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STEM Students' Academic Well-Being at University before and during Later Stages of the COVID-19 Pandemic: A Cross-Sectional Cohort and Longitudinal Study

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Abstract: This paper offers an indepth analysis of the impact of the COVID-19 pandemic on STEM students' academic well-being beyond the initial stages of the pandemic. We draw upon a unique self-collected cross-sectional cohort dataset (n = 990, prepandemic and pandemic first-year STEM students) and longitudinal dataset (n = 170, students who started their studies pre-pandemic and are in their second year during the pandemic). Study 1 revealed that STEM students' academic well-being during the COVID-19 pandemic was lower than before its onset, as shown when comparing a pre-pandemic and pandemic cohort of first-year students and from analyzing first-year students' changes in academic well-being over time (i.e., lower academic satisfaction, belonging, efficacy and persistence intentions). Study 2 showed that especially COVID-19-related worries regarding academic enjoyment and study progress were related to STEM students' decreased academic well-being, both for first and second-year students. Study 3 demonstrated that both peer support and faculty support contributed to higher academic well-being among first and second-year STEM students during the pandemic. These findings benefit policymakers and higher education institutions as they provide insight in how to safeguard sustainable academic well-being for STEM students in times of crisis or challenge.

Keywords: academic well-being; COVID-19 pandemic; STEM students; study stressors; social support

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1. Introduction

At the end of 2019, a novel coronavirus disease (COVID-19) arose that, by the start of 2020, had triggered a global pandemic. This led many governments all over the world to take far-reaching "lockdown" measures to reduce the spread of the virus. This also substantially impacted students' lives, as universities worldwide reduced or even stopped in-person classes and switched to online, remote teaching [1]. STEM students from multiple disciplines were concerned about losing hands-on experience in practical laboratories and through project work [2,3]. Alongside the closure of academic buildings and in-person classes, college students faced a myriad of other COVID-19-related hardships, such as deprivation of social activities, study delays, and financial pressures due to the loss of part-time employment or parental financial support. The impact of the pandemic and such specific COVID-19-related study worries (e.g., less academic enjoyment and study delays) on the academic well-being of students is not yet clear. With a longitudinal and a cross-sectional cohort study, the current paper provides insight how the pandemic affected STEM

students' academic well-being and highlight the importance of academic support systems in mitigating the negative effects of the pandemic on students' educational experiences. With this knowledge universities can implement sustainable measures and develop strategies to promote students' well-being and resilience.

Worldwide, scientific evidence is accumulating that the COVID-19 pandemic indeed had an enormous impact on students' university lives [4–6]. Most of this research focuses on the impact of the COVID-19 pandemic on students' general psychological well-being and mental health, showing an increase in depressive symptoms and a decline in general well-being among students at adolescent age during the pandemic compared to before the pandemic [1,7,8].

In this study, we examine the impact of the COVID-19 pandemic on academic well-being of STEM students. In contrast to general well-being, academic well-being can be understood as students' well-being in relation to the specific educational context of their academic study program [9]. Academic well-being can be defined as a multi-faceted construct, comprising sub-dimensions such as how satisfied, self-confident, and connected students feel as learners in their academic study program [9–11]. Our research project on STEM students' academic well-being and persistence started in fall of 2019, several months before the COVID-19 pandemic hit in March 2020. Adding survey data collected in the fall of 2020 enabled us to assess what impact the COVID-19-related stressors had on our students' academic well-being beyond the initial phase of the pandemic. Especially for STEM students, the adjustment to online teaching and the loss of in-person classes may have been difficult because hands-on experiences and inquiry in practice-based labs via teacher and peer interactions which foster student learning and applied skills were lacking [2,3]. Such laboratory work and collaborative projects are difficult to replicate in a remote learning context. Furthermore, while recognizing that the academic well-being of all students should receive attention, it is imperative to underscore that STEM educations are essential for safeguarding the future STEM workforce that is crucial for innovation, economic growth and to tackle global challenges (e.g., climate change), and therefore poor academic well-being and dropout in STEM educations may be reflected on society as a whole.

Capturing baseline data on academic well-being in the pre-pandemic context, along with student data on the impact of COVID-19-related shifts in the education environment is essential to improve our understanding of how remote and hybrid teaching impacts academic well-being in STEM students. Whereas most research focused on the sudden changes and restrictions of the COVID-19 pandemic, such as the switch to emergency remote teaching [12,13] our study focuses on the impact of the pandemic while students were used to months of online learning. Furthermore, we examine which COVID-19-related study stressors (e.g., worries about study delays, financial worries, or lack of enjoyment) had the most severe impact on students' academic well-being and which academic support systems may buffer academic well-being against these stressors. As such, insight will be gained into how STEM students' well-being can be improved when they cope with certain stressors or in case of future emergencies.

1.1. Studying during the COVID-19 Pandemic

The COVID-19 pandemic posed several changes for studying at a university in the Netherlands, where this data collection took place. During the first COVID-19 semester (spring and summer 2020) and the second COVID-19 semester (fall and winter 2020), teaching was realized in digital environments with asynchronous and synchronous courses [14]. In the current study, pandemic data were collected during the fall of 2020, thus at the start of the second COVID-19 semester. During this time, students spent a lot of time in front of their computers and, due to social contact restrictions, were often alone and had fewer interactions with others than before [14]. While some restrictions were eased in the summer of 2020 and social interactions were partially possible in the Netherlands, the lockdown restriction measures increased again in the fall 2020 semester when our data

were collected (see Figure 1 for an overview of the data collection timeline and enforced social distancing measures).

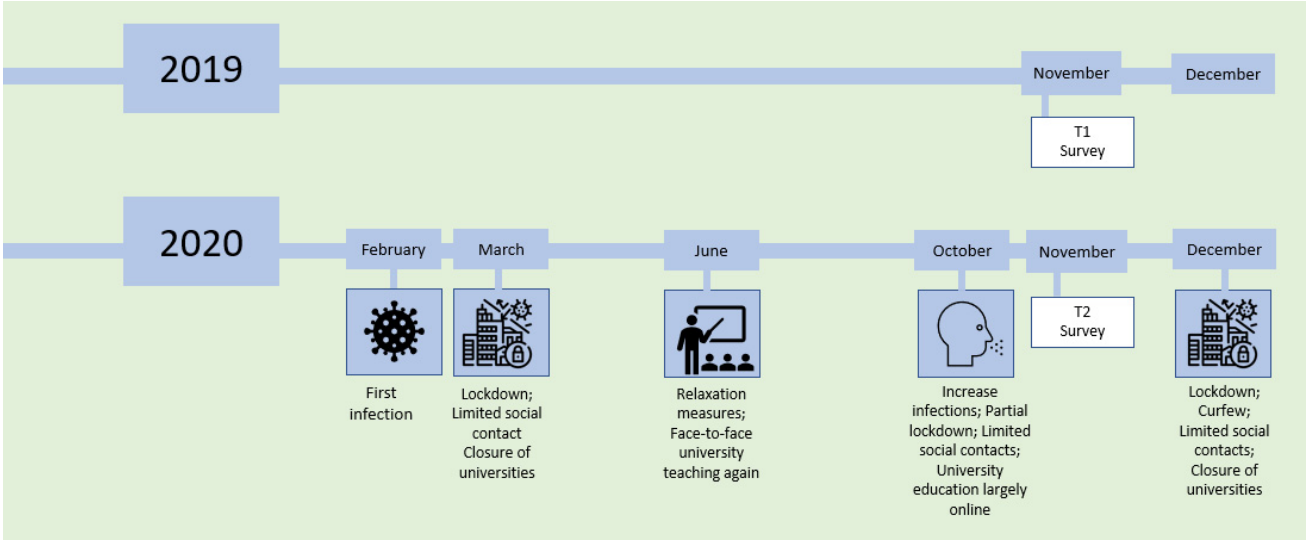

Figure 1. Timeline of the Current Research and the COVID-19 Measures that Were in Place in the Netherlands during the Timespan of this Research.

1.2. Academic Well-Being

Academic well-being can be described as a multifaceted construct [15] and prior empirical work typically operationalizes academic well-being with multiple dimensions such as academic self-confidence, academic satisfaction, academic engagement, and burnout; [9] and shows clear empirical links with academic achievement and drop out [9–11]. Only a few studies focus on the impact of COVID-19 and COVID-19-related stressors in the university context on indicators of students' academic well-being. For example, two cross-sectional studies in US universities reported high levels of uncertainty regarding their academic future in relation to COVID-19-related stressors [16] and significant correlations between academic stress and pandemic-related COVID-19 stressors among college students [17]. A cross-sectional study among Turkish college students showed that students' stress due to remote teaching (e.g., Zoom fatigue) during COVID-19 was significantly correlated with their academic well-being [18]. Notably, however, these studies are cross-sectional and do not focus on specific student groups (i.e., STEM students) for whom learning through face-to-face interaction in project-based educational settings is particularly important [2,3].

Adding to previous work, in the current study, we focus on multiple aspects of STEM students' academic well-being, namely their social connectedness in the study program (i.e., sense of belonging), their evaluation of their study program (i.e., satisfaction with their academic studies), their competency beliefs regarding their studies (i.e., academic self-efficacy), and their intentions to persist in their studies.

First, a sense of belonging can be defined as "students' perceived social support on campus, a feeling or sensation of connectedness, and the experience of mattering or feeling cared about, accepted, respected, valued by, and important to their community" [19] (p. 4). As students make the transition from high school to university, there are several opportunities to develop a sense of belonging in their study program. However, due to the COVID-19 pandemic, we expect these opportunities to be limited, reducing the sense of belonging.

Second, academic satisfaction captures students' positive and negative cognitive evaluations of diverse aspects of their studies [20]. Specifically, we focus on students' satisfaction with the taught content which represents students' feelings of joy and satisfaction related to their chosen program. Since students have reported experiencing several challenges and

dissatisfaction with digital education compared to face-to-face education [21,22], we expect a decrease in academic satisfaction during the COVID-19 pandemic.

Thirdly, we focus on self-efficacy, defined as individuals' belief in their capacity to accomplish something [23]. Because of the move to online teaching and learning, there was a lack of hands-on, practical experiences for students, which may have especially impacted STEM students. For example, experiences in the lab or project work, which typically group students into teams or partnerships, allow for enhanced vicarious sources of self-efficacy, such as seeing how others learn and navigate the activities, sharing challenges and concerns, and providing opportunities for interactions with professors, all of which have been shown to support the self-efficacy of students in STEM [24]. Due to the COVID-19 pandemic, we expect the exposure to vicarious sources of self-efficacy to be limited, reducing the student's academic self-efficacy.

Finally, we focus on how the COVID-19 pandemic has impacted students' dropout and persistence intentions in STEM. We measure both concepts, as apart from striving to understand the reasons behind students' decision to leave university, it is also critical to examine why certain students continue to persevere despite many challenges [25]. Students' college persistence can be described as student-level attributes, values, commitments, and skills that support them in completing their college education [26]. Research has highlighted several factors that promote college students' persistence, including a sense of purpose [27] and motivation [28], which have both been under pressure due to the COVID-19 pandemic. Dropout, on the other hand, can be described as a gradual process of goal disengagement [29]. Students are in conflict with their previous goal (i.e., to obtain a university degree) and the goal disengagement, which can end up in the abandonment of the goal (i.e., student dropout). Therefore, dropout intentions refer to increasing doubt or rumination about the goal of obtaining a university degree [29], which we expect has been increasing due to the COVID-19 pandemic.

Taken together, we expect that the COVID-19 pandemic severely impacted the four indicators of (STEM) students' academic well-being as defined above. However, there are only a few studies exploring this topic, and the available research mainly focuses on how the sudden changes and restrictions of the COVID-19 pandemic impacted students' attitudes towards the alternative teaching and educational methods (i.e., remote learning), with limited research focusing on the impact of academic well-being in the broader sense and on the long-term. These studies focus on the immediate impact on student learning during early stages of the pandemic (spring and summer 2020), and typically reported that students experienced decreased learning motivation and a lack of connection to peers and teachers. For example, in research among first-year pharmaceutical and medical science students at an Australian University (May 2020), the most commonly reported COVID-19-specific factors related to studying in the online environment were decreased learning motivation, feeling isolated from peers, increased difficulties in understanding course content, and increased stress [30]. In a Canadian study among second-year students taking chemistry courses (June 2020), the students reported that the transition to remote teaching was stressful and negatively impacted their interest and engagement with the course material. In addition, the remote learning experience was viewed unfavorably compared to in-person instruction, especially regarding a reduced ability to maintain an organized schedule and connect and interact with instructors and other students [12].

A few longitudinal studies compared data collected from before the pandemic (pre-COVID) with data collected during the pandemic, and paint a less clear picture across the national samples. For example, a study from the US comparing pre-COVID (fall 2019) and COVID (May 2020) belongingness did not find evidence for a decrease in belonging among undergraduate students [31]. Similarly, a UK study among undergraduate computer science students found a non-significant decline in their students' sense of belonging pre-COVID and COVID (summer 2020) [32]. From the empirical evidence above, it is not yet clear how a non-significant decline in academic belongingness should be interpreted. Normally, levels of academic belongingness tend to increase as students' progress further in their

study program, because they had more time to build connections with their academic peers and build academic self-efficacy in their program. Therefore, in the current research, next to a longitudinal comparison, we will also compare first-years pre-COVID with first-year students that started during COVID-19. To our knowledge, no studies combine cohort data with longitudinal data that investigate the impact on students' academic well-being beyond the initial stage of the pandemic so far.

In the current study, we took a unique approach by comparing the academic well-being of first-year STEM students before the COVID pandemic (September 2019) to their academic well-being beyond the initial stages of the COVID pandemic (fall 2020). As a result, we did not study the effect of the messy transition from face-to-face to online teaching, also known as "emergency remote teaching" [33] in which the insecurity problems with change was one of the main stressors. Instead, our research took place seven months after the onset of the COVID pandemic, when students already experienced months of online teaching. This allowed us to study the impact of less immediate COVID-19-related stressors, such as stressors related to study delays.

Hypothesis 1. *STEM students' academic well-being is lower during the COVID-19 pandemic than before the COVID-19 pandemic.*

1.3. COVID-19 Related Stressors

During the COVID-19 pandemic, many positive outcomes students expect from studying and completing a degree were under pressure. For example, students may have perceived their time and energy spent on studying as less well spent when they experienced their studies as less fun and interesting during the pandemic. The expectancy-value theory provides a useful framework for explaining how COVID-19-related stressors (e.g., worries that the study program will be less enjoyable) may have impacted students' academic well-being [34–36]. This framework incorporates three constructs: expectancies, values, and costs. Expectancies refer to subjective beliefs about students' expectations that they will succeed in their studies. The values students assign to their education can be divided into intrinsic value (the enjoyment derived from studying), attainment value (personal importance of succeeding in the study), and utility value (perceived usefulness of studying). Finally, costs describe the perceived negative consequences of studying. We argue that the subjective expectancies, value, and costs of studying may be under pressure as a result of the COVID-19-related measures and restrictions students faced during the pandemic. For example, students may have worried (more than usual) about incurring study delays, troubles to connect to fellow students, and financial hardships and therefore have lower expectations of finishing their studies successfully. As of yet, it is unclear what COVID-19-related stressors impacted students' academic well-being most.

In prior research, expectancy-value theory has been applied before to map indicators of STEM students' academic well-being. This evidence indicates that when students' perceived expectancies (e.g., finishing their studies successfully and timely) and values are high (e.g., having confidence in the value of their diploma) and costs are low (e.g., low worries about study payment), this is related to the highest psychological well-being and STEM career aspirations. In contrast, when next to high perceived expectancies and values, also perceived costs are high, students' well-being suffers; when students have low expectancies and values and high perceived costs, they are most likely to be disengaged with their studies and experience poor academic well-being [36,37].

In further applying expectancy-value theory to student's academic well-being during the pandemic, we hypothesized four COVID-19-related stressors: (1) worrying about study delay (i.e., lower expectancies), worrying about value diploma (i.e., lower utility value), worrying about a less enjoyable study period (i.e., lower interest value), and worrying about financial hardship making studying difficult to pay (i.e., higher cost). Indeed, empirical evidence from the Netherlands supports that, due to the pandemic, students worried about their finances, about having an enjoyable study period, about study delay, and about the

value of their diplomas [38]. Specifically, during the pandemic more than half of Dutch students reported worries about academic progress, and 25% of students report facing study delays due to the pandemic [38].

Furthermore, many students rely on part-time jobs to pay for their living expenses and studies. Due to the lockdown, many students temporarily lost income because of becoming unemployed or not receiving enough working hours due to the pandemic (e.g., students who worked in restaurants that were closed during lockdowns). Therefore, perhaps unsurprisingly, research results point out that in the Netherlands, worries about the financial situation were a severe to very severe stressor for a considerable group of Dutch students during the pandemic (22%), showing the financial hardship that many students faced [38].

Finally, worries about having a less enjoyable study period were pronounced. Seventy-two percent of students reported that they experienced low engagement in (online) lectures during the pandemic and indicated that this negatively impacted their learning experience [39]. Finally, lecturers at universities, university student councils, and politicians expressed their worries that the pandemic affects the diploma's value [40]. A fear that may resonate within students and affect their academic well-being. To summarize, we predict that higher COVID-19-related stressors are related to lower academic well-being among STEM students.

Hypothesis 2. *STEM students who suffer from higher COVID-19-related stressors (i.e., falling behind worries, enjoyable study worries, financial concerns, diploma value worries) will experience lower academic well-being.*

1.4. The Role of Perceived Social Support in the University Environment

Although the COVID-19 pandemic has likely caused a decrease in students' academic well-being, students may have been better able to cope with COVID-19-related stressors in academic contexts in which they received adequate social support. Both public and academic outlets suggest that receiving support is a crucial way to reduce the negative effects of the pandemic [41,42].

When facing a crisis, people generally turn to others for support and feelings of connectedness [43]. During such crisis times, social identities are activated to a greater extent: people tend to define themselves more in terms of their group memberships, because these group memberships act as a 'social cure' to protect people against vulnerabilities to their well-being [41]. Indeed, evidence shows that if group memberships provide support and feelings of connectedness, they are a source of psychological resilience that help people cope with the challenges they face [44]. Therefore, we propose that during the COVID-19 pandemic, it was (perhaps more) essential for students' academic well-being to have access to social support systems within the academic context, such as peer support and faculty support. When students experience more academic support, they may be better able to cope with COVID-19-related stressors.

The literature shows two routes through which social support helps to sustain (academic) well-being, namely (1) a general beneficial effect (i.e., social support directly improves well-being) and a buffering effect (i.e., social support buffers against the potentially negative effect of a stressor on well-being) [45]. Evidence indeed supports both the direct and buffering effects of social support [45,46]. For instance, research shows that college students who reported higher social support during the pandemic, also reported lower rates of anxiety, stress, and depression (i.e., supporting the general beneficial effect hypothesis) [42,47,48]. Furthermore, research also shows that perceived social support protected students against depression when they experienced higher stress levels, showing a buffering effect of social support on well-being (e.g., supporting the buffering hypothesis) [49].

However, studies until now did not distinguish between different sources of social support and often focused on general well-being outcomes. In contrast, in the current paper, the focus is specifically on academic support (i.e., peer support of fellow students,

faculty support and student advisor support) and the effect hereof on academic well-being. More than other sources of support (e.g., family support), perceived social support in the university environment enables students to build a student identity and to develop a sense of belonging in their studies. Peers can help college students to identify to a greater extent in terms of their student group, which in turn increases their academic belonging and well-being. Higher levels of peer support are linked to higher engagement and belonging [50] and more academic self-confidence [51]. Furthermore, peer support is helpful in coping with academic challenges (e.g., sharing notes) [51]. A second source is faculty support. Faculty may provide both instrumental support (e.g., understanding difficult study exercises) as well as help with building a student identity (e.g., by acting as a role model, providing relevant study information). Students who perceive higher faculty support experience more engagement with their education, feel more academic confidence, and perform better [50,52]. A third source of academic support can be the academic advisor. In the Dutch STEM context, an academic advisor is a mentor who helps students with their professional development, choosing their educational courses and career orientation. Most contact is initiated by students themselves when they face problems. Although research is limited, evidence shows that a higher quality academic advisor–advisee relationship contributes to higher academic well-being [53] and professional development [54]. Furthermore, because professional development may have become more troublesome during the pandemic, this advisor-advisee relationship may be critical for coping with COVID-19 stressors.

Both faculty and peer support uniquely contribute to academic well-being (i.e., student motivation, engagement and belonging) [50]. Furthermore, because the academic advisor may especially be influential for students to help them cope with challenges in their professional development (e.g., fear of falling behind due to the pandemic), this may have a unique effect next to peer support and faculty support. Therefore, we expect that all three sources of support uniquely contribute to academic well-being and buffer the adverse effects of COVID-19-related stressors on STEM students' academic well-being.

Hypothesis 3a. *Perceived social support in the university environment (i.e., from peers, faculty (i.e., teachers) and study advisors) during the COVID-19 pandemic is positively related to academic well-being.*

Hypothesis 3b. *Perceived social support in the university environment (i.e., from peers, faculty, and study advisors) during the COVID-19 pandemic moderates the negative effects of COVID-19-related study stressors on academic well-being, such that the relationship is more strongly negative among students who perceive lower social support.*

1.5. The Current Research

The aims of the current research were threefold. First, we examined if students experienced lower academic well-being during the COVID-19 pandemic than before. Second, we examined whether COVID-19 pandemic-related study stressors could explain lower academic well-being. Third, we explored to what extent social support systems in the university environment could help students to cope with the potential negative effects of the COVID-19 pandemic on their academic well-being.

To test the hypotheses, we used data collected in 2019 and 2020 among first and second-year STEM students at two technical universities in the Netherlands; one applied university and one research-intensive university. Data from three samples were used to make cross-sectional and longitudinal comparisons between students before and amidst the COVID-19 pandemic. For clarification, samples are labeled based on the tenure of the student in the program (academic year) and whether data collection took place pre-pandemic (i.e., year 2019) or during the pandemic (year 2020; see Figure 2). Specifically, (1) the FirstYearsPrePandemic sample were first-year students that started their university studies before the pandemic in September 2019; (2) the FirstYearsPandemic sample were first-year students that started studying at university during the pandemic in September

2020, and (3) the SecondYearsPandemic sample were the same students as in the FirstYearsPrePandemic sample, but in a second data collection round that took place in students' consecutive second year of their studies, namely in September 2020, eight months into the pandemic.

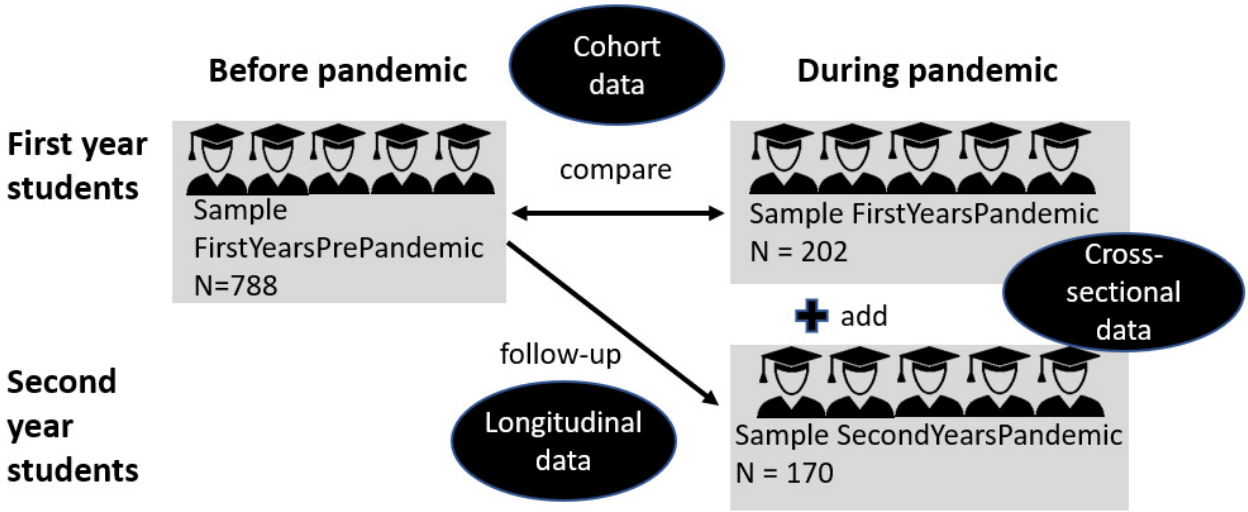

Figure 2. Overview of Student Samples and How They Were Combined or Compared in the Current Research.

The three samples were combined in different ways. To examine if students experienced lower academic well-being during the COVID-19 pandemic than before (H1), we drew upon (a) cohort data in which first-year students who started their study before the onset of the pandemic (i.e., FirstYearsPrePandemic were compared with the first-year students who started their study during the pandemic (i.e., FirstYearsPandemic) and (b) longitudinal data to examine if students experience a decline in their academic well-being at the start of their university studies in 2019 (i.e., before the onset of the COVID-19 pandemic; FirstYearsPrePandemic) relative to the second year when the COVID-19 pandemic started (SecondYearsPandemic). To examine how COVID-19-related study stressors (H2) relate to academic well-being and what the role of social support systems is in helping students cope with the potential negative effects of COVID-19 on academic well-being (H3), we drew upon cross-sectional data for which we combined the two datasets on student well-being that were collected during the pandemic (FirstYearsPandemic and SecondYearsPandemic samples combined). Below, we first provide an overview of the three studies' participants, procedure, and general analytical approach. We subsequently organize the results in three studies in accordance with formulated hypotheses.

2. General Method

Data of all three studies were collected among STEM students in the Netherlands. For more details about the sampling approach per sample, see online Supporting Information.

2.1. Participants

Sample 1: FirstYearsPrePandemic. Data were collected in October 2019, before the onset of the COVID-19 pandemic, as part of a larger research project on first-year STEM students' belonging and persistence in STEM education. In total, 817 students in 14 STEM study programs completed the survey, of which 788 students had data on most of the study variables, resulting in the FirstYearsPrePandemic sample. Of these 788 students, the average age was 19.11 (SD = 2.16), 147 (18.65%) were female, and 188 (23.86%) were international students.

Sample 2: SecondYearsPandemic. All students in the sample FirstYearsPrePandemic were approached again one year later during the COVID-19 pandemic in October 2020

when social distancing measures were in place (see Figure 1 for a data collection timeline). This resulted in 185 recurring students. Participants across both time points were matched with a unique code based on their student number, mobile phone number and place of birth, and it was possible to couple 170 students from wave 1 (2019) to wave 2 (2020), indicating a 77.41% attrition rate. This SecondYearsPandemic sample of 170 students had a mean age of 19.58 (SD = 1.58), consisted of 46 women (27.06%) and consisted of 35 international students (20.59%).

Sample 3: FirstYearsPandemic. Additional data were collected among first-year STEM students during the COVID-19 pandemic in October 2020. In total, 217 first-year students of 11 STEM study programs participated, of which 202 students had data on most of the study variables. This FirstYearsPandemic sample of 202 students had a mean age of 18.73 (SD = 1.32), and included of 78 women (38.61%) and 55 international students (27.22%).

2.2. Procedure

In all three samples, students completed an online questionnaire with measures on demographics (e.g., gender, age), their academic experiences (e.g., peer support) and academic well-being (e.g., academic satisfaction). For the FirstYearsPandemic sample and the SecondYearsPandemic sample, specific COVID-19-related questions (e.g., COVID-19-related study stressors) were added to the questionnaire.

Our sampling strategy was to obtain a sample size as large and representative for the population as possible. Because of this strategy, instead of an a priori power analysis, a post hoc sensitivity analysis was conducted using the G*Power 3.1 software tool [55]. We obtained the minimal effect size with sensitivity analysis that would render statistical significance at conventional error probability levels ($\alpha = 0.05$) to test our hypotheses given the sample size. We used the most complicated analyses given the sample size (testing H3 in Study 3) as a basis for the sensitivity analysis. In G*power 3.1 (F-test family, regression), we included 19 predictor variables (7 main effects and 12 interaction terms: 4 COVID-19-related study worries, 3 sources of study support, 4 study worries, and 3 sources of support), a minimal power requirement of 0.80, and a sample size of N = 353, which demonstrated the ability to detect small to medium effect sizes (f2 = 0.061) at 1.62 critical F-test ratios.

2.3. Analytic Strategy

In all datasets, participants were nested within study programs. Note, however, that dependency in the samples was very low, so we did not take clustering into account in the analyses (intraclass correlations are reported in the Supporting Information, Table S1). All data were analyzed with R 4.1.2. open-source statistical software package.

Cohort data in Study 1 (H1: students experience lower academic well-being during the COVID-19 pandemic than before) were analyzed using a series of four one-way analyses of covariance (ANCOVA's) on the four indicators of academic well-being with cohort (FirstYearsPrePandemic versus FirstYearsPandemic) as a between-subjects factor and age, gender (0 = men, 1 = women), nationality (0 = Dutch, 1 = other), and university type (0 = applied university, 1 = research-intensive university) as covariates. The covariates were included to ensure differences in academic well-being were not a result of demographic differences between the cohorts. Note that significance levels and direction of effects were identical when not including these covariates. We controlled for unequal sample size across cohorts by applying Type-III sums of squares in all the ANCOVAs (FirstYearsPrePandemic cohort: N = 788; FirstYearsPandemic cohort: N = 205).

Longitudinal data in Study 1 (H1: students experience lower academic well-being during the COVID-19 pandemic than before) were analyzed with multilevel regressions in R using the lmerTest package. Longitudinal data can be seen as multilevel data, with time points nested within students [56]. We specified a random-intercept, fixed-slope multilevel model (Model 1) that regressed academic well-being (level 1) on time (level 1), controlling for gender (level 2), nationality (level 2), age (level 2), and university type (level 2), using maximum likelihood estimation. Intraclass correlations of the continuous

academic well-being measures were 0.32 for academic satisfaction, 0.18 for belonging, 0.47 for self-efficacy, and 0.37 for persistence intentions. Thus, for self-efficacy, about half of the explained variance can be attributed to individual differences between students (47%) and the other half to differences within students (53%), while for belonging, only 18% of the variance can be attributed to individual differences between students and 72% between how students change over time in their belonging.

In Study 2 (H2: academic well-being is lower for STEM students who experience higher COVID-19-related study worries), the cross-sectional data were analyzed by applying multiple regression analyses where four COVID-19-related stressors were entered simultaneously as predictors of each of the four academic well-being indicators (i.e., for each well-being indicator a separate multiple regression analysis was performed). This way, we could investigate the unique explained variance of each COVID-19-related stressor on academic well-being. Again, in all analyses, we controlled for background variables (i.e., gender, nationality, age, and academic year).

In Study 3 (H3: students' experience of social support in the university environment helps to buffer the potentially negative effects of COVID-19-related stressors on academic well-being), the cross-sectional data were analyzed by performing hierarchical regression analyses on the four continuous academic well-being outcomes [57] and a hierarchical logistics regression was performed on the dichotomous academic well-being variable measuring dropout intention. Background variables (i.e., gender, nationality, age, study year) were again inserted as covariates. All predictors were grand_mean_centered before they were entered into the analyses. In step 1, the main effects of four COVID-19-related stressors were entered. In step 2, the main effects of three sources of support were entered. In step 3, all two-way interactions between COVID-19 worries and sources of support were added. Significant interactions were interpreted by testing simple slopes [58]. The self-report data in these studies may raise concerns about common method bias [59]; however, scale testing demonstrated this was negligible.

3. Study 1: Do STEM Students Experience Lower Academic Well-Being during the COVID-19 Pandemic than Before?

3.1. Research Design

To test Hypothesis 1, first, a cross-sectional cohort comparison design was adopted to compare academic well-being of the participants in the FirstYearsPrePandemic sample who started their studies before the COVID-19 pandemic (N = 788) with the FirstYearsPandemic sample who started their studies during the COVID-19 pandemic (N = 202). Second, a longitudinal design was used (i.e., combining the FirstYearsPrePandemic sample and the SecondYearsPandemic sample; N = 170) to examine if academic well-being decreased within students over time (i.e., before the pandemic vs. during the pandemic).

3.2. Measures

Academic well-being was measured with identical scales in the FirstYearsPrePandemic, FirstYearsPandemic and SecondYearsPandemic datasets. Unless otherwise stated, all academic well-being constructs were measured with 7-point response scales from 1 (completely disagree) to 7 (completely agree). Exploratory factor analysis confirmed that these measurements really assessed different aspects of academic well-being and had good factor loadings (see Supporting Information, Table S8).

Academic satisfaction was assessed with two items, namely (1) "I am satisfied with my choice of the study program" and (2) "So far, I enjoy my study program" (rFYPrePandemic = 0.73; rFYPandemic = 0.67; rSYPandemic = 0.77), adapted from the Satisfaction with study content (SAS-Content) subscale of the Satisfaction with Academic Studies questionnaire [60].

Academic belonging was assessed with two items adapted from Walton and Cohen's [61] Sense of Academic Fit scale, namely (1) "So far, I feel at home in my study

program, (2) "I feel like I belong in my study program". The scale had good internal reliability across the samples (rFYPrePandemic = 0.71, rFYPandemic = 0.71; rSYPandemic = 0.81).

Academic efficacy was assessed using the three items adapted from the Self-Efficacy for Learning and Performance subscale of the Motivated Strategies for Learning Questionnaire (MSLQ) [62], namely (1) "I'm certain I can understand the most difficult material presented in my study texts", (2) "I'm confident I can understand even the hardest things taught by the lecturer", and (3) "I'm confident I can do an excellent job on difficult assignments and tests", and had good internal reliability across the samples (McDonald's Ω FYPrePandemic = 0.86, Ω FYPandemic = 0.90; Ω SYPandemic = 0.89).

Persistence intentions were assessed with two items [63] in two ways, namely continuous ("I will definitely complete this study"; 7-point Likert scale) and categorical ("Since starting your study, have you seriously considered quitting your study?", 0 = no; 1 = yes), and were therefore investigated as separate variables in statistical models. From here on, we will refer to the continuous measure as persistence intentions and the dichotomous measure as dropout intentions.

3.3. Results Cohort Data

In the first step, we tested H1 with the cross-sectional cohort data. Means, standard deviations, and bivariate correlations of this dataset's demographic variables and academic well-being variables are reported in the Supporting Information (Table S2). Results of the ANCOVA's are summarized in Figure 3.

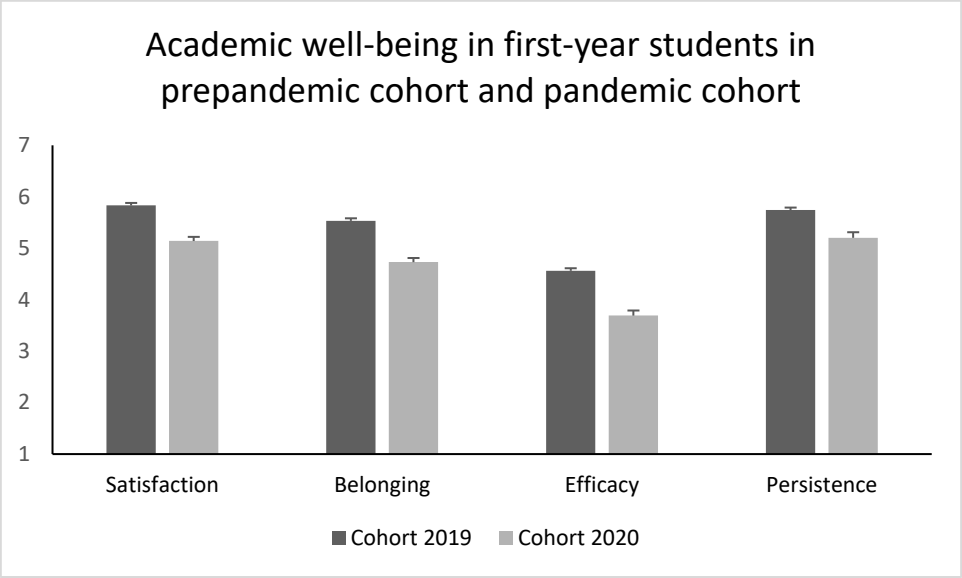

Figure 3. Academic Well-Being before the Onset of the COVID-19 Pandemic (Cohort 2019) and during the COVID-19 Pandemic (Cohort 2020).

Confirming Hypothesis 1, compared to students who started their studies before the COVID-19 pandemic (FirstYearsPrePandemic cohort), first-year students who started their studies during the COVID-19 pandemic (FirstYearsPandemic cohort) experienced lower academic satisfaction, $F(1, 980) = 64.88$, $p < 0.001$, $\eta p2 = 0.06$; MFYPrePandemic = 5.83, SE = 0.05, 95% CI [5.74, 5.93]; MFYPandemic = 5.14, SE = 0.08, 95% CI [4.98, 5.29]; lower belonging, $F(1, 980) = 88.71$, $p < 0.001$, $\eta p2 = 0.08$; MFYPrePandemic = 5.53, SE = 0.05, 95% CI [5.44, 5.62], MFYPandemic 4.73, SE = 0.08, 95% CI [4.58, 4.88]; lower efficacy, $F(1, 967) = 67.81$, $p < 0.001$, $\eta p2 = 0.07$, MFYPrePandemic = 4.56, SE = 0.06, 95% CI [4.45, 4.67], MFYPandemic = 3.69, SE = 0.10, 95% CI [3.50, 3.88]; and lower persistence intentions, $F(1, 967) = 22.15$, $p < 0.001$, $\eta p2 = 0.02$, MFYPrePandemic = 5.74, SE = 0.06, 95% CI [5.62, 5.86], MFYPandemic 5.20, SE = 0.11, 95% CI [4.99, 5.40]. Furthermore, logistic regression on the dichotomous variable of dropout intentions showed that, holding age, gender,

university, and nationality constant across cohorts, students who started their studies during the pandemic were almost three times as likely to consider dropping out compared to students who started their studies before the pandemic (OR = 2.72, Χ2 = 13.46, $p < 0.001$). See the Supporting Information (Table S3) for confidence intervals and test statistics of the covariates.

3.4. Results Longitudinal Data

In the second step, we tested H1 with the longitudinal data. Means, standard deviations, and bivariate correlations of the demographic and academic well-being variables are reported in the Supporting Information (Table S4).

Confirming H1, the results showed a decrease in students' academic satisfaction (β = −0.19, SE = 0.07, 95% CI [−0.33, −0.04], t = −2.56, $p = 0.012$) and academic belonging (β = −0.18, SE = 0.09, 95% CI [−0.35, −0.01], t = −2.06, $p = 0.041$) over time. Moreover, students were sixteen times more likely to consider dropout in their second year during the pandemic than in their first year before the pandemic (β = 2.83, OR = 16.91, 95% CI [4.11, 69.51], Χ2 = 37.81, df = 6, $p < 0.001$). However, no significant longitudinal change in academic efficacy was found (β = 0.14, SE = 0.10, 95% CI [−0.05, 0.33], t = 1.45, $p = 0.147$). Moreover, students' persistence intentions increased over the course of their first to second year (β = 0.34, SE = 0.10, 95% CI [0.14, 0.54], t = 3.39, $p < 0.001$). See Figure 4 for a visualization of the results and Table S5 in the Supporting Information for an overview of test statistics, including the covariates. Note that the direction of effects and significance levels remain identical when not including the covariates gender, nationality, age, and university type. Furthermore, no significant interaction effects were found when adding the cross-level interactions between predictors (e.g., gender * time) in random slope random intercept models, indicating that effects were similar across covariates.

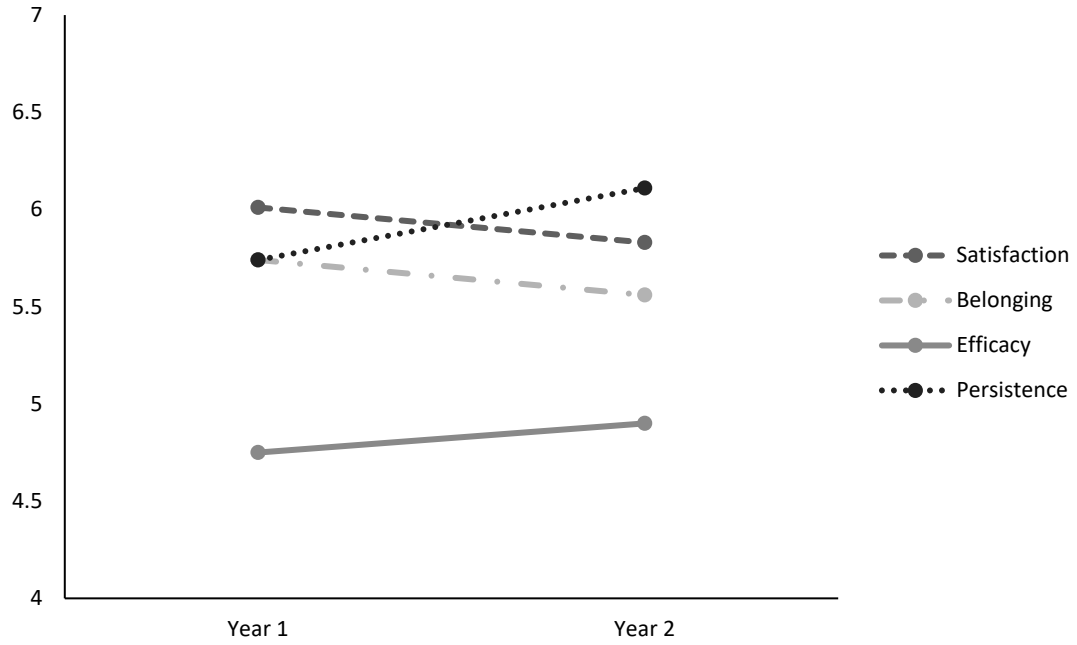

Figure 4. The Change in Student Well-Being from Before the Onset of the COVID-19 Pandemic (FirstYearsPrePandemic) to Their Well-Being during the COVID-19 Pandemic (SecondYearsPandemic).

3.5. Discussion Study 1

Our survey data gathered among STEM students before and during the COVID-19 pandemic partially support H1, such that academic well-being during the COVID-19 pandemic was lower than before the pandemic, both in the cohort and the longitudinal data. For the cohort data, H1 was confirmed on all four indicators of academic well-being, namely academic satisfaction, academic belonging, academic efficacy and persistence

intentions. For the longitudinal data, these effects were replicated for academic belonging and satisfaction. Additionally, more students considered dropping out in their second year (i.e., during the COVID-19 pandemic) compared to their first year (i.e., before the COVID-19 pandemic).

Longitudinal analyses did not demonstrate a decrease in academic efficacy nor lowered persistence intentions in students' second (during the COVID-19 pandemic) compared to their first (pre-COVID-19 pandemic) year. Yet, students' academic efficacy and persistence intentions usually increase as they progress further in their study program [64]. Thus, the absence of an expected increase in academic efficacy may signal a potential adverse effect of the COVID-19 pandemic. Moreover, 'normally' university students' dropout rates are higher in their first year compared to their second year [65]. This makes our result that STEM students were sixteen times more likely to consider dropping out in their second year (during COVID-19) than compared to their first year (pre-COVID-19) all the more striking.

Taken together, our cross-sectional and longitudinal data analyses provide compelling evidence that the COVID-19 pandemic, and all the changes and restrictions imposed on students' education and study life, explain students' lower academic well-being compared to before COVID-19. Nevertheless, alternative time and cohort explanations (other than COVID-19 imposed restrictions) for lower academic well-being cannot be ruled out. The question is whether COVID-19-related stressors and what COVID-19-related stressors specifically are responsible for STEM students' lower academic well-being during COVID-19. Study 2 aims to shed light on this question.

4. Study 2: Do COVID-19-Related Stressors Explain Lower Academic Well-Being during the COVID-19 Pandemic?

4.1. Research Design

To test Hypothesis 2 (i.e., higher COVID-19 stressors are related to lower academic well-being among STEM students), a correlational design was adopted to examine the relationship between COVID-19-related stressors and academic well-being. The datasets collected during the COVID-19 pandemic, namely FirstYearsPandemic and SecondYearsPandemic, were combined (N = 353).

4.2. Measures

Academic well-being. All measures were identical to Study 1.

COVID-19-related stressors. COVID-19-related stressors were measured on a 7-point Likert scale (1 = completely disagree; 7 = completely agree). Two items focused on students' worries about the possible negative effects of COVID-19 on their studies, namely worries about falling behind with the study (i.e., "Because of the corona crisis, I am concerned that I will fall behind with my studies") and academic enjoyment (i.e., "Because of the corona crisis, I am worried that I will have a less enjoyable study period), one item focused on financial concerns (i.e., "Because of the corona crisis, I am worried about my financial situation"), and one item focused on worries about the diploma value (i.e., "Because of the corona crisis, I am worried that my diploma is worth less").

4.3. Results

Means, standard deviations, and bivariate correlations of demographic background variables, COVID-19-related stressors and academic well-being measures are reported in the Supporting Information (Table S6).

In line with H2, multiple regressions controlling for age, gender, nationality, and academic year showed that worries about falling behind with the study and worries about having a less enjoyable study period as a consequence of the COVID-19 pandemic both explained unique variance of the academic well-being outcomes over and above the effects of the other COVID-19-related worries (see Table 1). Specifically, higher worries about falling behind with the study were uniquely related to lower academic satisfaction ($\beta = -0.14$, SE = 0.03, 95% CI [−0.20, −0.07], t = −4.12, $p < 0.001$), lower academic be-

longing (β = −0.10, SE = 0.04, 95% CI [−0.17, −0.03], t = −2.72, $p = 0.007$), lower efficacy (β = −0.20, SE = 0.04, 95% CI [−0.28, −0.12], t = −4.81, $p < 0.001$), lower persistence intentions (β = −0.18, SE = 0.04, 95% CI [−0.27, −0.10], t = −4.54, $p < 0.001$), and students were 1.23 more likely to consider dropout (β = 0.20, OR = 1.23, 95% CI [4.08, 68.64], $\chi 2 = 5.90$, df = 1, $p = 0.015$). Furthermore, higher worries about an enjoyable study period uniquely predicted lower academic satisfaction (β = −0.11, SE = 0.04, 95% CI [0.18, −0.03], t = −2.69, $p = 0.007$). All other relationships were non-significant.

Table 1. Results from Separate Hierarchical Multiple Regression Analyses and Logistic Regression Analysis with Academic Well-Being Measures as Outcome Variables and COVID-19-Related Worries as Predictors.

	Academic Well-Being Outcomes				
	Academic Satisfaction	**Academic Belonging**	**Academic Efficacy**	**Persistence Intentions**	**Dropout Intentions (Dichotomous)**
Predictors	**Estimate [95% CI]**	**Estimate [95% CI]**	**Estimate [95% CI]**	**Estimate [95% CI]**	**OR (z-Value)**
Step 1: Background variables					
Age	0.00 [−0.07, 0.08]	−0.02 [−0.11, 0.07]	0.04 [−0.06, 0.13]	0.10 * [0.00, 0.19]	0.95 (−0.53)
Gender	−0.17 [−0.40, 0.06]	−0.27 * [−0.53, −0.01]	−0.50 ** [−0.79, −0.20]	0.02 [−0.27, 0.31]	1.61 (1.73)
Nationality	−0.19 [−0.45, 0.07]	−0.22 [−0.51, 0.07]	−0.17 [−0.50, 0.15]	0.42 * [0.09, 0.74]	1.17 (0.50)
Academic Year	0.56 ** [−0.34, 0.78]	0.79 ** [0.54, 1.03]	0.83 ** [0.55, 1.10]	0.85 ** [0.58, 1.13]	1.29 (0.94)
Adjusted R^2/Nagelkerke R^2	0.08	0.12	0.13	0.12	0.02
Step 2: COVID-19 worries					
Fall behind studies	−0.14 ** [−0.20, −0.07]	−0.10 ** [−0.17, −0.03]	−0.20 ** [−0.28, −0.12]	−0.18 ** [−0.27, −0.10]	1.23 * (2.43)
Less enjoyable study	−0.11 ** [−0.18, −0.03]	0.00 [−0.09, 0.09]	0.00 [−0.10, 0.10]	−0.08 [−0.18, 0.02]	1.20 (1.65)
Financial concerns	−0.03 [−0.10, 0.03]	−0.07 [−0.14, 0.01]	0.05 [−0.04, 0.13]	0.04 [−0.04, 0.12]	0.94 (−0.70)
Diploma worth less	0.00 [−0.06, 0.06]	−0.06 [−0.14, 0.01]	−0.04 [−0.12, 0.04]	0.01 [−0.07, 0.09]	1.00 (0.02)
Adjusted R^2/Nagelkerke R^2	0.18	0.17	0.21	0.19	0.07

Note. Unstandardized regression coefficients and the adjusted R^2 are presented for academic satisfaction, academic belonging, academic efficacy, and study persistence. For dropout, the Odds Ratio (OR), *z*-value (similar to *t*-value of an ANOVA) and Nagelkerke R^2 are presented. N = 187. Because in the FirstYearsPandemic dataset all data were collected at a research-intensive university, we no longer include university type (research-intensive versus applied university) as a covariate since this completely overlaps with the covariate study year. * $p < 0.05$. ** $p < 0.01$.

4.4. Discussion Study 2

Our cross-sectional dataset that measured academic well-being and COVID-19 worries among first-year and second-year STEM students during the later stage of the COVID-19 pandemic supported H2, such that COVID-19-related worries were negatively related to the academic well-being of students. Specifically, higher worries about the negative effects of the COVID-19 pandemic on study progress and academic enjoyment were uniquely related to lower academic well-being over and above financial concerns and concerns about the value of the diploma. Since, especially study-related COVID-19 worries (i.e., worries about falling behind and having a less enjoyable study period) are related to lower academic well-being, the academic environment may play an important role in worsening or protecting students' academic well-being in COVID-19 times. Therefore, it is worth investigating what supportive systems at the university can provide a buffer against the lower academic

well-being students experience due to high COVID-19 stressors. Study 3 tests to what extent peer support, faculty support and study advisor support provide a buffer for the negative relationships between academic well-being and COVID-19-related worries.

5. Study 3: Do Social Support Systems at University Buffer the Negative Effects of COVID-19-Related Stressors on Academic Well-Being?

5.1. Research Design

To test Hypothesis 3a (perceived social support in the university environment during the COVID-19 pandemic is positively related to academic well-being) and 3b (perceived social support at university can provide a buffer against the negative relationship between academic well-being and COVID-19-related stressors), a correlational design was adopted (i.e., FirstYearsPrePandemic dataset and the SecondYearsPandemic dataset combined, N = 353).

5.2. Measures

Unless otherwise stated, all items were measured on a 7-point Likert scale (1 = completely disagree; 7 = completely agree). Measures of academic well-being were identical to Study 1, and measures for COVID-19-related study worries were identical to Study 2. Perceived social support measures are presented below. Exploratory factor analysis confirmed that the measures really assessed different aspects of perceived social support and had good factor loadings (see Supporting Information, Table S9).

Peer support was measured with three items [66], namely: (1) "I've already made some friends within my study program", (2) "I expect I can count on my fellow students if I have problems in my study", (3) "I think I will be able to talk about my study with my fellow students" (McDonald's $\Omega = 0.84$).

Faculty support was measured with three items [67]: (1) "The teachers take their time to respond to my needs", (2) "The teachers help me to resolve problems", and (3) "The teachers make an effort to also accommodate my wishes as far as possible" (McDonald's $\Omega = 0.84$).

Study advisor support was assessed with three self-developed items: (1) "Study advisors offer the support that I need", (2) "Study advisors offer the resources that I need", and (3) "Study advisors offer the advice that I need" (McDonald's $\Omega = 0.95$).

5.3. Results

Means, standard deviations, and bivariate correlations of perceived social support, COVID-19 stressors, and academic well-being measures are reported in the Supporting Information (Table S6).

We tested Hypothesis 3a and 3b in a series of five hierarchical (logistic) regression analyses for each academic well-being indicator. For an overview of all results of the regression models, see Table 2). In support of hypothesis 3a, results showed that the more STEM students reported feeling supported by their peers and their teachers during COVID-19, the higher their academic satisfaction, academic belonging, and behavioral intentions to persist in their study. No main effects were found for peer and faculty support on academic efficacy and dropout intentions during the COVID-19 pandemic. Furthermore, study advisor support was not significantly related to any of the academic well-being outcomes.

Table 2. Overview of Results of Hierarchical Regression Analyses.

	Academic Well-Being Outcomes									
	Academic Satisfaction		**Academic Belonging**		**Academic Efficacy**		**Academic Persistence**		**Dropout Intentions**	
Predictors	***b***	**95% CI**	***b***	**95% CI**	***b***	**95% CI**	***b***	**95% CI**	***OR***	**95% CI**
Step 1: Main effects demographics and COVID-19 stressors										
Intercept	4.00 **	[2.47, 5.54]	3.11 **	[1.37, 4.84]	2.12 *	[0.22, 4.02]	2.25 *	[0.35, 4.15]	0.34	[0.008, 20.25]
Age	0.05	[−0.03, 0.13]	0.05	[−0.04, 0.14]	0.07	[−0.03, 0.16]	0.11 *	[0.02, 0.21]	0.95	[0.77, 1.46]
Gender	−0.17	[−0.40, 0.06]	−0.24	[−0.50, 0.02]	−0.53 **	[−0.82, −0.24]	−0.01	[−0.30, 0.27]	1.75	[0.99, 3.09]
Nationality	−0.14	[−0.40, 0.13]	−0.10	[−0.40, 0.20]	−0.21	[−0.53, 0.12]	0.36 *	[0.03, 0.68]	1.20	[0.62, 2.26]
Academic year	0.49 **	[0.27, 0.72]	0.77 **	[0.51, 1.02]	0.87 **	[0.59, 1.15]	0.82 **	[0.55, 1.10]	1.39	[0.80, 2.43]
Worry falling behind	−0.14 **	[−0.21, −0.08]	−0.11 **	[−0.18, −0.03]	−0.20 **	[−0.29, −0.12]	−0.19 **	[−0.27, −0.11]	1.22*	[1.04, 1.45]
Worry enjoyable study period	−0.10 **	[−0.18, −0.03]	0.00	[−0.09, 0.09]	0.00	[−0.09, 0.10]	−0.08	[−0.17, 0.02]	1.20	[0.98, 1.50]
Financial concerns	−0.02	[−0.09, 0.04]	−0.06	[−0.14, 0.01]	0.06	[−0.02, 0.14]	0.04	[−0.04, 0.13]	0.94	[0.80, 1.11]
Worry value diploma	−0.00	[−0.06, 0.06]	−0.06	[−0.14, 0.01]	−0.05	[−0.13, 0.03]	0.01	[−0.07, 0.08]	1.01	[0.87, 1.17]
R^2	0.18 **		0.17 **		0.21 **		0.20 **		0.07	
Step 2: Main effects sources of support										
Intercept	4.76 **	[3.33, 6.18]	4.06 **	[2.50, 5.63]	2.39 *	[0.48, 4.30]	2.95 **	[1.11, 4.78]	0.16	[0.03, 1.10]
Peer support	0.21 **	[0.13, 0.30]	0.34 **	[0.25, 0.43]	0.06	[−0.05, 0.18]	0.24 **	[0.13, 0.35]	0.83	[0.66, 1.03]
Faculty support	0.25 **	[0.13, 0.37]	0.24 **	[0.12, 0.37]	0.11	[−0.05, 0.27]	0.16 *	[0.01, 0.31]	0.77	[0.56, 1.06]
Study advisor support	0.01	[−0.07, 0.10]	−0.05	[−0.14, 0.05]	−0.01	[−0.13, 0.10]	0.02	[−0.09, 0.13]	1.06	[0.83, 1.35]
R^2	0.31 **		0.34 **		0.22 **		0.27 **		0.11	
ΔR^2	0.13 **		0.17 **		0.01		0.07 **		0.04	
Step 3: Two-way interactions										
Intercept	5.16 **		4.19 **	[2.61, 5.77]	2.45 *	[0.57, 4.32]	3.36 **	[1.54, 5.19]	0.10	[0.00, 8.53]
Peer support										
Peer support * worry falling behind	0.07 **	[0.02, 0.11]	0.07 **	[0.02, 0.12]	0.10 **	[0.04, 0.16]	0.11 **	[0.05, 0.17]	0.84 *	[0.73, 0.97]
Peer support * worry enjoyable study period	0.01	[−0.05, 0.06]	−0.03	[−0.09, 0.04]	0.02	[−0.06, 0.09]	−0.06 *	[−0.12, −0.01]	1.00	[0.84, 1.18]
Peer support * financial concerns	0.06 *	[0.01, 0.10]	0.01	[−0.04, 0.06]	0.01	[−0.05, 0.07]	0.05	[−0.03, 0.12]	1.00	[0.89, 1.13]
Peer support * worry value diploma	−0.02	[−0.07, 0.02]	−0.04	[−0.09, 0.01]	−0.08 **	[−0.13, −0.02]	0.02	[−0.04, 0.07]	1.06	[0.95, 1.19]
Faculty support										
Faculty support * worry falling behind	−0.06	[−0.12, 0.01]	−0.13 **	[−0.20, −0.05]	−0.09	[−0.18, 0.00]	−0.10 *	[−0.18, −0.01]	1.11	[0.92, 1.34]
Faculty support * worry enjoyable study period	−0.00	[−0.09, 0.09]	0.08	[−0.02, 0.18]	0.05	[−0.07, 0.16]	0.03	[−0.05, 0.10]	0.92	[0.69, 1.22]
Faculty support * financial concerns	−0.06	[−0.12, 0.01]	−0.05	[−0.12, 0.03]	0.05	[−0.04, 0.13]	0.05	[−0.06, 0.17]	1.14	[0.95, 1.38]
Faculty support * worry value diploma	−0.01	[−0.07, 0.05]	0.06	[−0.01, 0.12]	0.13 **	[0.05, 0.21]	−0.06	[−0.14, 0.02]	1.00	[0.85, 1.18]
Study advisor support										
Study advisor support * worry falling behind	0.01	[−0.04, 0.07]	0.01	[−0.05, 0.07]	−0.03	[−0.10, 0.04]	−0.01	[−0.08, 0.06]	0.99	[0.84, 1.15]
Study advisor support * worry enjoyable study period	0.01	[−0.04, 0.07]	−0.03	[−0.09, 0.03]	−0.11 **	[−0.18, −0.04]	0.02	[−0.04, 0.09]	1.13	[0.96, 1.34]
Study advisor support * financial concerns	0.00	[−0.05, 0.05]	0.03	[−0.03, 0.08]	0.04	[−0.02, 0.10]	0.05	[−0.02, 0.12]	1.03	[0.90, 1.2]
Study advisor support * worry value diploma	0.02	[−0.03, 0.07]	0.00	[−0.06, 0.06]	0.01	[−0.06, 0.07]	−0.03	[−0.09, 0.03]	0.88	[0.76, 1.01]
R^2	0.35 **		0.38 **		0.30 **		0.32 **		0.16	
ΔR^2	0.04		0.04		0.08 **		0.06 **		0.05	

Note. N = 353 (19 participants did not fill out the questions about sources of support and were therefore not included in the hierarchical regression). Separate regressions were performed for each academic well-being outcome. Unstandardized regression coefficients are reported. All predictors were grand mean_centered before they were entered in the analyses. OR represents Odds Ratio. * $p < 0.05$. ** $p < 0.01$.

Next, 12 two-way interaction variables (4 COVID-19 worries * 3 sources of support) were added to the regression model to test if the social support systems could buffer the negative effect of COVID-19-related stressors on academic well-being (H3b; see Figures 5–11 for visualization of significant two-way interactions). Results indicated that peer support served the most protective function in students' academic well-being during COVID-19 pandemic times, particularly for those students who suffer the most from COVID-19-related worries. For faculty, their supportive role on academic well-being was less comprehensive and, surprisingly, most evident for those students who suffer the least from COVID-19-related worries. Finally, support from study advisors hardly played a role in negating the effects of COVID-19-related stressors on academic well-being. However, we do find a reversed pattern, namely, students who worried more about having a less enjoyable study period because of the pandemic and also experienced low academic efficacy reported receiving higher support from the study advisor. That effect may be driven by these students seeking higher support from the study advisors. Below, we discuss the statistical results for each support system in more detail.

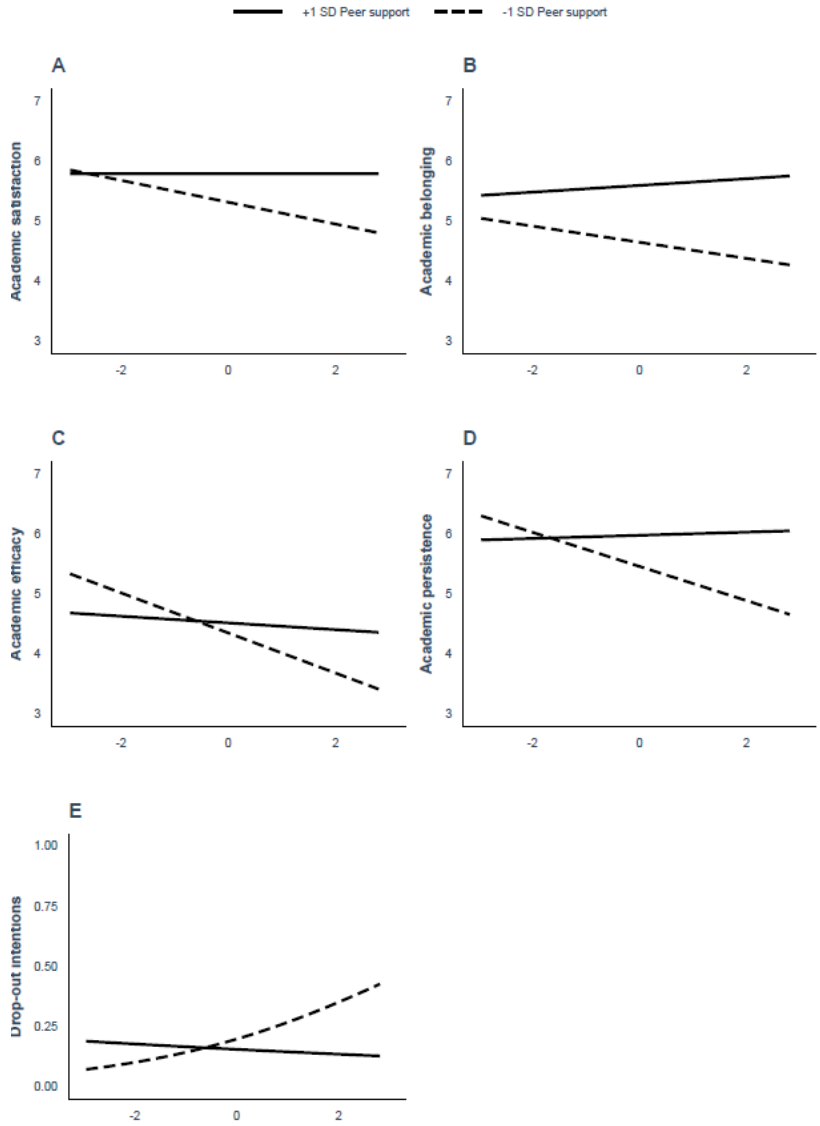

Figure 5. Interactive Effects of Peer Support and Worries About Falling Behind with The Study on Academic Well-Being Outcomes, showing academic satisfaction in Panel (**A**), academic belonging in Panel (**B**), academic efficacy in Panel (**C**), academic persistence in Panel (**D**), and drop-out intentions in Panel (**E**).

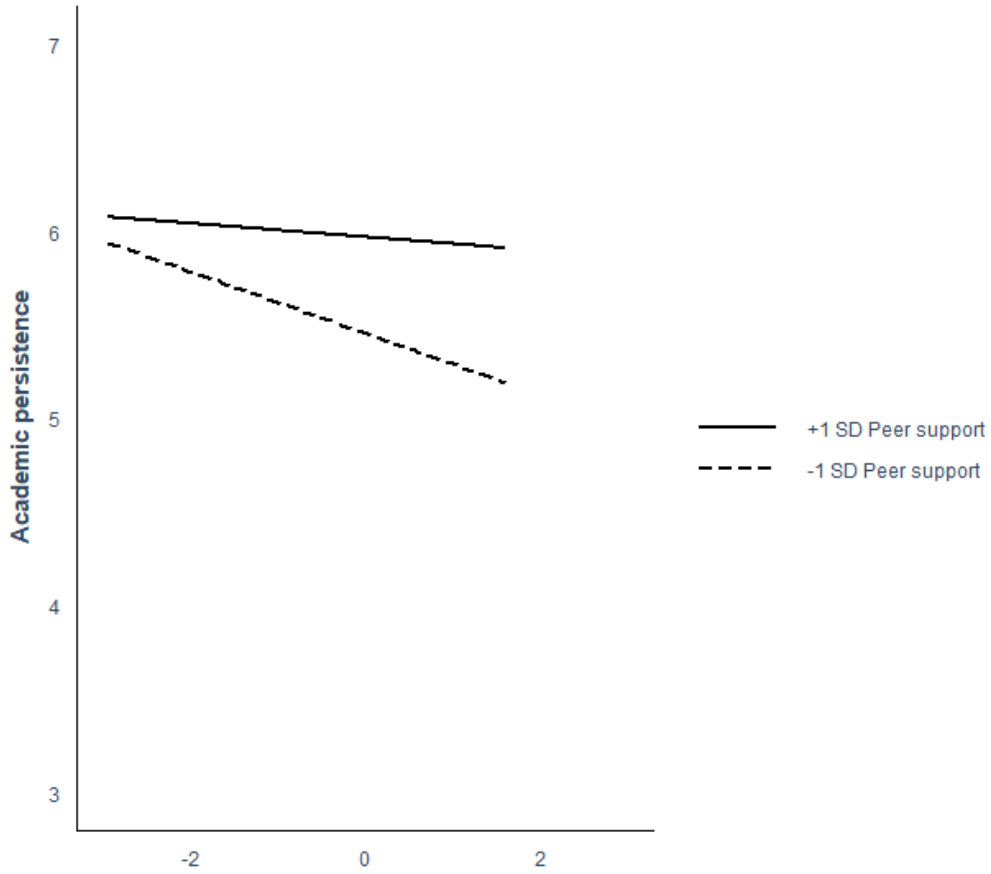

Figure 6. Interactive Effects of Peer Support and Worries about Having a Less Enjoyable Study Period on Academic Persistence.

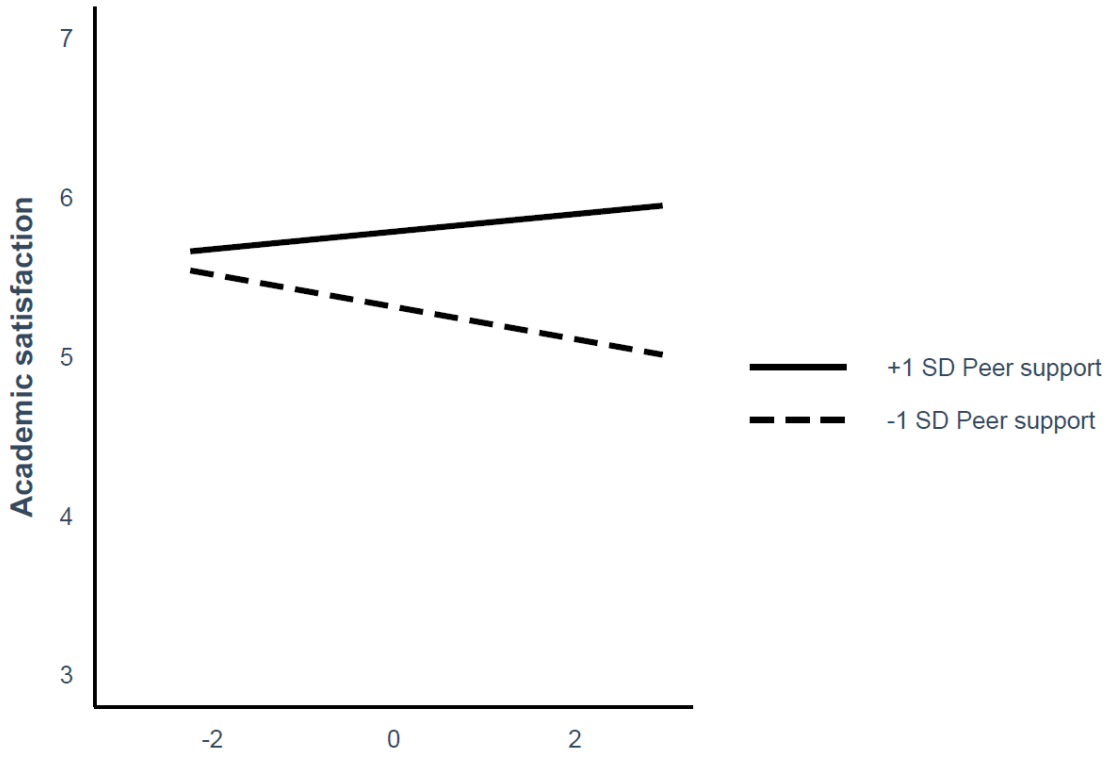

Figure 7. Interactive Effects of Peer Support and Financial Worries on Academic Satisfaction.

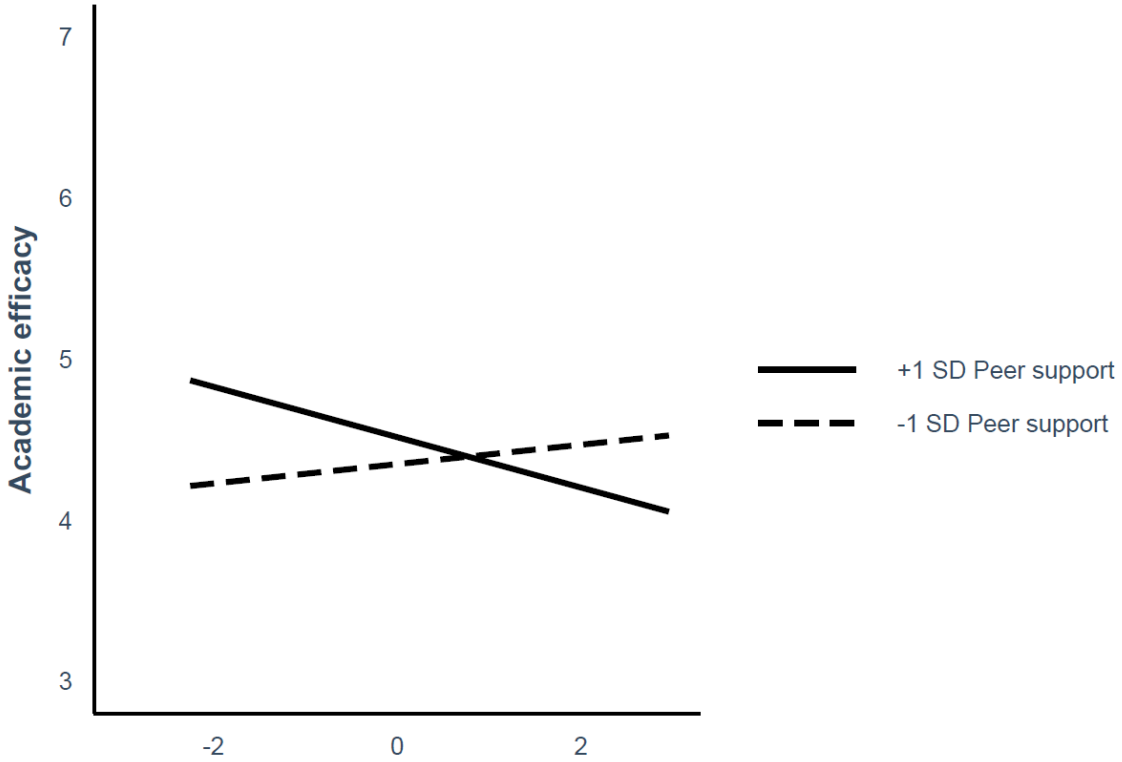

Figure 8. Interactive Effects of Peer Support and Worries about Value Diploma on Academic Efficacy.

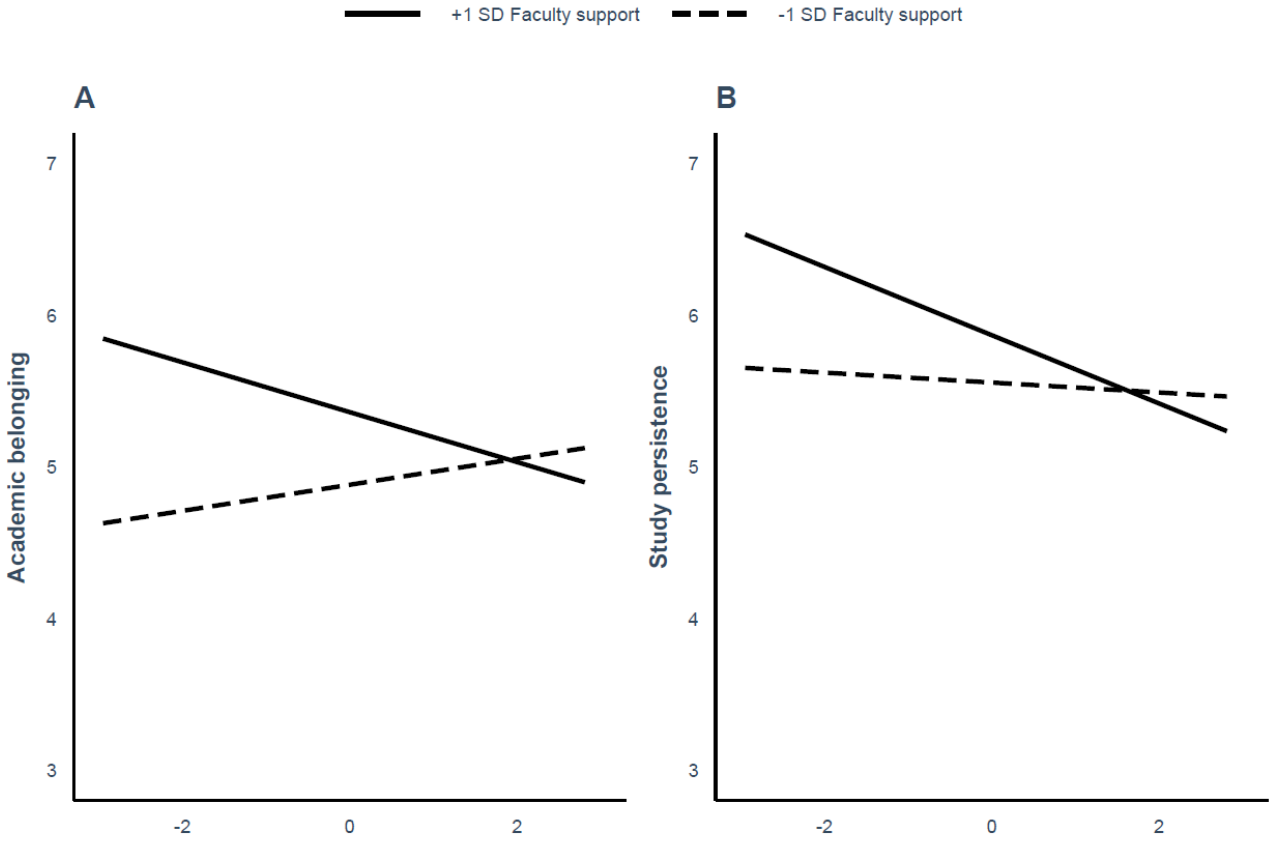

Figure 9. Interactive Effects of Faculty support and Worries about Falling with the Study on Academic Belonging Panel (**A**) and Academic Persistence Panel (**B**).

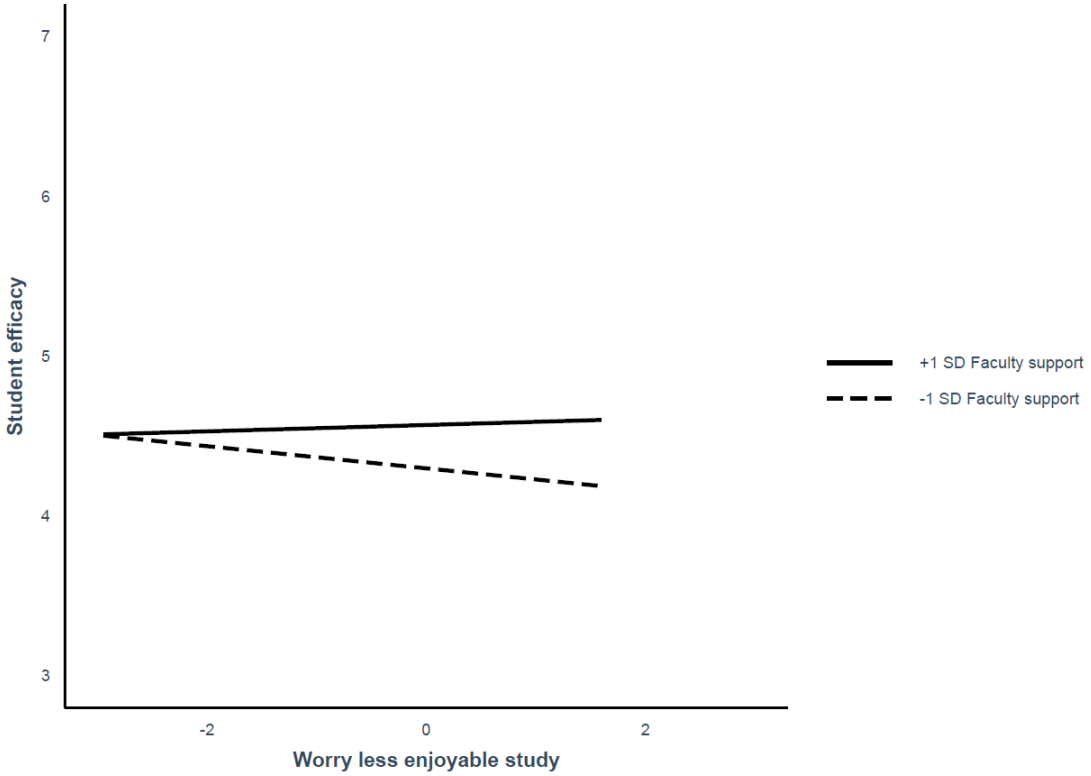

Figure 10. Interactive Effects of Faculty support and Worries about Enjoyable Study Period on Academic Efficacy.

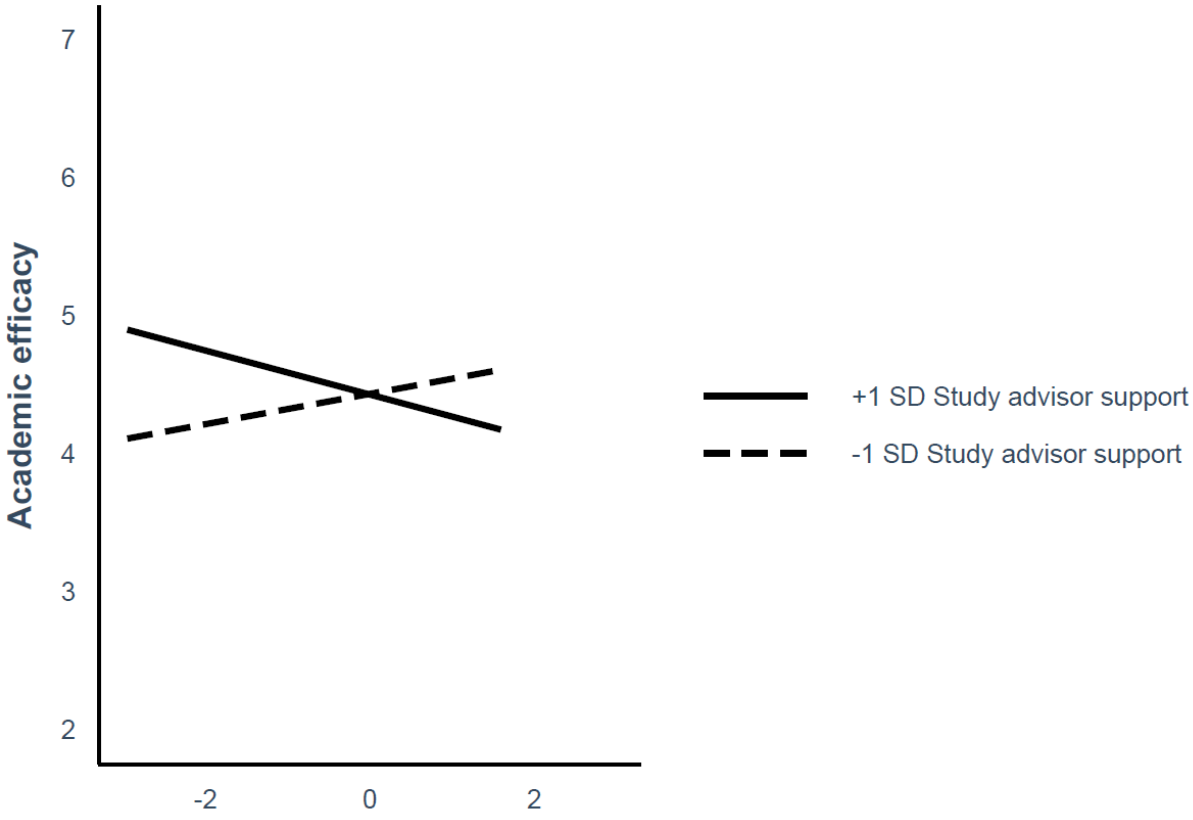

Figure 11. Interactive Effects of Study Advisor Support and Worries about Enjoyable Study Period on Academic Efficacy.

5.3.1. Peer Support

Peer support moderated the effect of students' worries about falling behind in their studies on all five academic well-being outcomes (i.e., satisfaction, belonging, efficacy, persistence intentions, and dropout intentions, see Figure 5A–E). In line with Hypothesis 3b, simple slope analyses revealed that when there is a lack of peer support (−1 SD) stronger worries about falling behind in the study relate to lower academic satisfaction (β = −0.17, SE = 0.07, t = −2.69, p = 0.01), lower academic belonging (β = −0.13, SE = 0.05, t = −2.76, p = 0.01), lower academic efficacy (β = −0.33, SE = 0.06, t = −5.76, p < 0.01), lower study persistence (β = −0.28, SE = 0.06, t = −5.06, p < 0.01), and higher dropout intentions (β = 0.39, SE = 0.14, OR = 1.48, z = 2.82, p < 0.01). When students report stronger peer support (+1 SD) academic well-being indicators were higher irrespective of their worries about falling behind with their studies due to the pandemic (academic satisfaction: β = −0.01, SE = 0.05, t = −0.24, p = 0.81; academic belonging: 0.06, SE = 0.05, t = 1.07, p = 0.28; academic efficacy: β = −0.06, SE = 0.06, t = −0.90, p = 0.37; academic persistence: β = 0.03, SE = 0.06, t = 0.44, p = 0.66; dropout intentions: β = −0.08, SE = 0.13, OR = 0.92, z = −0.61, p = 0.54).

Furthermore, peer support significantly moderated the effect of COVID-19-related worries about having a less enjoyable study period on academic persistence (see Figure 6) but not on other indicators of academic well-being. In line with Hypothesis 3b, simple slope analyses again revealed that when there is a lack of peer support (−1 SD), stronger worries about having a less enjoyable study period relate to lower academic persistence intentions (β = −0.16, SE = 0.07, t = −2.26, p = 0.02). When students reported stronger peer support (+1 SD), academic persistence intentions (β = −0.04, SE = 0.07, t = −0.54, p = 0.59) were higher irrespective of their worries about a less enjoyable study period due to the COVID-19 pandemic.

A similar moderating effect of peer support was again found on the effect of COVID-19-related financial concerns on academic satisfaction (see Figure 7) but not on other indicators of academic well-being. When students reported a lack of peer support (−1 SD), stronger financial concerns were related to lower academic satisfaction (β = −0.10, SE = 0.05, t = −2.25, p = 0.03). When students reported stronger peer support (+1 SD) financial concerns did not relate to their academic satisfaction (β = 0.06, SE = 0.04, t = 1.25, p = 0.21).

Finally, a cross-over two-way interaction of peer support and COVID-19-related concerns about the value of the diploma was found on academic efficacy (see Figure 8). When students reported to worry very little about a possible decrease in the value of their diploma due to the pandemic (−1 SD), stronger peer support was related to higher academic efficacy (β = 0.21, SE = 0.08, t = −2.60, p = 0.01). When students reported to worry a lot about the value of their diploma (+1 SD), peer support was not related to their academic efficacy (β = −0.09, SE = 0.08, t = −1.06, p = 0.29). This may indicate that peers reassure each other about their study skills and the value of their diploma. Hence students who receive little peer support may not get this reassurance and worry more about the value of their diploma and about their academic capacities.

Taken together, when students worry about falling behind with their studies, less study enjoyment, and to a lesser extent financial concerns due to the COVID-19 pandemic, it is particularly the absence of peer support (e.g., not having fellow students to study with, to discuss study content with, or to lend some financial help) that makes students vulnerable in their academic well-being at times when COVID-19-restrictive measures are in place. Students with strong peer networks seem to be more resilient against COVID-19-related stressors with regard to studies during these times.

5.3.2. Faculty Support

Faculty support also moderated the effect of COVID-19-related worries about falling behind due to the pandemic on two well-being indicators: academic belonging and persistence intentions (see Figure 9). The pattern of results, however, was quite different from peer support. Specifically, only among students who reported to worry very little about

falling behind due to the COVID-19 pandemic (−1 SD), faculty support was significantly related to higher academic belonging (β = 0.47, SE = 0.09, t = 5.03, $p < 0.01$) and academic persistence (β = 0.34, SE = 0.11, t = 3.09, $p < 0.01$). By contrast, for those who worried a lot about falling behind in their studies (+1 SD), faculty support was not related to academic belonging (β = 0.01, SE = 0.10, t = 0.10, $p = 0.92$) and persistence intentions (β = −0.02, SE = 0.11, t = −0.18, $p = 0.85$).

With regards to worries about having a less enjoyable study period (see Figure 10), among students who reported to worry very little about having a less enjoyable study period due to COVID-19 (−1 SD), faculty support was not significantly related to higher academic efficacy (β = 0.07, SE = 0.13, t = 0.54, $p = 0.59$); however, when students worried a lot about having a less enjoyable study period due to the COVID-19 pandemic (−1 SD), their academic efficacy was marginally higher when they experienced more faculty support (β = 0.20, SE = 0.11, t = 1.87, $p = 0.06$).

These results indicate that faculty support may be particularly helpful for academic well-being among those STEM students who are already quite resilient to COVID-19-related worries about falling behind but do not protect students who are vulnerable to high COVID-19-related concerns about falling behind. Furthermore, faculty support seems to protect students' academic efficacy when they worry a lot about the effect of the COVID-19 pandemic on their academic enjoyment.

5.3.3. Study Advisor Support

Study advisor support only moderated the effect of COVID-19-related worries about having a less enjoyable study period on academic efficacy (see Figure 11). Specifically, when students reported having low study advisor support (−1 SD), their worries about having a less enjoyable study period were not related to their academic efficacy (β = 0.11, SE = 0.07, t = 1.69, $p = 0.09$). When students reported having higher study advisor support (+1 SD), the more they worried about having a less enjoyable study period because of the pandemic, the lower their academic efficacy (β = −0.16, SE = 0.07, t = −2.30, $p = 0.02$). This somewhat puzzling finding may indicate that students who are more insecure about their academic capabilities are also more worried about the effect of the COVID-19 pandemic on their academic enjoyment and hence seek more support from study advisors.

5.4. Discussion Study 3

Support was found for H3a as results showed that the more STEM students reported feeling supported by their peers and their teachers during COVID-19, the higher their academic satisfaction, academic belonging, and behavioral intentions to persist in their study. No main effects were found for peer and faculty support on academic efficacy and dropout intentions during the COVID-19 pandemic. Furthermore, study advisor support was not significantly related to any of the academic well-being outcomes. In addition, partial support was found for H3b, showing that peer support can protect students' academic well-being against the negative effects of COVID-19-related worries. Students with strong peer networks seem to be more resilient to the negative effect that worries that the COVID-19 pandemic may result in study delays, fewer study enjoyment, and financial problems have on academic well-being.

On the other hand, faculty support and study advisor support do not seem to improve the students' resilience against the negative effect of COVID-19-related stressors on academic well-being. While faculty support appears to be helpful for academic well-being among STEM students who worry little about study delay due to the COVID-19 pandemic, it does not help students who worry a lot about this. Furthermore, study advisor support seemed to play no (positive) role in negating the effects of COVID-19-related stressors on academic well-being.

6. Discussion

We provide the first comprehensive overview of the impact of the later stages of the COVID-19 pandemic on academic well-being in STEM students. Previous research has found a decrease in students' general psychological well-being and mental health during the COVID-19 pandemic [1,7,8], a decrease in measures of academic well-being in the early part of the pandemic (i.e., spring and summer 2020), and a negative impact of "emergency remote teaching" on study motivation [68]. We extend this body of work by focusing on academic well-being in the STEM population beyond the initial phase of the pandemic and identify the most impactful COVID-19-related concerns (i.e., worries about study delays and study enjoyment) while also examining the potential protective effect of several social support systems.

Using a cross-sectional cohort dataset, comparisons in academic well-being between a pre-pandemic and pandemic cohort of first-year STEM students showed that students studying during the COVID-19 pandemic felt lower academic satisfaction, lower sense of belonging in the study, lower academic self-efficacy, and lower persistence intentions compared to students who started their studies a year earlier, before the COVID-19 pandemic. The longitudinal dataset, comparing pre-pandemic students' academic well-being at the start of their university studies, to academic well-being of these students in their second year, several months into the COVID-19 pandemic, showed similar results. Moreover, this dataset showed that students' academic satisfaction and sense of academic belonging decreased, and more students indicated that they had seriously thought about quitting their studies. Although students' academic efficacy remained consistent and, in general students' persistence intentions increased, it is important to consider these findings in the context of the usual pre-pandemic trends. Studies have demonstrated that students tend to have higher persistence intentions as they advance in their academic programs, and their academic self-efficacy also typically increases. Thus, it is notable that there was no significant change in students' self-efficacy levels over time, and also while persistence intentions generally followed the typical upward pattern over the course of study years, as previously stated, there were more students considering dropping out of their studies, which signals how impactful this COVID-19 pandemic was for students' academic well-being. Our work confirms other cross-sectional studies that show a negative impact of the pandemic academic persistence intentions and academic well-being [69].

Academic well-being during the pandemic was mainly influenced by worries about study delays. Students who were more likely to worry that the COVID-19 pandemic would result in study delays showed lower academic satisfaction, lower sense of belonging in the study, lower academic self-efficacy, lower persistence intentions, and higher intentions to quit. These effects of concerns about study delay on academic well-being were found over and above financial concerns due to the pandemic, worries about the decreased value of the diploma due to the pandemic, and worries about the impact of the pandemic on study enjoyment. The only exception was the additional relationship between worries about study enjoyment and academic satisfaction, as students who were more likely to worry about the impact of the COVID-19 pandemic on their study enjoyment experienced lower academic satisfaction.

When interpreting our findings within the expectance-value framework, it suggests that students' academic well-being during the COVID-19 pandemic is mainly influenced by concerns regarding doing well (i.e., as measured by worries about study delays) and, to a lesser extent, by concerns regarding the intrinsic value of studying (i.e., personal enjoyment), rather than by concerns about the costs of studying (i.e., as measured by the financial costs of studying) and the utility value of studying (i.e., the usefulness of studying for future goals, as measured by the concerns regarding the worth of their diploma). Thus, although STEM students expressed concerns on all worries, it weremainly concerns about doing well academically that were negatively related to academic well-being.

The third study provides empirical evidence that social support systems within the university context can buffer the negative impact of the pandemic on students' academic

well-being. In general, both peer and faculty support were found to increase students' academic well-being during the pandemic. In addition, students were buffered against the negative effects of pandemic-related worries about facing study delays on academic well-being when they experienced high peer support. These findings confirm theorizing that social support can be an important protective mechanism in the face of crisis [70]. Furthermore, these results align with findings of previous COVID-19 studies that show that support is related to higher academic well-being and lower academic stress [5,71]. Furthermore, these findings are in line with recent research on the impact of perceived teacher support on student engagement and achievement [72].

In line with theorizing and some empirical studies, findings support both a general beneficial effect and a buffering effect of social support. Regarding a general beneficial effect, our data suggest that experiencing peer support and faculty support is directly related to higher academic well-being. This is consistent with the belonging hypothesis [73], stating that social support functions as a safety net in crisis situations and enables a reduction in the negative appraisal of threat. Regarding a buffering effect, findings showed that peer support buffered for the negative effect of worries about study delay on academic well-being. These results support the stress-buffering hypothesis that posits that social support helps an individual to perceive more control over a stressful situation because others can assist with coping with the stressful event [45].

Unexpectedly, study advisor support was not related to students' academic well-being. One reason could be that especially students with high worries and lower academic well-being seek out the support of the study advisor. Still, as evidence demonstrated the importance of high-quality advisor–advisee relationships for the academic well-being of pupils [53], it may be beneficial for all students to seek the support of a study advisor. Therefore, more research is warranted on how study advisors can support the well-being of all students.

6.1. Practical Implications

This study confirms the detrimental impact of the COVID-19 pandemic on STEM students' academic well-being. Most students experienced a decline in their academic engagement and belonging, and there are more students to report dropout intentions than before the pandemic. As there is a high shortage of qualified STEM professionals in the Netherlands [74], and they are sorely needed for technological advancements, innovations and the global challenges that we face today (e.g., climate change, dealing with a pandemic), it is crucial to prevent dropout among STEM students. Over and above other pandemic-related worries (e.g., financial worries), worries about incurring study delays had the most impact on STEM students' belongingness to their studies and their academic efficacy. They were most predictive of their persistence intentions. Therefore, in the aftermath of the pandemic, it is crucial to develop support for these students who worry a lot about having incurred study delays due to the COVID-19 pandemic. Long-term support measurements may be needed to recover STEM students' academic well-being.

Both peer and faculty support were found crucial in helping students cope with the pandemic. Next to a general beneficial effect, peer support also buffered the negative impact of worrying about study delay on academic well-being. This highlights the value peer networks can have in managing students' academic well-being during a stressful period. One way to formalize peer support may be by designing peer coaching interventions as part of study programs. First empirical evidence demonstrates the beneficial effects of such peer coaching interventions [75,76]. Furthermore, academic well-being of STEM students may be improved by providing faculty with the right tools and time to support STEM students adequately.

6.2. Strengths and Limitations

There are several noteworthy strengths of the current research. First, we used a unique combination of datasets to investigate our hypotheses. The cross-sectional cohort dataset

allowed us to compare the academic well-being of a pre-pandemic cohort with a pandemic cohort of first-year STEM students. In contrast, the longitudinal dataset allowed us to follow the academic well-being of first-year students over time, starting in a pre-pandemic situation and continuing into their second year in a pandemic context. Thereby, we were able to examine the same hypotheses using different analyses providing a more robust answer to what extent the COVID-19 pandemic was related to academic well-being in STEM students. Another strength of the study is that longitudinal and cohort comparisons were made during the same time point of the academic year, namely at the start of the academic year (fall 2019 and 2020). Therefore, it is less likely that pre-pandemic and pandemic comparisons were influenced by natural fluctuations in the academic well-being of students during the academic year.

Limitations of our research design resulted from the naturalistic context in which the data were collected (i.e., during an unexpected pandemic). First, because our results are based on correlational data, they do not allow us to draw hard conclusions about the causal impact of the COVID-19 pandemic on academic well-being. However, the fact that higher COVID-19-related worries were related to lower academic well-being signals the negative consequences of the COVID-19 pandemic for students' academic well-being. Nevertheless, alternative time and cohort explanations (other than COVID-19 imposed restrictions) for lower academic well-being cannot be ruled out. Second, in our pre-pandemic questionnaire, we did not include measures on different academic support systems and general study-related worries (such as worries about study delays or the financial situation). Therefore, we could not directly compare how these relationships are similar or different to general study worries (e.g., general worries about study delays), their relationship with academic well-being, and the buffering effect of support systems in a 'normal' academic context. However, our results do still provide relevant insights into how worries about the impact of the COVID-19 pandemic and potentially other long-term crises are related to academic well-being during a long-term crisis situation, and which university support systems can buffer these effects.

7. Conclusions

In summary, findings of a cross-sectional cohort and longitudinal dataset showed that the COVID-19 pandemic had a negative impact on university STEM students' academic well-being beyond the initial emergency phase. Students experienced a lower affective connection to their studies, lower academic efficacy, and lower persistence intentions. Especially, worries about incurring study delays due to the pandemic were related to poorer academic well-being. In contrast, other COVID-19-related worries, such as less enjoyable study periods and lower value of their diploma and finance, were less strongly or not related to academic well-being indicators. This suggests that students' academic well-being may mainly be influenced by concerns about doing well rather than the costs or usefulness of studying. Peer and faculty support were found to be crucial in increasing students' academic well-being during the pandemic. Moreover, university students could be buffered against the negative relationship between pandemic-related worries about facing study delays and academic well-being when they experience high peer support. Study advisor support, however, did not directly impact students' academic well-being, nor did it buffer the effects of negative COVID-19-related stressors such as worries about incurring study delay. Possibly so because especially students with high worries and lower academic well-being seek out the support of the study advisor. To conclude, while during the COVID-19 pandemic students were encouraged to be physically far away from each other, they were in a higher need for social support to cope with the crisis. By facilitating networking among students and providing faculty staff with the right tools and time to support their students, students' academic well-being may be improved during challenging times, such as the prolonged effects of the COVID-19 pandemic. By investing in the academic well-being of our students, we will create a resilient and sustainable society.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su151914267/s1, Table S1: Intraclass Correlations; Table S2: Descriptive Statistics for the Cohort data (Study 1); Table S3: Analyses with Cohort as Predictor and Academic Well-being Indicators as Outcome (Study 1); Table S4: Descriptive Statistics for the Longitudinal Data (Study 1); Table S5: Analyses with Year as Predictor and Academic Well-being Indicators as Outcome (Study 1); Table S6: Descriptive Statistics for Cross-Sectional Pandemic Data (Study 2); Table S7: Descriptive Statistics for Cross-Sectional Pandemic Data (Study 3); Table S8: Factor Loadings for Oblique Rotated Four-Factor Solution for 10 Academic Well-Being Items; Table S9: Factor Loadings for Oblique Rotated Four-Factor Solution for 9 Sources of Support Items.

Author Contributions: L.A. set up the study, performed the data collection, analyzed and interpreted the data, and was a major contributor in writing the manuscript. M.N. set up the study, performed the data collection, interpreted the data, and was a major contributor in writing the manuscript. M.D.E. set up the study, interpreted the data, and provided feedback on the manuscript. R.v.V. set up the study and provided feedback on the manuscript. S.M.K. set up the study, performed the data collection, interpreted the data, and provided feedback on the manuscript. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of the University of Twente (FirstYearsPrePandemic/SecondYearsPandemic, 191054; FirstYearsPandemic, 201188) for studies involving humans.

Informed Consent Statement: Informed consent was obtained from all participants involved in the study.

Data Availability Statement: As the data are still used for another study on how STEM students' belongingness develops depending on their social identity, we do not make the data publicly available yet. We expect to make the data publicly available within 6 months. Currently, data and materials will be made available upon request. Please contact -blind for review-.

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