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The Dropout of First-Year STEM Students: Is It Worth Looking beyond Academic Achievement?

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Abstract: The expansion of Higher Education increased the diversity of students, with heterogenous characteristics, needs, and values. Institutions, intending to preserve the mission and the transformative potential of the tertiary level of education, are facing and implementing policies and practices that enhance success conditions, persistence, and avoid student dropout, in order to meet the goals for sustainable development of people and societies. The present study aims to analyze the impact of personal and academic variables on students' academic difficulties in adaption to HE, academic achievement, and dropout among first-year STEM students. From a cohort of STEM first-year students at a Portuguese public university, the participants numbered 1376. Applying the structural equation modelling, the results highlight the effect of the variables age, gender, scholarship, and grade point average on access to higher education, difficulties in adapting to higher education, and dropout decision. Understanding STEM students who have already dropped out can contribute to better identification of institutional actions to prevent and reduce its occurrence, especially in first-year students.

Keywords: higher education; first-year students; student adjustment; academic achievement; dropout

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1. Introduction

In last decades we have witnessed a great expansion of Higher Education (HE), explained by the increasing acknowledgement of HE as a context with high transformative potential, which has the mission to provide opportunities for students' global development and training in technical and professional knowledge and skills (Harman, 2017). Frequently, students and their families invest in tertiary education as a chance to obtain a degree and thus widen their opportunities. This is especially true for people from socioeconomically disadvantaged backgrounds [1,2].

In this framework, the sustainable development goals (SDG) assumed by the United Nations highlight the scientific and social role of higher education in the global objectives of sustainable development, generalized to the entire population. In line with the SDG 4–Education and the SDG8–Decent work and Economic Growth objectives, it is urgent to provide lifelong learning opportunities for youth and adults (target 4.3), to substantially reduce the proportion of youth not in employment, education, or training (target 8.5), and to achieve full and productive employment and decent work for all (target 8.6), increasing the number of youth and adults who have relevant skills for employment, decent jobs, and entrepreneurship (target 4.4). The educational goals are also related with more healthy and sustainable lifestyles, promoting more democratic societies, based on the respect of human rights and the promotion of a culture nonviolence (target 4.7) [3].

Given this world context, the dropout of students from HE can be understood as a phenomenon that goes against the objectives of societies and governments [3]. Students

who drop out usually experience the non-fulfilment of a personal and professional project, with negative impact on their own expectations, but also on their family's expectations. The negative impact also occurs in HE institutions, since internal quality assurance systems consider not only the attraction of students, but also course completion rates as indicators of the quality. From an economic perspective, HE institutions lose public and family funding which are directly associated with the number of students who attend them. For all these reasons, institutions are becoming increasingly attentive in monitoring and predicting the phenomenon to develop institutional strategies and services to promote persistence and support students at-risk [4,5].

Dropping out can be understood as a complex and multidetermined phenomenon. According to V. Tinto [6], assuming an interactionist approach with dynamic and reciprocal interactions, dropout is the result of a gradual process of disengagement of the student from the course and/or institution. The students' personal characteristics, the formal and informal characteristics of the HE institution, and the characteristics of the community in which the students are inserted play an important role in the decision to remain or drop out [7–10]. In the same line, other authors point out that dropping out cannot be analyzed as a decision taken at a given moment, because it is essentially the result of a process of investment, in affective, cognitive, and behavioral terms, of students in academic activities, which is associated with the quality and degree of attachment of students to their course and institution [11–14]. For some students with low levels of maturity and autonomy, the transition and adaptation to HE is more challenging, especially for those who need to develop coping mechanisms to manage the demands and/or perceived lack of support from the institution [15–18].

In this article, considering STEM first-year students, we will analyze some of the variables identified in the research as relevant to explaining the student dropout. In the area of STEM, student dropout does not favor countries' development strategies and economic competitiveness [18]. Given the great importance of STEM skills in solving most everyday problems and exercising citizenship [19], the dropout of students in these undergraduate areas becomes socially more critical.

One of the variables assumed as relevant in the dropout process is related to the students' learning and academic performance levels [20,21]. In the first weeks, the student evaluates the levels of understanding of the curricular subjects or the effectiveness of lessons and the work done in various groups, for example [22]. When the levels of performance achieved are not representing the efforts made by the student, the first doubts about the course and higher education emerge and some intentions to drop out could also emerge [23,24]. The first tests or exams at the end of the semester may confirm such academic difficulties, and at that point the decision to drop out can be made. The student can weigh the marks obtained and the number of curricular units successfully completed to appreciate whether the investment made in the academic activities was compensated or not. In this sense, in our study, we considered the number of curricular units completed by first-year students as a possible predictor of dropout in line with research that points to academic performance as the closest determinant or the most relevant predictor of the dropout decision [12,25]. Thinking about dropout as a gradual disengagement process, achievement difficulties appear in our model as a variable related to the dropout decision.

On the other hand, research shows that several students experience difficulties in their transition and adaptation to higher education, and that these difficulties impair their academic performance and thus may be the origin of the dropout decision [12,16,26]. HE makes several demands and students do not always have the necessary skills and levels of autonomy to successfully overcome such demands [27–29]. Such students, without support, may progressively disengage from academic activities, exacerbating feelings and behaviors associated with academic maladaptation [30–32].

Research in the area indicates, for example, that first-year STEM courses have foundational curricular units in the areas of mathematics, physics, and chemistry, and students with poorer academic skills in secondary school may experience more difficulties in their

learning [32,33]. Problems in the academic adjustment of incoming students are not limited to difficulties in learning and academic achievement; some students arrive in higher education with insufficient levels of personal autonomy to manage new daily responsibilities or to establish relationships with new classmates and teachers [10,34,35], while others have unrealistic expectations about the course and HE, sometimes with poorly defined vocational projects. Finally, the institution and academic environment in ES is quite different and less welcoming than the reality experienced in secondary school, and students do not always have the personal resources to cope with less structured and more anonymous environments [15,36]. Due to its relevance, in our model, we introduced the difficulties of academic adaptation that students verbalize when entering HE as a factor that can impact academic performance at the end of first semester and present a direct or/and indirect impact on the decision to remain or leave during the first year [23,37,38].

Research also shows that other entrance characteristics of students can have an impact on their adaptation, performance, and permanence. One of these variables has to do with the grade point average (GPA) to access HE, which reflects the set of skills that the student has developed throughout his or her previous schooling. At the same time, and especially when we talk about STEM courses, this access average may condition the access of students to certain courses when the admission rules are determined by the seriation of candidates based on the access marks. In Portugal, the numerus clausus system determining the access to courses and institutions is based on the application mark of the students, weighting their school performance in secondary education and the marks in the entrance examinations to higher education. The grade point average (GPA) is assumed to be a predictor of academic success and explains around 20% of the variance of academic performance in the first year [10,25,39].

Another variable that could influence the students' adaptation to HE is that of socioeconomic resources, and the financial support policies for students (scholarships) may be an relevant to their access and permanence, particularly for students from low-income families. These financial supports help students' engagement, persistence, and higher completion rates [40–43].

Moreover, student age is a relevant variable to consider. Older students, being workers, seem to have a higher propensity to drop out than traditional students; they usually present a higher familiar level of cultural and economic capital that allows them to understand and become implicated in academic university life [40,44,45]; however, older students may have fewer skills in organizing their learning activities because they have been disconnected from their academic training for some time or because they need to manage studying with other social, professional, or family responsibilities, missing more classes and showing less availability for group work and losing the opportunity to ask questions of colleagues and teachers [46]. On the other hand, due to their older age and socioprofessional status, they may also be stereotyped by their peers, and even by teachers, about their role as students, complicating their academic adaptation. Students from low social backgrounds and students with no family tradition of attending HE tend to have lower skills in mathematics and reading, critical thinking, and aspirations, and have the perception of less parental support and encouragement [47]. The research points, therefore, to the need to investigate the difficulties experienced by "non-traditional" students when adapting to higher education, which, if not overcome, may be at the origin of low academic performance and higher dropout rates.

Finally, some differences in academic achievement and on dropout rates are associated with sex. Male students usually drop out more frequently and devote less time on academic activities and tend to be older [48]. For female students, age is not a determinant variable to explain dropout decision; more frequently female students exhibit more difficulties with social integration [12,38,49]. Sex-based differences between students' decision to drop out could be explained by that fact that female students are often more methodical, focused, and organized in planning their academic activities, more diligent in class and group work, more participatory in class, and seek more support from faculty and peers [17,50],

obtaining better grades along academic trajectories and enhancing access to universities the degree of their preference. However, in STEM courses, the situation can be quite different and some authors present higher dropout levels in female students [51–53]. In this case, female students often experience a low sense of belonging, low self-efficacy, and weak STEM identity, largely because of the remaining stereotypes that such students do not meet the requirements of STEM courses [51,54]. For example, some research shows that sexist bias against women persists in teachers and students [55,56]. The dropout ratio by gender increase for students in scientific areas of graduation where their gender are underrepresented, such as in some engineering courses [57].

In sum, the present study aims to analyze the impact of personal and academic variables on students' academic difficulties in adaption to HE, academic achievement, and first-year dropout rate. It is also intended to analyze how this wide set of variables interact with each other (direct effects and mediated effects) in the students' decision to drop out during the first-year. Understanding the gradual dropout process by STEM students can contribute to the better identification of institutional actions to prevent and reduce its occurrence, especially in first-year students. For the reflective construct 'Adaptation difficulties', the moderating variables are illustrated in Figure 1.

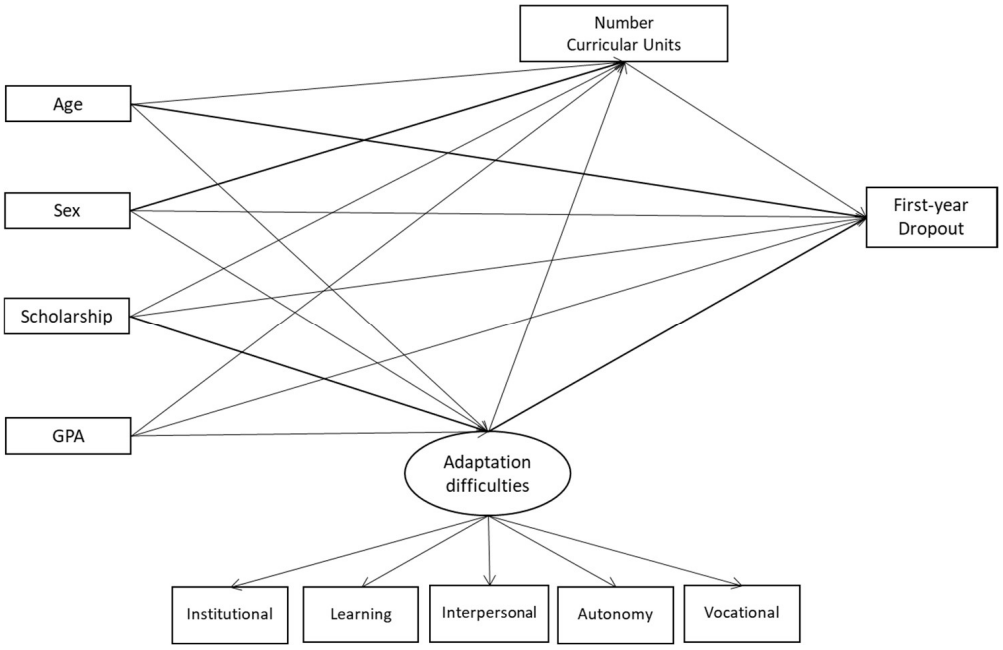

Figure 1. Path diagram of gradual process of students' disengagement and dropout.

2. Materials and Methods

2.1. Participants

The study was carried out in a public university in the north of Portugal, in which 1376 students were enrolled in different STEM degree courses who had enrolled in higher education for the. According to the research by [58], for this type of analysis, they recommend having samples larger than 100 respondents. Therefore, our study fulfills this requirement. The majority of the students were male (59.9%), with a mean age of 18.51 years (SD = 2.52) with values ranging from 16 to 44 years. There are no significant differences in age according to gender (M*male* = 18.62, *SD* = 2.78; M*female* = 18.35, *SD* = 2.48). In the sample, 36.8% of students receive scholarship, reflecting social support by the government to students from less well-off households. Grade point average to access HE ranged from 10.00 to 19.64, with a mean value of 15.19 (*SD* = 1.83).

2.2. Instruments

This study considers part of the data from the research project on first-year dropout rate in HE students. The instruments used to collect the data/information contained in this study are presented.

Sociodemographic questionnaire. Students' information: participants' age (years), sex (0—female, 1—male); students' information on academic history and vocational options: grade point average of access to HE (from 10 to 20 points), degree in which the student enrolled (name of the degree).

Academic Services Report on academic situation and dropout. Academic situation on students' dropout rate or permanence (1 = permanence; 2 = dropped out), number of curricular units approved during students' first year (students take on 5 or 6 subjects per semester, totaling 60 ECTS credits per year), have benefited from a study grant (0 = no, 1 = yes).

Instrument to Explore Difficulties in Academic Higher Education Adaptation [59]. This assesses the difficulties anticipated by students regarding six situations of academic life: (i) adaptation to the institution (welcome, spaces and services, relationship with academic staff); (ii) learning (knowing how to study, participating in classes or completing assignments on time, academic results); (iii) interpersonal (making new friends, integrating into the class, participating in activities and social gatherings outside classes); (iv) economic (defraying daily expenses); (v) autonomy (living on your own, self-confidence, managing stress, taking on responsibilities on your own, missing your family); and (vi) vocational (not liking the course, finding out that the course is not what you expected, future job prospects). The answers are pointed on a 5-point Likert scale, from 1=no difficulties at all to 5=many difficulties. The present study will use all the difficulties except economic difficulties because the variable social grant was considered. The reliability of the scale scores was estimated by Cronbach's α coefficient (being 0.79).

2.3. Procedure

The study was conducted according to the ethical standards of research with human beings, following the guidelines of the Declaration of Helsinki and the Oviedo Convention, and, as part of a wider project, was presented and approved by the Ethics Committee of the HE institution where the participants first enrolled.

Initially, first-year students were invited to participate in the study at enrolment in the university. They were informed of the study objectives and gave their free, informed, written consent to match the data collected when they started their course (sociodemographic questionnaire). The confidentiality of the data was assured, and students were able to decline to participate or to drop out of the study at any time simply by communicating their wishes. In a second moment, at the beginning of the second academic year, data about academic achievement and the dropout rate from Academic Services (academic and dropout report) was collected and matched with the sociodemographic questionnaire. Only students for whom we had information about their HE entry and dropout status were considered in the study.

2.4. Data Analysis

Data were analyzed using the statistical program Stata v.14 [60,61]. The relationships hypothesized in Figure 1 are assessed through structural equation modeling (SEM), and mediation analysis is performed to estimate indirect, direct, and total effects of the potential mediators. Data were analyzed using the statistical program Stata v.14 [62–64]. The use of structural equations is derived from the variance–covariance matrix, so that a variable is measured with a series of observable measures that facilitate the analysis of the relationships between variables. This allows us to compare the model with other alternatives and to account for measurement errors [62]. In this case, we have used the Stata v.14 program to analyze the causal relationships between the variables.

3. Results

To carry out the analysis, internal consistency and discriminant validity were studied for the construct "Adaptation difficulties". In the case of internal consistency, composite reliability (CR) values should ideally be higher than 0.70 [62]. In this case, a value of 0.880 is obtained. Therefore, the results satisfy the internal consistency criteria. Likewise, convergent validity requires an average variance extracted (AVE) for each construct greater than 0.50 [62], which, in this case, has a value of 0.660 and therefore also satisfies this criterion. Afterwards, we calculate R-square for the coefficients (Dis1, Dif2, Dif3, Dif4, and Dif5) that explain the construct "Adaptation difficulties". In this way, the results were 0.52, 0.26, 0.54, 0.34, 0.20, and 0.25, respectively.

The goodness-of-fit indices were the χ^2/df (ratio chi-square and degrees of freedom), comparative fit index (CFI), Tucker–Lewis index (TLI), root mean square error of approximation (RMSEA) and standardized root mean square residual (SRMR). The fit of the model was considered good for values of $\chi^2/df < 5$, values of CFI and TLI > 0.90, and values of SRMR and RMSEA < 0.08 [63–66].

3.1. Difficulties on Adaptation to Higher Education

Five situations (items) have been described to students in order to explore the level of difficulties experienced or anticipated by students in their first days at university. Table 1 presents the results on the 5-points Likert scale per item, including skewness and kurtosis of results distribution.

Table 1. Items results distribution (n = 1268).

Variables	Min.	Max.	M	SD	Swek.	Kurt.
Number of Curricular Units	0	12	7.67	3.70	−0.752	−0.541
Adaptation Difficulties (Total score)	5	23	11.33	3.02	0.440	0.516
Institutional adaptation	1	5	2.42	0.836	0.313	0.262
Learning	1	5	2.61	0.799	0.155	0.168
Interpersonal	1	5	2.41	0.916	0.489	0.133
Autonomy	1	5	2.00	0.902	0.781	0.370
Vocational	1	5	1.88	0.858	0.904	0.758

Note. Min. = Minimum; Max. = Maximum; M = Media; SD = Standard Deviation; Skew. = Skewness; Kurt. = Kurtosis.

In all five situations, the minimum and maximum obtained cover the values of the 5-points Likert scale. More difficulties are being experienced and anticipated by students in learning and academic achievement, and inversely vocational difficulties tend to be lower. Skewness and kurtosis coefficients are above the unit suggesting a normal distribution of values. A standard deviation near unit in a 5-points scale can also be interpreted as an adequate variance coefficient.

Table 2 presents the goodness-of-fit indices of the global model that have been tested. The model includes a confirmatory factor analysis to identify a latent variable of students' adaptation based in five situations of potential difficulty and the relationships among variables to explain the students' dropout rate (path analysis).

Table 2. Model fit indexes.

Index	Value	Suggested Value
χ^2/df	4.52	<5
Comparative Fit Index (CFI)	0.944	>0.90
Tucker Lewis Index (TLI)	0.906	>0.90
Root Mean Square Error of Approximation (RMSEA)	0.054	<0.08
Standardized Root Mean Square Residual (SRMR)	0.032	<0.05

All the goodness-of-fit indices assume values that are included in the intervals of suggested values. The 90% confidence interval for RMSEA is above 0.08.

In Figure 1, the direct and indirect effects of variables to explain dropout rate are present. Initially, results confirm the unidimensional structure of the five items of the questionnaire to assess students´ adaptation difficulties. All five items converge on the latent variable assumed in model, and the loadings values are higher than 0.50 (the vocational item presents the lower loading value which means that the career or professional questions are less important when students just start their graduation compared to other domains of potential difficulty).

3.2. Direct and Indirect Effects on Dropout Rates

The hypotheses proposed in this study were evaluated through the covariance based structural equation modeling (CB-SEM) approach [58]. For this approach, bootstrapping with 10,000 resamples was used to assess the significance of the path coefficients. Figure 2 represents standardized coefficients on the direct and indirect effects of variables in dropout explanation, the SEM results revealed a direct significant relationship between number of curricular units (academic achievement) and the variables included in the assessment model. In particular, there is a direct significant relationship between age and number of curricular units approved ($\beta = -0.17$, $p < 0.001$). Moreover, there is a direct significant relationship between having a scholarship and the number of curricular units approved in the first year ($\beta = -0.12$, $p < 0.001$). In addition, there is a direct significant relationship from GPA to access HE and the number of curricular units approved ($\beta = 0.77$, $p < 0.001$). However, the direct causal relationship between sex and number of curricular units approved is not significant ($\beta = 0.2$, $p > 0.001$).

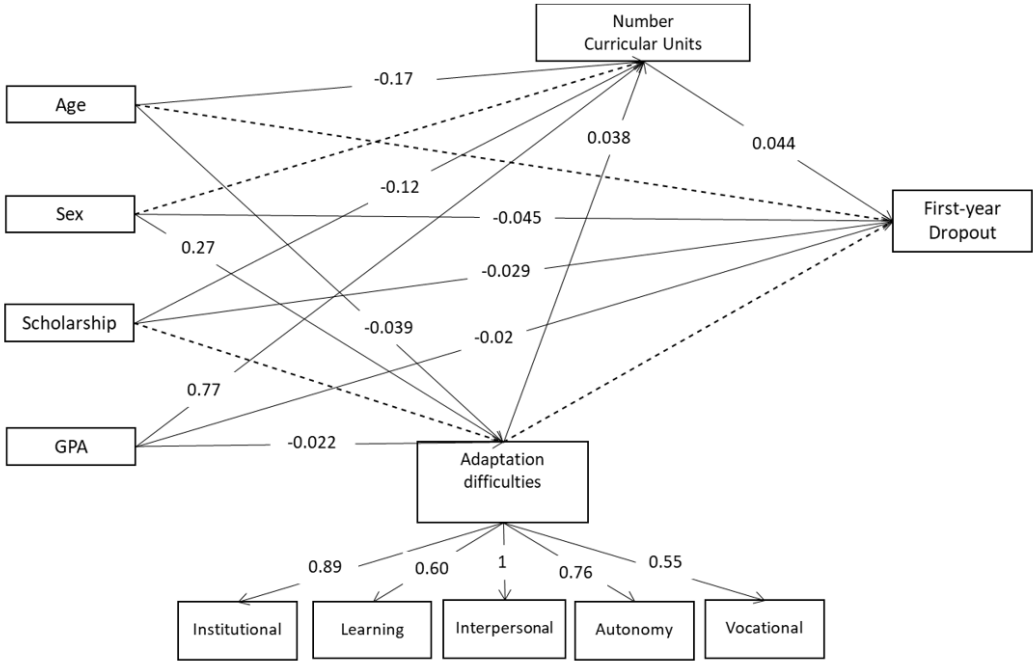

Figure 2. Path diagram of students' disengagement and dropout (the dashed paths represent non-significant paths).

It is also observed that the input variables show certain causal relationships with the difficulties of adaptation to HE. In this sense, there is a direct significant causal relationship between age and adaptation difficulties ($\beta = 0.039$, $p < 0.001$), between sex and adaptation difficulties ($\beta = 0.027$, $p < 0.001$), and between GPA and adaptation difficulties ($\beta = -0.022$, $p < 0.05$). Nevertheless, the direct causal relationship between scholarship and adaptation difficulties is not significant ($\beta = -0.045$, $p > 0.001$).

Considering intermediate variables in model (adaptation difficulties and number of curricular units approved), it has been observed that there is a direct causal relationship between difficulties and number of subjects ($\beta = 0.038$, $p > 0.001$). Finally, the results show a direct causal relationship between the antecedents with the higher education dropout variable. In particular, there is a direct significant causal relationship among number of subjects and higher education dropout rate ($\beta = -0.044$, $p > 0.001$), between sex and higher education dropout rate ($\beta = -0.045$, $p > 0.001$), between scholarship and higher education dropout rate ($\beta = -0.029$, $p < 0.001$), and between GPA and dropout rate ($\beta = -0.019$, $p < 0.001$). However, the direct causal relationship between age and higher education dropout rate is not significant ($\beta = 0.0048$, $p > 0.001$), and the direct causal relationship between adaptation difficulties and dropout rate is not significant ($\beta = -0.016$, $p > 0.001$).

4. Discussion and Conclusions

The dropout of students in higher education appears to be a serious problem that negatively affects the expectations of students and their families, as well as goes against the goals of social and economic development of countries and societies, since such goals require highly qualified professionals [3,67]. In this sense, it is necessary to know the most relevant personal, curricular, and contextual variables in explaining dropout rates, particularly among first-year and STEM students, and to implement intervention programs to reduce their rate of occurrence [5,23].

Assuming a gradual students' disengagement and decisions prior to dropping out in STEM courses, the set of direct and indirect effects on intermediate variables (the adaptation difficulties and the number of subjects approved) and the outcome variable (dropping out), in the first instance, positive goodness-of-fit indices have been obtained comparing theoretical and empirical model tested. Considering difficulties anticipated or experienced, there was a direct significant causal association between age and gender with adaptative difficulties, with older and female students presenting a higher level of difficulty. One the other side, students with higher GPA to access HE present lower difficulties of adaptation to HE.

Considering the number of curriculum units approved, there was a direct significant impact of previous variables, like age, scholarship, and GPA to access HE. Older students, students without scholarship, and those with lower GPA are associated with lower numbers of curricular units approved in the first year. Previous research presented studies demonstrating academic achievement by older students, usually with many sociofamiliar responsibilities and less time for academic activities or lacking some basic curricular knowledge or study habits [12,46]. Moreover, students from socioeconomically and socioculturally more disadvantage groups, tend to present difficulties in their academic achievement and adaptation, a situation that can be mitigated for those who obtain a scholarship [41–43]. A scholarship can be an incentive to engage with academic activities and obtain a sufficient level of academic achievement, especially in systems (like in Portugal) when this later is a condition to maintain the scholarship. Finally, as expected from the research available, there is a direct significant relationship between GPA to access HE and the number of curricular units approved in the first year. GPA access to HE reflects a global set of competencies in terms of motivation, study habits, and previous academic achievement, being, in the literature, assumed to be the best individual predictor of first-year students' achievement on HE [27–29]. This aspect increases its relevance when we consider STEM graduation students because, during the first year, some subjects, such as mathematics, physics, and chemistry, are in continuity with the academic competency students have developed in secondary school [32,33]. Contrary to what has been found in other studies, no relationship has been found between gender and number of curricular units approved. Some authors mention that female students are more methodical or organized in planning their academic activities, being more active in classes and group works [12,17,23,50], what may reflect better academic achievement, but this was not found in this study. Some authors comment on the specific case of women in STEM courses, namely their low sense of

belonging, low self-efficacy, and weak STEM identity because of the remaining stereotypes against women [55–57]. Those negative experiences impact lower achievement and higher dropout rates by women in STEM courses [46,51,52].

To conclude, it is important to highlight a direct causal relationship between students´ level of difficulties in academic adaptation and the number of curricular units approved on first-year graduation. As expected, lower academic achievement is observed among students that experienced or anticipated more adaptation difficulties during the initial weeks on university [12,16,26]. Those difficulties are diverse; some of them are not directly related to academic achievement; in fact, students could be facing more immediate demands like the socioemotional needs of belonging—e.g., the need to identify people/peers that could provide social support—and could thus be less engaged or invested in learning process.

This study presents some limitations that can be mentioned in the interest of future developments. First, the sample was collected from a single university which reduces diversity in terms of the personal and contextual variables present on academic adaptation, academic achievement, and dropout causes. Secondly, dropout information was provided by Academic Services at the end of first year; it will be interesting to consider the students leaving university during the academic year and the specific characteristics they can present. This last aspect points to the relevance of considering dropout as a dynamic and continuous process in students' disengagement with course and institution; we recommend longitudinal data collection and analysis. Finally, taking first-year students from STEM, it is relevant to integrate into the research specific curricular aspects like academic background in math and sciences learning strategies students mobilize daily. HE institutions have the tradition of introducing in the first year propaedeutic subjects in those fields where several students present more learning and achievement difficulties. This highly established practice could be an important aspect to analyze and should be reflected on by institutions and course-directors; they could ensure that teachers who enforce the curricular units of STEM in the first year present nor merely scientific competence but also pedagogical and relational competences.

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