest, the zeros, departed the model. The solution to the defined Lasso estimate L_1 optimization problem:

$$\hat{\beta}(\lambda) = \underset{\beta}{argmin} \left(\frac{\|Y - X\beta\|_2^2}{n} + \lambda \|\beta\|_1 \right)$$

Where $\|Y - X\beta\|_2^2 = \sum_{i=0}^n (Y_i - (X\beta)_i)^2$, $\|\beta\|_1 = \sum_{j=1}^k |\beta_j|$ and $\lambda \geq 0$ is the parameter that commands the strength of the penalty; the larger the value of λ , the greater the amount of shrinkage (Fonti, 2017).

5.3.3. Data

An anonymized dataset from the 2018-2019 academic year, provided by the Directorate-General of Statistics for Education and Science of the Portuguese Ministry of Education, was used. The data includes virtually every student attending a public upper-secondary year in Portugal. We include data from the mathematics and mother tongue (Portuguese) national exams used in Portugal to access tertiary education. The dataset includes the grades of 19,445 unique students who performed 35,780 exams (14,207 for mathematics exams and 21,573 for Portuguese). Hence, we could create three target variables measuring AA: the mathematics and the Portuguese exams; and an aggregate grade that combines the two.

5.4. RESULTS

A parameter tuning phase was applied in all the data science methods for the learning phase to yield better results. We used cross-validation and grid search provided by scikit-learn. Then, the models were trained using the chosen parameters. Cross-validation with repeated K-fold was implemented to assess each technique's performance and to prevent overfitting. The performance of each method was assessed using the mean R-Squared of all the iterations for each model, i.e., from each K in the cross-validation.

5.4.1. Feature Importance

To examine the features (i.e., AA drivers) included, we started by looking at the significance of the top 10 features of the best models. Feature importance was also assessed using scikit-learn. This method randomly shuffles each feature and computes the models' performance changes. Features significantly impacting the model's performance are considered the most important (please see Table 5.1).

As mentioned earlier, one of the main contributions of this work is that it intends to provide an exact measure of how much each driver impacts AA. In this sense, while feature importance provides a measure regarding the importance of each feature, it does not show to what extent each variable impacts the grade. In other words, although it allows us to have an ordinal measure (rank) of importance, it is not particularly useful for understanding how much AA is affected and even less to draw policies to engender AA. This limitation of data science methods is commonly known as the "black-box effect", which is why sometimes researchers prefer to use less powerful, but more interpretable methods, as discussed in subsection 5.2.2.

To mitigate this limitation, we use a new approach, creating a dataset made with "prototypes" to understand the importance of the variables in the neural networks' scoring process. A prototype dataset was built for each target (Portuguese, mathematics, and aggregated grades). The baseline is given by a prototype (fictional student) whose all variables have the average dataset value. Then, for

each variable in the dataset, we add two rows (prototypes): one with one standard deviation above the mean; the other with one standard deviation below. For both cases, all other variables are fixed with average dataset values. For binary variables, the rows are added with one or zero. As an example, to quantify the effect of age on AA, we add two prototypes, one with average values for all the variables, except age with one standard deviation below and one above the mean, respectively. For gender, as another example, we also created two prototypes (i.e., rows), where one as gender=0 and the other gender=1. In both cases, the baseline is given by a row with average values for all variables. The score, i.e., the predicted grade that the neural network assigns to each prototype, is then compared with that of the baseline. This difference gives us the weight that each AA driver has on the students' grades (please see Table 5.1).

Table 5.1 – Predicted impacts of the changing a unit in each variable, ceteris paribus, using prototypes

AGGREGATE GRADE				PORTUGUESE EXAM			MATHEMATICS EXAM		
RANK	variable	change	$\hat{\beta}$	variable	change	$\hat{\beta}$	variable	change	$\hat{\beta}$
#1	Stu_Age	0.58	-1.2	Stu_Age	0.61	-1.1	Stu_Age	0.54	-1.5
#2	LG_Educ	3.30	0.9	LG_Educ	3.29	0.9	LG_Educ	3.27	1.5
#3	Sch_FailR	0.08	-0.7	Stu_Fem	1 (Yes)	0.6	Sch_Elem&High	1 (Yes)	-0.9
#4	Stu_Fem	1 (Yes)	0.5	Sch_FailR	0.08	-0.5	Sch_FailR	0.08	-0.8
#5	Stu_EnrolNum	0.19	-0.3	Sch_SocSup	0.06	-0.2	Prof_MscPhD	0 (No)	-0.5
#6	Sch_SocSup	0.06	-0.1	Stu_SocSup	1 (Yes)	-0.2	LG_mother	1 (Yes)	0.3
#7	Sch_ProfDeg	0.20	-0.1	LG_mother	1 (Yes)	0.2	Stu_Fem	1 (Yes)	0.2
#8	Sch_Elem&High	1 (Yes)	-0.1	Sch_Elem&High	1 (Yes)	-0.2	Sch_SocSup	0.06	-0.1
#9	LG_mother	1 (Yes)	0.03	Sch_ProfDeg	0.2	0.1	LG_own	1 (Yes)	0.1
#10	LG_father	1 (Yes)	0.03	Stu_Net	1 (Yes)	0.1	Stu_Net	1 (Yes)	0.1

Note: rate of student's who failed the year in that school (Sch_FailR), student's age (Stu_Age), education years the legal guardian completed (LG_Educ), rate of students with school social support (Sch_SocSup), rate of teachers with MSc or PhD at the school (Sch_ProfDeg), the student being female (Stu_Fem), number of enrolments that the student did (Stu_EnrolNum), students having the highest level of social support (Stu_SocSup), the legal guardian being the mother (LG_mother), the father (LG_father) or being the student himself (LG_own), teachers holding an MSc or a PhD (Prof_MscPhD), schools offering elementary and high school (Sch_Elem&High), and students' access to the Internet (Stu_Net).

5.5. DISCUSSION, IMPLICATIONS, AND LIMITATIONS

5.5.1. Discussion of findings

We assessed the impact of several potential AA drivers in Portuguese public upper-secondary schools.

To the best of our knowledge, this work is the first, at least in this research stream, to use prototypes in quantify the impact of each feature on a specific target, i.e., AA drivers on AA. Hence, we bring to sophisticated data science methods some advantages of traditional techniques, i.e., interpretability.

Besides the methodological aspect, in this work, we used data from the whole national reality and not data based on a sample, which is always a partial representation of a larger reality. We found that the

three most crucial AA drivers are student age, the rate of failing students at the school, and the legal guardians' education. More importantly, we can indicate exactly by how much each driver affects mother tongue (PT) and mathematics (MAT) national exams.

Students' age is a proxy for a driver of utmost importance in AA research, i.e., previous retention, as older than average students in a class are synonymous with previous retention. We demonstrate that older students perform worse in terms of AA, especially in Mathematics ($MAT: \beta = -1.5$; $PT: \beta = -1.1$). This point is absolutely critical, as it seems that preventing a student from progressing in his/her school path does not prevent future retention either, perhaps on the contrary. Moreover, it is known that students who experience retention also suffer from a psychosocial point of view. Besides the impact on the individual students, it should be noted that the failing rate at the school level is also amongst the most important AA (negative) drivers we found ($MAT: \beta = -0.8$; $PT: \beta = -0.5$). Hence, one may question the need to revise the process of failing students across all school years from a pedagogical and policy point of view. We should note that we found evidence that retention has deleterious effects on AA for the failing student's progress and the entire school community.

Our results also indicate that the legal guardians' education level is amongst the most critical AA drivers. The legal guardian's education has a strong positive effect on exam results, as students whose legal guardians have more than 12 years of education (tertiary education) outperform their peers by as much as 1.5 points out of 20. This driver is especially significant in Mathematics ($MAT: \beta = 1.5$; $PT: \beta = 0.9$), a significant result to consider as there is a high and rising demand for STEM (science, technology, engineering, and mathematics) skills in the job market (European Centre for the Development of Vocational Training, 2018). It seems that difficulties in Mathematics are easier to overcome when the legal guardians have tertiary education. Likewise, when this is not the case, a student who lags behind in this subject is significantly penalized, especially considering mathematics' importance to the job market and society (OECD, 2021). Hence, we posit that enabling teachers to know the degree of education of the legal guardians may be an effective tool to prevent poor AA.

School-related characteristics are also relevant in the AA context. Starting with the schools' sizes, our results show that in bigger schools, where middle and high school students are together, high school exam scores tend to be lower ($MAT: \beta = -0.1$; $PT: \beta = -0.2$), in line with previous research (Egalite & Kisida, 2016). Schools with higher rates of unprivileged students (e.g., receiving government support) are more likely to present lower levels of AA ($MAT: \beta = -0.1$; $PT: \beta = -0.2$). Likewise, schools with a higher rate of teachers holding an MSc or PhD tend to present slightly higher AA levels, although only in Mathematics ($MAT: \beta = 0.5$). In this context, it is worth mentioning that in Portugal, (public) school enrolment is determined by students' addresses because students should be as close to home as possible. This criterion is a disadvantage for those living in underprivileged neighborhoods, making a snowball effect challenging to escape. Hence, one may question if it would make sense to develop specific learning programs in these locations to prevent the formation of underprivileged clusters.

Additional findings of this study show other relevant AA drivers. We find that females tend to outperform boys, especially in Portuguese ($MAT: \beta = 0.2$; $PT: \beta = 0.6$). Previous studies also found this link (Brunner et al., 2008). The use of the internet seems to be a positive driver of AA, even with a small impact. This link between the internet and AA is far from unanimous in the literature. Some authors find that the internet positively affects AA (Bowers & Berland, 2013); whereas others report an adverse effect (Rozgonjuk et al., 2021).

It is interesting to note that education itself plays a decisive role in AA. Note that, for students, the legal guardians' and teachers' education are amongst the main important AA drivers. Hence, students with more educated legal guardians and teachers are also more likely to perform better at school. Hence, it is absolutely critical that education stakeholders (researchers, teachers, and policymakers) try to avoid a contagion effect, where unprivileged students now will also be legal guardians of unprivileged students in the future. It should be noted that higher education levels lead to more personal development and improved life conditions (i.e., a better job, higher S.E.S., and cultural capital)

and that legal guardians in these conditions also help their children succeed at school, it is understandably the path to follow by decision-makers in the education field.

5.5.2. Theoretical Implications

Our results contribute to the literature by using sophisticated methods to understand AA at the upper-secondary level. Moreover, we develop an innovative approach based on prototypes to quantify how much each driver influences AA, comparing the results between arguably the two most essential subjects in high school: mathematics and mother tongue.

Our results are mainly in line with previous research on this topic, as it indicates that the effects of school retention are mainly adverse to AA itself (Andrew, 2014). Our results demonstrate that older, previously retained (older) students perform worse, with even higher prejudice toward mathematics. Anderson et al. (2011) also posit that retention is a strong predictor of upper-secondary school dropout, mainly because there is an absence of effective strategies to increase competencies and peer stigmatization that may exacerbate behavioural socioemotional adjustment problems. Any short-term positive academic results from retention tend to fade, and failing students subside their promoted counterparts within a few years (Tolen & Quinlin, 2017). Retention is also related to lower academic self-concept and higher maladaptive motivation and absenteeism (Martin, 2011).

We also show that upper-secondary AA is affected by legal guardians' education, as students with legal guardians with tertiary education have better results in final exams, particularly in Mathematics. Despite the fact that the literature shows evidence of the positive impact of legal guardians' education level (Steinmayr et al., 2010), identifying a university or post-secondary degree as one of the most significant aspects of enhancing student AA is a very important and novel finding. According to previous research, legal guardians' education seems to be a driver of AA across all levels, evidencing positive effects from as early as kindergarten (Tan et al., 2019). Hence, it is shown that students' home contexts play a decisive role in school experiences and AA. This dynamic has been studied at both the

classroom level, where the higher education level of peers' parents improves AA (Wang, 2021), and at the school level, as in middle school, attending a school with a higher proportion of students from educationally disadvantaged families' harms AA (Chesters & Daly, 2017).

5.5.3. Implications for Practice

Besides its theoretical implications, this study also helps shape education practices. By quantifying the impact of each driver on AA precisely, we provide meaningful insights for education policymakers and practitioners to implement substantial adjustments and improve school success. The first practical implication is related to the retention criteria and process. We believe this could be revisited, as school retention has deleterious effects on AA. Interestingly, retention policies have been under recent debate in Portugal. Retention rates have been decreasing, but further work at the student level (specialized tutoring at school for students at risk of failing, for example) and at the institutional level, namely changing retention criteria, is recommended, according to this study. Eurydice (2011) found a prevalent culture of retention in some European countries. In countries where this culture exists, the dominant belief is that year repetition benefits learning, even though recent research and results show the contrary. Some teachers still share this idea with school community and legal guardians, even though it has been repeatedly called into question. Therefore, the challenge may reside more in questioning such assumptions before implementing legislative changes.

Concerning legal guardians' education, a main positive driver of AA found in this study; some measures can be suggested, such as considering the education of the legal guardian when assigning students to classes. This measure will create heterogeneous groups that integrate students with low and high educated parents or provide teachers with information about parents' education level at the beginning of each academic year, helping to flag students who may need extra support in class, considering the high impact of parental education on exam grades.

The teacher education level (graduate vs. MSc or PhD) is also a promising positive driver of AA, so policymakers could facilitate career opportunities for teachers who pursue post-graduate education and motivate schools to hire post-graduate teachers. Policies at the school level are also contemplated: our results show that Internet use can help enhance AA, and therefore, schools could implement an effective digital reinforcement, allowing all students to have internet access, granting equality of access, and minimizing any prior disadvantages (e.g., students who do not have a computer or internet access at home). Likewise, because our results also show lower exam scores in schools with higher rates of students who receive an allowance, policymakers may want to implement measures to minimize the effects of living in socially and economically disadvantaged territories.

5.5.4. Limitations and Future Work

Like with any other work of this nature, ours have some limitations that need to be acknowledged. First, although we use data from virtually every upper-secondary student attending a public school, our data still pertains to only one moment (academic year) in time. Hence, changes that may occur in AA drivers may be partially overlooked as time goes by. The second limitation is also related to the data. It should be noted that some potentially important AA drivers have not been included in our study. There is a trade-off between the data's depth and width, i.e., the more observations we include, the smaller the number of available variables is. Because we used data from the Portuguese Ministry of Education, we were not able to collect specific variables of interest, which could only be collected using surveys and, therefore, through samples. Future research should aim to include multiple years and try to expand the types of variables used (e.g., sleeping habits or personality traits).

5.6. CONCLUSIONS

This study allowed us to understand the primary drivers of AA in upper-secondary public schools. Our results highlight the importance of promoting AA and provide valuable insights into increasing compulsory graduation rates and increasing the speed of university enrollments and graduates. Analyzing data from virtually all Portuguese public upper-secondary schools led us to identify new AA

drivers, such as legal guardians' tertiary degrees and schools with highly educated teachers. AA operates a contagion effect, as parents with university education and teachers with higher degrees (M.Sc. or Ph.D.) are positive AA drivers. Higher education levels lead to more personal development and improved life conditions (i.e., a better job, higher socioeconomic status, and cultural capital). It equips parents to help their children succeed at school. Hence, it is undoubtedly the path for decision-makers in the education field.

6. OVERALL CONCLUSION

The path to academic success is complex and derives from the interaction of multiple drivers, but it is widely regarded as one of the most significant in a student's life, from the early stage as a child, but particularly during adolescence and transition to adult life. It has implications for one's future, as graduating high school is a necessary step to enroll in university, thus allowing one to access more skilled jobs and leading to a prosperous and fulfilled life. It is also the main tool to overcome inequalities, promote social change, earnings, and health, and diminish poverty. Public school systems ensure equal access to education for all individuals, regardless of socioeconomic background or ethnicity, thus granting equal opportunities and promoting a more equal and prosperous society. Formal education fosters personal development since it provides knowledge and intellectual skills, critical thinking, and new thoughts and attitudes in youngsters, and also promotes social competences and emotional maturing.

This work allowed for a comprehensive overview of the main determinants of high school academic achievement in the Portuguese public school system. These determinants are intrinsically related to the students. However, school success also stems from other types of influences: the familiar background, the school environment, and the quality of relationships that students maintain with their parents, their teachers, and peers. The integrated analysis of different sources of information (significant literature review, primary and secondary data) allowed us to conduct the four studies here presented to achieve our research goals: i) the first one, a weight and meta-analysis that aimed to describe the more studied determinants of high school AA in literature, their significance and importance in explaining grades; ii) the second one, a PLS-SEM analysis of a conceptual model of AA examining the interaction of student, parent, and teacher-related variables; iii) a third one, where we proposed a model that further explored parents and teacher influence on academic self-efficacy, AA and perception of success; iv) and finally the fourth study, where we explored what are and to what

extent do the main AA determinants impact final high school exam grades, resorting to machine learning techniques and analyzing institutional data collected by schools.

6.1. FINDINGS

Our work shows a comprehensive overview of high school AA drivers and highlights that the triad student-parent-teacher is of particular relevance to explain AA, as the main drivers of success in high school are reliant on interactions between the three.

Our first study, a literature review, and meta-analysis allowed us to confirm the increasing interest in AA research as more studies were found in more recent years. In this study, we found the drivers about students are the most studied. However, parent-related determinants, specifically SES and parental involvement, also emerged in the analysis. The best predictors of high school AA found in the literature are academic self-efficacy and SES, and the predictors are consistent across the countries included in the weight analysis and meta-analysis.

Considering specifically Portugal, which was the scope of this research, the main finding of our work is that the two main drivers of high school AA in the Portuguese public high school system are previous retention and having a legal guardian (whom most of the times are the student's mother) who holds a university degree. This result is particularly relevant since it was found both in the PLS-SEM analysis of survey data (a self-report measure) and in the prototype approach employed in the analysis of the institutional dataset stored by the Directorate-General for Statistics of Education and Science (DGEEC) of the Portuguese Ministry of Education information system. Both these methods quantify and qualify the impact of each driver on the grades, thus, providing confidence to assume that, for policy makers, these are the main drivers to address to promote AA.

Breaking down the results in more detail, we found that student academic track record has a major impact on achievement since having failed at least a year during the course of school life has negative impacts on subsequent grades. This is a particularly relevant finding as it informs practitioners and

decision-makers of the importance of discussing retention criteria. Our results show, as others in previous literature have hinted that failing a year may have more detrimental than beneficial effects for a student.

AA is also driven by parental education, as we demonstrated that the children of parents who have completed university have better grades in school and higher scores on final exams. Student background, namely coming from a family with a lower socioeconomic status (measured by an educational allowance that is attributed to legal guardians – usually the mother – in underprivileged situations), has a negative effect, particularly on Math grades. Both these results are intertwined, as it is more likely that a higher-educated parent has a higher SES and a cultural capital that is beneficial for the student.

Parents' influence is, in fact, and not surprisingly quite extensive: higher parental expectations also promote AA and capacitate students with higher mastery goals (i.e., students for whom learning and knowledge consolidation are most important) to achieve. Parents' expectations about students' academic path, in particular regarding their academic future and post-secondary plans, are also important to increase academic self-efficacy, one of the main drivers of AA in literature. We found no effect of academic self-efficacy on grades, yet higher self-efficacy elicits higher academic self-perception.

Teacher influence, particularly the quality of relationships teachers and students establish (measured by the student perception of teacher social and pedagogical involvement) is also significant in explaining achievement, in particular promoting Math grades for previously retained students. Additionally, results showed that teachers who hold a higher degree of education (MSc or PhD) enhance, even if slightly, their performance on final high school exams.

6.2. CONTRIBUTIONS

The present work contributed to demonstrating the advantages of combining various data sources to explain a phenomenon as complex and that stems from a wide number of diverse drivers. It also attested to the reliability of applying artificial intelligence techniques in a data-driven approach in Education research. This is particularly relevant as, traditionally, research on AA has relied on classical statistical methods and self-report measures. Yet, we found that the predictions based on the “prototype-student” behavior, generated with machine learning algorithms on secondary data, are akin to the self-report results found when we asked questions to students directly.

Both methods have their strengths and limitations - a survey-driven approach is powerful as it allows to collect of a plethora of drivers that are not stored in institutional databases, for example, intrinsic drivers and perceptions, which are crucial for AA, broadening the field of research. However, and as occurred in this project due to the disruptions the pandemic caused, conducting surveys on a large scale can be an endeavor as it requires a significant amount of time, and there are complex governance issues to access participants – in this case, the students. Machine learning methods have proven superiority compared to survey-based methods, yet they are reliant on the quality and availability of data. We demonstrated that, when trying to understand a complex phenomenon such as high school AA, complementing primary and secondary data sources, analyzed with sophisticated techniques, poses an advantage, providing richness and robustness to findings and insights.

In addition, we have provided an overview of the main drivers of AA in public high schools in Portugal. We analyzed the influence of many determinants that go beyond the student-related ones, as it is crucial to consider their enveloping environment. Thus, including drivers that pertain to parents and teachers allows us to achieve more extensive insights.

Results allow us to assume that, as of the period when these studies were conducted, the key directions for policy makers to make informed and effective educational policy decisions are well

identified. In particular, and to reduce dropout and promote graduation rates, we highlighted the importance of i) reviewing the retention criteria across all school years, ii) advocating teachers' role, highlighting their importance in promoting AA by revising the career conditions and facilitating the pursuit of higher education levels and iii) capacitating parents to accompany their children during school years, in particular parents with lower education levels – i.e., parents who are not university graduates, from a disadvantaged background. Retention criteria, teacher career track, and work conditions have been under public discussion in the past years in Portugal. It is our belief that this work contributes to shedding light on the directions to the policy changes that are being considered.

6.3. LIMITATIONS AND RECOMMENDATIONS FOR FUTURE WORKS

The COVID-19 pandemic occurred during the development of this research project. It had an impact on data collection, as schools were closed for a period of time and then were handling governance measures to ensure the safe access of the school community to in presence-classes. This meant that even though a high number of contacts with schools was made. Our sample size is relatively smaller than what we had anticipated. We also did not assess the impact of the pandemic and the transformations it brought to school life, as the differences in the evaluation criteria that took place during the pandemic made it impossible to compare internal and final exam grades in the years 2019, 2020, and 2021. However, this analysis is important and can lead to further conclusions about AA drivers. Combining the prototype-based predictions of grades and increasing the survey sample size, and selecting schools may also yield significant results, for example, comparing the effect of governmental policies for AA that are already implemented. In Portugal, there are 146 schools that are under the TEIP Program - Priority Intervention Educational Territories Program (Programa Territórios Educativos de Intervenção Prioritária), schools located in economically and socially disadvantaged territories, marked by poverty and social exclusion, where violence, indiscipline, abandonment, and school failure are more manifest. The program's main objectives are the prevention and reduction of early school leaving and absenteeism, the reduction of indiscipline, and the promotion of educational

success for all students. It would be of interest to compare these schools with non-TEIP schools as to assess how its efficacy and further explain AA. Also, including other school-related variables in the models and analysis would enrich the findings.

It is worth noticing that this project sheds light on the current drivers of AA, as of the beginning of the second decade of the 21st century. Drivers of AA are likely to change as social and policy changes occur, graduation rates increase, and the social tissue evolves.

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APPENDIX I

- List of useful datasets, indicating school grade and school subject (when indicated),

number of subjects, country, and method of analysis

Study	Original Variable Name	Merged/Modified Variable Name
Meyer et al. (2019)	Gender	
Kim & Hong (2018)	Gender	
Zhang et al. (2018)	Gender	
Novak, et al. (2018)	Gender	
Zhou & Zhou (2018)	Gender	
Rahafar et al. (2016)	Gender	
Saele et al. (2015)	Gender	
Peklaj et al. (2015)	Gender	
Levi et al. (2014)	Gender	Gender
Ergene (2011)	Gender	
Gibson et al. (2006)	Gender	
Bursik & Martin (2006)	Gender	
Anderson & Keith (1997)	Gender	
Tonetti et al. (2015)	Gender	
Robinson et al. (2018)	Gender	
Osborne (2001)	Sex	
Koller et al. (2019)	Sex	
Ahinful et al. (2019)	Gender	
Soric et al. (2017)	Intellect	
Koller et al. (2019)	Intelligence	
Di Fabio & Busoni (2007)	Intelligence	
Meyer et al. (2019)	IQ	
Wang et al. (2019)	General intelligence	
Gilar-Corbi et al. (2019)	IQ	Cognitive Ability
Cho & Coulton (2016)	Household income per year	
Dickhauser et al. (2016)	Family SES	
Anderson & Keith (1997)	Family SES	
Oljaca et al. (2012)	Material situation of the family	
Koller et al. (2019)	SES	
Ishak et al. (2012)	SES	
Meyer et al. (2019)	SES Socio economic status	Social economic status (SES)

Study	Original Variable Name	Merged/Modified Variable Name
Koller et al. (2019)	SES	
Crook et al. (2015)	SES	
Zhang et al. (2018)	Social Economic Status	
Novak et al. (2018)	Self-perceived SES	
Howard et al. (2019)	SES	
Carolan, BV 2016	Family SES	
Wang et al. (2019)	SES	
Wernette & Emory (2017)	Bedtime	
Gibson et al. (2006)	Consistent bedtime routine	
Siversten et al. (2015)	Sleep duration	Sleep habits
Gibson et al. (2006)	Weeknight sleep hours	
Luo et al. (2014)	Performance approach	
Liem et al. (2012)	Performance approach	
Dinger et al. (2013)	Performance approach goals	
Dickhauser et al. (2016)	Performance approach	Performance approach
Crouzevialle & Butera (2017)	Performance approach	
Soric et al. (2017)	Performance goal orientation	
Minano et al. (2012)	Performance goals	
Bursik & Martin (2006)	Grade orientation	
Luo et al. (2014)	Performance avoidance	
Liem et al. (2012)	Performance avoidance	Performance avoidance
Dinger et al. (2013)	Performance avoidance goals	
Dickhauser et al. (2016)	Performance avoidance goals	
King & Ganotice (2014)	Work avoidance goals	
Peklaj et al. (2015)	Procrastination/distractibility	Work avoidance
Soric et al. (2017)	Work-avoidance goal orientation	
Ishak et al. (2012)	Academic self-concept	
Di Giunta et al. (2013)	Academic self-efficacy	
McIlroy et al. (2017)	Academic self-efficacy	
Levi et al. (2014)	Academic self-efficacy	
Abdi et al. (2012)	Cognitive confidence	
Abdi et al. (2012)	Cognitive self-awareness	Academic self-efficacy
Kozina et al. (2019)	Confidence	
Peklaj et al. (2015)	Self-efficacy	
Abdi et al. (2012)	Self-efficacy beliefs	
Arsilan (2016)	Academic efficacy	
Gilar-Corbi et al. (2019)	Academic self-concept	
Inal et al. (2012)	Absence	

Study	Original Variable Name	Merged/Modified Variable Name
McIlroy et al. (2017)	Absenteeism	Absenteeism
Siversten et al. (2015)	School absence (days)	
Meyer et al. (2019)	Agreeableness	Agreeableness
McIlroy et al. (2017)	Agreeableness	
Soric et al. (2017)	Agreeableness	
Di Fabio & Busoni (2007)	Agreeableness	
Peklaj et al. (2015)	BFI Agreeableness	
Wang et al. (2019)	Agreeableness	
Köller et al. (2019)	Conscientiousness	Conscientiousness
Meyer et al. (2019)	Conscientiousness	
McIlroy et al. (2017)	Conscientiousness	
Soric et al. (2017)	Conscientiousness	
Rahafar et al. (2016)	Conscientiousness	
Peklaj et al. (2015)	BFI Conscientiousness	
Di Fabio & Busoni (2007)	Conscientiousness	
Wang et al. (2019)	Conscientiousness	
Sampasa-Kanyinga et al. (2019)	Social media usage heavy	ICT leisure use
Inal et al. (2012)	Time spent on the internet	
Sahin et al. (2014)	WGPT - weekly game playing time	
Robinson et al. (2018)	Usage intensity - Leisure use computing	
King & Ganotice (2014)	Mastery goals	Mastery approach
Luo et al. (2014)	Mastery approach	
Crouzevialle & Butera (2017)		
King & Ganotice (2014)	Parent support	Parental involvement
Anderson & Keith (1997)	Parental involvement	
Howard et al. (2019)	Parental involvement	

APPENDIX II - Questionnaire – constructs table

Constructs	Code	Item	Reference
Previous retention (PRet)	PRet	Have you been previously retained? (Y/N)	
Previous achievement (PAch)	PAch1	<i>Please indicate, on a scale of 0-20, what was your:</i> Portuguese previous achievement (final grade of the previous school year)	Day et al. (2010)
		Math previous achievement (final grade of the previous school year)	
		Grade point average of the previous school year	
	PAch3		
ICT Use (second-order reflective-formative type)	ICT access (ICTA)	ICTA1 Internet access via a computer or tablet	Tang & Patrick (2018)
		ICTA2 Internet access via smartphone	
	ICT Use Academic (ICTAc)	ICTAc1 Online search for information related to schoolwork	
		ICTAc1 Use of ICT to communicate with teachers	
	ICT Use Hedonic (ICTHe)	ICTHe1 Use of social networks (including WhatsApp, Facebook Messenger, etc.)	
		ICTHe2 Use of ICT for fun (i.e., playing online, watching multimedia content such as movies or music, etc.)	
Age (Age)	Age	How old are you?	Chowa et al. (2015)
Teacher involvement (TInv) (second order reflective-reflective type)	Teacher pedagogical involvement (TPInv)	<i>Scale from 1 (Strongly Disagree) to 7 (Strongly Agree)</i> TPInv1 My teacher cares much about how I learn	Johnson & Johnson (1983)
		TPInv2 My teacher likes to see me work	
		TPInv3 My teacher likes to help me learn	
		TPInv4 My teacher wants me to do my best in my schoolwork	
	Teacher social involvement (TSInv)	TSInv1 My teacher thinks it is important to be my friend	
		TSInv2 My teacher likes me as much as he/she likes other students	
		TSInv3 My teacher cares about my feelings	
		TSInv4 My teacher really cares about me	
Parental expectations (PExp)	Expe1	<i>Scale from 1 (Strongly Disagree) to 7 (Strongly Agree)</i> My parents think that I will complete compulsory education successfully.	Veas et al. (2015)
		Expe2 My parents believe I can continue to pursue post-compulsory education	
		Expe3 My parents think that I can perform work successfully.	

Constructs	Code	Item	Reference
	Expe4	My parents think that I will pursue higher education (university).	
	Expe5	My parents discuss my post-compulsory education plans with me.	
Parental education (PEdu)	PEdu	What is the highest education level your legal guardian has completed?	Chesters & Daly (2016)
Educational allowance (EAlo)	EAlo	Do you benefit from an educational allowance? (Y/N)	
		<i>Please indicate, on a scale of 0-20, what was your:</i>	
AA Portuguese (AAPT)	AAchi1	Portuguese achievement in the current year (grade on a scale of 0-20)	(Gonzalez-pienda et al., 2002)
AA Math (AAMat)	AAchi2	Math achievement in the current year (grade on a scale of 0-20)	

APPENDIX III - Loadings and cross-loadings

	PRet	PAchi	ICTA	ICTAc	ICTHe	Age	TSInv	TPInv	PExp	PEdu	EAllo
PRet	1.000	-0.060	0.177	0.015	0.047	0.317	0.099	0.058	-0.222	-0.196	-0.220
PAch1	0.007	0.788	-0.068	0.021	-0.077	0.047	0.035	0.090	0.043	-0.022	0.209
PAch2	-0.063	0.999	-0.106	0.019	-0.100	-0.024	0.099	0.136	0.167	0.135	0.228
PAch3	0.000	0.668	-0.035	0.072	-0.045	0.023	0.061	0.096	0.078	-0.002	0.130
ICTA1	0.203	-0.124	0.777	0.332	0.328	0.065	-0.002	-0.062	-0.034	0.014	-0.150
ICTA2	0.087	-0.046	0.826	0.170	0.573	-0.044	-0.055	-0.049	0.028	-0.004	-0.062
ICTAc1	-0.058	0.021	0.277	0.831	0.167	0.024	0.128	0.197	0.263	-0.056	-0.039
ICTAc2	0.080	0.017	0.238	0.846	0.243	0.000	0.245	0.246	0.124	0.028	-0.036
ICTHe1	0.057	-0.058	0.556	0.252	0.872	-0.069	-0.033	-0.056	0.054	0.008	-0.106
ICTHe2	0.016	-0.113	0.356	0.137	0.764	0.007	-0.049	-0.098	0.016	0.124	-0.022
Age	0.317	-0.021	0.009	0.015	-0.044	1.000	-0.134	-0.188	-0.264	-0.158	0.037
TsIn1	0.091	0.089	-0.025	0.243	-0.015	-0.156	0.870	0.596	0.073	-0.016	-0.084
TsIn2	0.104	0.012	-0.027	0.193	-0.041	-0.074	0.723	0.371	0.171	0.056	-0.020
TsIn3	0.117	0.104	-0.044	0.141	-0.030	-0.117	0.922	0.551	0.085	0.040	-0.051
TsIn4	0.042	0.119	-0.032	0.201	-0.080	-0.109	0.925	0.648	0.144	0.058	0.021
TPIn1	0.022	0.085	-0.052	0.290	-0.146	-0.087	0.618	0.813	0.173	-0.009	0.053
TPIn2	0.059	0.181	-0.070	0.158	-0.060	-0.203	0.442	0.847	0.276	0.071	0.026
TPIn3	0.100	0.101	-0.025	0.248	-0.077	-0.153	0.630	0.921	0.257	0.000	0.024
TPIn4	0.011	0.109	-0.095	0.202	-0.019	-0.209	0.478	0.847	0.240	0.096	-0.025
Expe1	-0.233	0.164	0.025	0.105	0.076	-0.314	0.074	0.155	0.875	0.273	0.173
Expe2	-0.171	0.141	-0.029	0.217	0.051	-0.241	0.120	0.278	0.929	0.204	0.206
Expe3	-0.130	0.128	-0.051	0.225	-0.036	-0.198	0.190	0.330	0.870	0.164	0.205
Expe4	-0.247	0.180	-0.001	0.269	0.044	-0.202	0.094	0.234	0.889	0.211	0.249
Expe5	-0.088	-0.019	0.110	0.222	0.093	-0.044	0.106	0.223	0.637	0.102	0.076
PEdu	-0.196	0.128	0.006	-0.015	0.071	-0.158	0.039	0.043	0.241	1.000	0.306
EAllo	-0.220	0.227	-0.129	-0.045	-0.085	0.037	-0.039	0.023	0.228	0.306	1.000

Note: The correlations of the formative items (ICT use) and control variables (Gender and LG Mother) have been omitted. PRet=previous retention; PAch=previous achievement; ICTA=ICT access; ICTAc=ICT academic use; ICTHe=ICT hedonic use; TSInv=teacher social involvement; TPInv=teacher pedagogical involvement; PExp=parental expectations; PEdu=parental education; EAllo=educational allowance; AAPT=academic achievement Portuguese; AAMat=academic achievement Math.

APPENDIX IV

- Heterotrait-Monotrait Ratio (HTMT)

	PRet	PAch	ICTA	ICTAc	ICTHe	Age	TSInv	TPInv	PExp	PEdu	EAllo	AA PT	AA MAT
PRet													
PAch	0.027												
ICTA	0.270	0.125											
ICTAc	0.109	0.058	0.616										
ICTHe	0.061	0.125	1.137	0.430									
Age	0.317	0.036	0.102	0.020	0.064								
TSInv	0.109	0.079	0.075	0.314	0.073	0.141							
TPInv	0.060	0.137	0.123	0.366	0.142	0.203	0.707						
PExp	0.216	0.118	0.123	0.341	0.111	0.248	0.160	0.325					
PEdu	0.196	0.062	0.017	0.066	0.112	0.158	0.053	0.055	0.237				
EAllo	0.220	0.221	0.197	0.059	0.108	0.037	0.054	0.040	0.226	0.306			
AA PT	0.268	0.187	0.129	0.051	0.078	0.132	0.085	0.069	0.368	0.349	0.230		
AA MAT	0.197	0.142	0.164	0.035	0.130	0.129	0.209	0.254	0.131	0.114	0.039	0.422	

Note: PRet=previous retention; PAch=previous achievement; ICTA=ICT access; ICTAc=ICT academic use; ICTHe=ICT hedonic use; TSInv=teacher social involvement; TPInv=teacher pedagogical involvement; PExp=parental expectations; PEdu=parental education; EAllo=educational allowance; AAPT=academic achievement Portuguese; AAMat=academic achievement Math.

APPENDIX V – Instrument

Constructs		Code	Item	Reference
			Scale from 1 (Strongly Disagree) to 7 (Strongly Agree)	
Mastery Approach (MApp)		MApp1	It is important to me that I learn a lot of new concepts this year.	Midgley et al. (1998)
		MApp2	One of my goals in class is to learn as much as I can.	
		MApp3	One of my goals is to master a lot of new skills this year.	
		MApp4	It is important to me that I thoroughly understand my classwork.	
		MApp5	It is important to me that I improve my skills this year.	
			Scale from 1 (Strongly Disagree) to 7 (Strongly Agree)	
Parental expectations (Expe)		Expe1	My parents think that I will successfully complete compulsory education.	Veas et al. (2015)
		Expe2	My parents believe I can continue to pursue post-compulsory education	
		Expe3	My parents think that I can perform work successfully.	
		Expe4	My parents think that I will pursue higher education (university).	
		Expe5	My parents discuss my post-compulsory education plans with me.	
			Scale from 1 (Strongly Disagree) to 7 (Strongly Agree)	
Teacher involvement (TInv) (second order reflective-reflective type)	Teacher pedagogical involvement (TPIInv)	TPIInv1	My teacher cares much about how I learn	Johnson & Johnson (1983)
		TPIInv2	My teacher likes to see me work	
		TPIInv3	My teacher likes to help me learn	
		TPIInv4	My teacher wants me to do my best in my schoolwork	
	Teacher social involvement (TSInv)	TSInv1	My teacher thinks it is important to be my friend	
		TSInv2	My teacher likes me as much as he/she likes other students	
		TSInv3	My teacher cares about my feelings	
		TSInv4	My teacher really cares about me	
			Scale from 1 (Strongly Disagree) to 7 (Strongly Agree)	
Academic self-efficacy (ASEf)		ASEf1	If I try, I can even do the hardest work in the course.	(Midgley et al., 2000)
		ASEf2	I can do all the work of the course if I do not give up.	
		ASEf3	Even if the work in the course if hard, I can learn it.	
		ASEf4	I am sure I can find the way of getting the work done	
Parental education (PEdu)	PEdu	What is the highest education level your legal guardian has completed?		Chesters & Daly (2016)
Gender	Gen	What gender do you identify with? (F/M/Other)		
Educational allowance (EAlo)	EAlo	Do you benefit from educational allowance? (Y/N)		
			Please indicate, on a scale 0-20, what was your:	(Gonzalez-pianda et al., 2002)
AA Portuguese (AAPT)	AAchi1	Portuguese achievement in the current year (grade on a scale 0-20)		al., 2002)
AA Math (AAMat)	AAchi2	Math achievement in the current year (grade on a scale 0-20)		
			Scale from 1 (Strongly Disagree) to 7 (Strongly Agree)	
Academic self-perception (ASPe)		ASPe1	I am confident in my scholastic abilities.	(McCoach, 2002)
		ASPe2	I do well in school.	
		ASPe3	I learn new concepts quickly.	
		ASPe4	I am successful.	
		ASPe5	I am confident in my ability to succeed in school.	

APPENDIX VI — Loadings and cross-loadings

	MApp	Expe	TSInv	TPInv	ASEf	AA	ASPe
MApp1	0.773	0.287	0.232	0.315	0.432	0.015	0.236
MApp2	0.876	0.334	0.261	0.334	0.511	0.018	0.327
MApp3	0.869	0.341	0.232	0.372	0.434	0.023	0.311
MApp4	0.784	0.399	0.149	0.309	0.396	0.113	0.305
MApp5	0.780	0.312	0.138	0.288	0.380	-0.033	0.237
Expe1	0.310	0.828	0.053	0.156	0.349	0.408	0.289
Expe3	0.354	0.893	0.169	0.330	0.440	0.318	0.454
Expe4	0.378	0.869	0.086	0.235	0.367	0.340	0.278
Expe5	0.327	0.743	0.088	0.223	0.375	0.100	0.380
TsIn1	0.214	0.073	0.889	0.595	0.211	0.077	0.227
TsIn3	0.190	0.104	0.939	0.550	0.231	0.147	0.261
TsIn4	0.288	0.159	0.936	0.647	0.254	0.160	0.341
TPIn1	0.276	0.203	0.620	0.810	0.218	0.074	0.245
TPIn2	0.374	0.284	0.459	0.849	0.280	0.160	0.311
TPIn3	0.360	0.261	0.649	0.921	0.324	0.130	0.333
TPIn4	0.354	0.239	0.485	0.849	0.334	0.092	0.298
ASEf1	0.377	0.317	0.149	0.280	0.841	0.091	0.529
ASEf2	0.482	0.394	0.172	0.277	0.865	0.056	0.458
ASEf3	0.446	0.413	0.258	0.294	0.878	0.198	0.589
ASEf4	0.531	0.466	0.284	0.318	0.891	0.087	0.483
AAchi1	0.035	0.381	0.086	0.064	0.136	0.951	0.135
AAchi2	0.018	0.142	0.206	0.238	0.052	0.681	0.101
ASPe1	0.309	0.320	0.258	0.280	0.488	0.072	0.868
ASPe2	0.263	0.401	0.252	0.276	0.460	0.134	0.862
ASPe3	0.230	0.363	0.161	0.238	0.597	0.172	0.815
ASPe4	0.351	0.406	0.350	0.375	0.535	0.154	0.905
ASPe5	0.365	0.343	0.288	0.330	0.488	0.079	0.896

Note: The correlations of the control variables have been omitted. MApp=Mastery approach; Expe=Parental expectations; TSInv=Teacher social involvement, TPInv=Teacher pedagogical involvement; ASEf= Academic self-efficacy; AA=Academic achievement; AAchi1=Portuguese grade; AAchi2=Math grade; ASPe=Academic self-perception

APPENDIX VII - Heterotrait-Monotrait Ratio (HTMT)

	MApp	Expe	Tinv	ASEf	AA	ASPe
MApp						
Expe	0.475					
Tinv	0.408	0.262				
ASEf	0.595	0.523	0.364			
AA	0.079	0.428	0.264	0.149		
ASPe	0.387	0.472	0.391	0.651	0.185	

Note: MApp=Mastery approach; Expe=Parental expectations; TInv=Teacher social involvement, TPIInv=Teacher pedagogical involvement; ASEf= Academic self-efficacy; AA=Academic achievement; ASPe=Academic self-perception.

