Supplementary Online Materials

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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Sampling Approach

Sampling approach of first year STEM students pre-pandemic

The sampling approach to invite students was done in three ways: 1) a student advisor or teacher of the study program invited the students to take part in the research in their class as part of their lesson, 2) one of the authors or research-assistant from the research project visited the students in class and administered the survey as part of their lesson, 3) students were invited to participate in the study via email from a study advisor. To standardize across contexts, the study was always introduced using a 3-minute video in which the study was presented to students as an investigation into students' expectations of university life and students participated voluntarily. Students were also informed that apart from participating in this wave of data collection, there would be two additional measurement moments to follow them in their studies over the course of the year. After the video, students received a link to the online survey. Participants could take part in a lottery to win 25 euro of prize money after every measurement. Furthermore, all students received feedback on their personal results after this survey.

Sampling approach of second year STEM students during pandemic

The sampling approach to invite students to participate in wave 2 was done in three ways: 1) students were invited via the email-address that they gave in the first wave, 2) one of the authors or research-assistant from the research project visited the students in an online lecture and administered the survey as part of their lesson, 3) students were invited to participate in the study via advertisement from a study advisor. There was an additional lottery to win a monetary prize (25 euro) if they completed all measurements. Furthermore, all students received feedback on their personal results after this survey.

Sampling approach of first year STEM students during pandemic

The sampling approach to students to participate in wave 2 was done 1) students were invited to participate in the study via advertisement from a study advisor, 2) students received an e-mail from their study advisor with an invitation to participate. Students received feedback on their personal results after the survey.

Intraclass correlations

In all three datasets participants were nested within study programs which may lead to dependency in the data and influences the statistical analysis to be used. To test for statistical dependency in our data , we calculated for each dataset the intraclass correlations (ICC's) for the four main measures (i.e., academic satisfaction, academic belonging, study efficacy, and study persistence), using study program as cluster variable. Bickel (2007) and Maas and Hox (2005) recommend taking clustering into account if ICC's are larger than .10 (i.e., more than 10% of the variance in an outcome is than explained by the level 2, thus in our study is explained by the study program level). All our ICC's were .10 or smaller (for an overview of the ICC's, see Table 1), except the ICC of persistence intentions in the FirstYears2020 sample, that was .11. Therefore, we chose to perform our analyses without taking nesting of our participants within study programs into account.

Table S1

Intraclass correlations (ICC) for study program level on the main outcome measures for each of the samples

Measures	**Datasets**		
	FirstYearsPrepandemic	FirstYearsPandemic	SecondYearsPandemic
Study satisfaction	.01	.00	.00
Study belonging	.04	.01	.04
Study efficacy	.09	.04	.00
Persistence intentions	.02	.11	.10

Descriptive Statistics for the Cohort Data (Study 1)

Table S2

Means, standard deviations and bivariate correlations among demographic variables and academic well-being measures in cohort data

	M *(SD)*		Correlations								
	Cohort 1	Cohort 2	1	2	3	4	5	6	7	8	9
1. Age	19.11	18.73*									
	(2.16)	(1.32)	-	-.08*	.17**	.06	.06	.00	.09*	.13**	.01
2. Gender	0.19	0.39*									
(0 = men, 1 = women)[a]	(0.39)	(0.49)	-.07	-	.04	-.08*	.02	-.03	-.19**	-.05	.01
3. Nationality	0.24	0.27									
(0 = Dutch, 1 = other)	(0.43)	(0.45)	.31**	-.19**	-	-.38**	-.03	-.15**	-.06	.11**	.10**
4. University type	0.61	1.00*									
(0 = applied, 1 =	(0.45)	(0)									
research-intensive)			NA	NA	NA	-	.11**	.19**	.24**	.11**	-.06
5. Academic satisfaction	5.88	5.25*									
	(0.94)	(1.16)	-.04	-.07	-.11	NA	-	.67**	.31**	.53**	-.39**
6. Academic belonging	5.58	4.73*									
	(1.05)	(1.26)	-.10	-.11	-.11	NA	.67**	-	.36**	.48**	-.39**
7. Academic efficacy[b]	4.78	4.01*									
	(1.18)	(1.40)	.06	-.18*	-.01	NA	.47**	.41**	-	.45**	-.19**
8. Persistence intentions[b]	5.71	5.30*									
	(1.39)	(1.46)	.16*	-.10	.19**	NA	.59**	.42**	.38**	-	-.36**
9. Drop-out intentions	0.08	0.19*									
(0 = no, 1= yes)	(0.27)	(0.39)	-.10	.17*	.01	NA	-.50**	-.38**	-.26**	-.52**	-

Note. N cohort 1 = 788, N cohort 2 = 202, total N = 990. All study well-being measures are measured on a 7-point Likert scale, unless otherwise stated. When the cohorts differed significantly from each other ($p < .05$) this was indicated with an * in the Cohort2 column. Correlations above the diagonal are for Cohort 1 and below the diagonal for Cohort 2.

[a] 4 missing cases

[b] 13 missing cases

* $p < .05$. ** $p < .01$.

Analyses with Cohort as Predictor and Academic Well-being Indicators as Outcome (Study 1)

Table S3a

ANCOVA's with Prepandemic (2019) vs. Pandemic (2020) Cohort as Predictor and Academic Well-being Indicators as Outcome

	Measures			
	Academic satisfaction	Academic belonging	Academic efficacy[a]	Persistence Intentions[a]
Cohort 2019: *EM (SE), [95% CI]*	5.83 (0.05), [5.74, 5.93]	5.53 (0.05), [5.44, 5.62]	4.56 (0.06), [4.45, 4.67]	5.74 (0.06), [5.62, 5.86]
Cohort 2020: *EM (SE), [95% CI]*	5.14 (0.08), [4.98, 5.29]	4.73 (0.08), [4.58, 4.88]	3.69 (0.10), [3.50, 3.88]	5.20 (0.11), [4.99, 5.40]
Test statistics for Cohort Differences	$F(1, 980) = 64.88$, $p < .001$, $\eta p2 = 0.06$	$F(1, 980) = 88.71$, $p < .001$, $\eta p2 = 0.08$	$F(1, 967) = 67.81$, $p < .001$, $\eta p2 = 0.07$	$F(1, 967) = 22.15$, $p < .001$, $\eta p2 = 0.02$
Test statistics for Covariates				
Gender	$F(1, 980) = 0.00$, $p = .99$, $\eta p2 < 0.01$	$F(1, 980) = 2.57$, $p = .11$, $\eta p2 < 0.01$	$F(1, 967) = 29.45$, $p < .01$, $\eta p2 = 0.03$	$F(1, 967) = 1.74$, $p = .19$, $\eta p2 < 0.01$
Nationality	$F(1, 980) = 0.71$, $p = .40$, $\eta p2 < 0.01$	$F(1, 980) = 15.86$, $p < .001$, $\eta p2 = 0.02$	$F(1, 967) = 0.07$, $p = .79$, $\eta p2 < 0.01$	$F(1, 967) = 19.86$, $p < .001$, $\eta p2 = 0.02$
University	$F(1, 980) = 5.91$, $p = .02$, $\eta p2 < 0.01$	$F(1, 980) = 9.78$, $p < .001$, $\eta p2 = 0.01$	$F(1, 967) = 33.67$, $p < .01$, $\eta p2 = 0.03$	$F(1, 967) = 18.23$, $p < .001$, $\eta p2 = 0.02$
Age	$F(1, 980) = 1.53$, $p = .22$, $\eta p2 < 0.01$	$F(1, 980) = 0.99$, $p = 0.32$, $\eta p2 < 0.01$	$F(1, 967) = 2.12$, $p = .15$, $\eta p2 < 0.01$	$F(1, 967) = 7.76$, $p = .005$, $\eta p2 < 0.01$

Note. Separate ANCOVA's controlling for age, gender (0 = men, 1 = women), nationality (0 = Dutch, 1 = other) and university type (0 = applied ; 1 = research). [a] 13 missing cases .

Table S3b

Logistic Regression with Prepandemic vs. Pandemic Cohort as Predictor and Drop-out as Outcome

	β	SE	χ^2 (Wald), p-value	OR [95% CI]
Intercept	-0.002	0.05	13.47	
Cohort (0 = prepandemic; 1 = pandemic cohort)	1.00	0.27	13.45	2.72 [1.60, 4.67]
Gender (0 = men, 1 = women)	0.37	0.24	2.40	1.45 [0.89, 2.30]
Nationality (0 = Dutch, 1 = non-Dutch)	0.55	0.25	4.77	1.73 [1.05, 2.83]
University type (0 = applied, 1 = research intensive)	-0.25	0.29	0.75	0.78 [0.45, 1.37]
Age	-0.08	0.07	1.50	0.92 [0.80, 1.04]

Note. Logistic regression was performed. $N = 973$. OR = odds ratio. *Nagelkerke* $R^2 = 0.06$

Descriptive Statistics for the Longitudinal Data (Study 1)

Table S4

Means, Standard Deviations and Bivariate Correlations for Longitudinal Data in Study 1.

	M *(SD)*		Correlations				
	Year 1	Year 2	1	2	3	4	5
1. Academic satisfaction	6.01	5.83					
	(0.71)	(0.94)	1	.63**	.25**	.47**	-.05
2. Academic belonging	5.74	5.56					
	(0.92)	(1.13)	.69**	1	.31**	.48**	-.12
3. Academic efficacy	4.75	4.90					
	(1.19)	(1.22)	.17*	.28**	1	.43**	-.09
4. Persistence intentions	5.74	6.11					
	(1.26)	(1.12)	.54**	.44**	.23**	1	-.06
5. Dropout intentions	0.03	0.22					
(0 = no, 1 = yes)	(0.18)	(0.41)	-.41**	-.33**	-.14	-.41**	1

Note. N = 170. All academic well-being measures are measured on a 7-point Likert scale, unless otherwise stated. Correlations above the diagonal are for Year 1 and below the diagonal for Year 2.

* $p < .05$. ** $p < .01$.

Analyses with Year as Predictor and Academic Well-being Indicators as Outcome (Study 1)

Table S5a

Multilevel regressions with Year as Predictor and Academic Well-being Indicators as Outcome

	Measures			
	Academic satisfaction	Academic belonging	Study efficacy[a]	Study persistence[a]
Test statistics for Academic Year	β = -0.19, *SE* = 0.07, *t* = -2.56, *p* = 0.012*	β = -0.18, *SE* = 0.09, *t* = -2.06, *p* = 0.04*	β = 0.07, *SE* = 0.05, *t* = 1.46, *p* = 0.15	β = 0.17, *SE* = 0.05, *t* = 3.39, *p* = 0.001**
Test statistics for Covariates				
Gender (0 = men, 1 = women)	β = -0.06, *SE* = 0.12, *t* = -0.48, *p* = 0.63	β = -0.05, *SE* = 0.14, *t* = -0.33, *p* = 0.74	β = -0.49, *SE* = 0.17, *t* = -2.83, *p* = 0.005**	β = 0.01, *SE* = 0.17, *t* = -0.08, *p* = 0.94
Nationality (0 = Dutch, 1 = non-Dutch)	β = 0.00, *SE* = 0.01, *t* = 0.72, *p* = 0.47	β = 0.01, *SE* = 0.01, *t* = 1.24, *p* = 0.22	β = 0.01, *SE* = 0.01, *t* = 1.01, *p* = 0.32	β = 0.01, *SE* = 0.01, *t* = 1.67, *p* = 0.10
Age	β = -0.01, *SE* = 0.03, *t* = -0.38, *p* = 0.71	β = -0.01, *SE* = 0.04, *t* = -0.28, *p* = 0.78	β = -0.01, *SE* = 0.05, *t* = -0.23, *p* = 0.82	β = 0.08, *SE* = 0.05, *t* = -01.67, *p* = 0.10
University type (0 = applied, 1 = research intensive)	β = -0.18, *SE* = 0.11, *t* = -1.59, *p* = 0.11	β = -0.48, *SE* = 0.14, *t* = -3.60, *p* = 0.00	β = -0.51, *SE* = 0.16, *t* = -3.14, *p* = 0.002	β = -0.24, *SE* = 0.16, *t* = -1.52, *p* = 0.13

Note. Multilevel analyses with time as level 1 and participants as level 2 (with random intercept).

[a] One extra missing participant (n = 169)

* $p < .05$. ** $p < .01$.

Table S5b

Multilevel regressions with Year as Predictor and Drop-out as Outcome

	β	OR	OR[95% CI]
Intercept	-8.44	0.00	[0.00, 0.38]
Cohort	1.41	4.11	[2.03, 8.34]
Gender (0 = men, 1 = women)	-0.48	0.62	[0.18, 2.12]
Nationality (0 = Dutch, 1 = non-Dutch)	-0.02	0.98	[0.91, 1.05]
University (0 = applied, 1 = research intensive)	1.01	1.14	[0.81, 1.60]
Age	-0.13	2.76	[0.83, 9.16]

Note. OR stands for Odds ratio.

Descriptive Statistics for the Cross-Sectional Data (Study 2)

Table S6.

Means, Standard Deviations and Bivariate Correlations among COVID-19 Stressors and Academic Well-being Measures

Variable	*M*	*SD*	1	2	3	4	5	6	7	8	9	10	11	12
1. Age	18.66	1.44												
2. Gender (0 = men, 1 = women)	0.33	0.47	-.07											
3. Nationality (0 = Dutch, 1 = Other)	0.24	0.43	.20**	-.08										
4. Study Year (0 = first year, 1 = second year)	1.47	0.50	-.05	-.12*	-.08									
5. Worry: Fall behind studies	4.19	1.84	.15**	-.03	.02	-.00								
6. Worry: Less enjoyable study	5.41	1.50	-.02	-.02	.07	-.19**	.30**							
7. Worry: Financial	3.25	1.81	.25**	.11*	.26**	-.09	.25**	.18**						
8. Worry: Value diploma	3.26	1.89	.18**	-.03	.12*	.13*	.36**	.24**	.24**					
9. Study satisfaction	5.53	1.10	-.02	-.09	-.08	.26**	-.27**	-.27**	-.16**	-.09				

10. Study belonging	5.14	1.25	-.04	-.13*	-.08	.31**	-.20**	-.15**	-.19**	-.13*	.71**			
11. Study efficacy	4.42	1.39	.03	-.20**	-.05	.32**	-.25**	-.14**	-.07	-.09	.42**	.43**		
12. Study persistence intentions	5.69	1.37	.11*	-.04	.12*	.30**	-.24**	-.20**	.01	-.01	.61**	.48**	.39**	
13. Dropout intentions (0 = no, 1 yes)	0.21	0.41	-.03	.09	.01	.04	.16**	.12*	.02	.07	-.43**	-.33**	-.18**	-.44**

Note. Descriptives and correlations are presented for the combined dataset of the FirstYearsPrepandemic sample and SecondYearspandemic sample.

*$p < .05$. **$p < .01$.

Descriptive Statistics for Cross-Sectional Data (Study 3)

Table S7.

Means, Standard Deviations and Bivariate Correlations among University Support, COVID-19 Stressors and Academic Well-being Measures

Measures	*M*	*SD*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Age	18.64	1.44	1															
2. Gender	0.33	0.47	-.07	1														
3. Nationality	0.24	0.43	.19**	-.08	1													
4. Study year	1.47	0.50	-.04	-.12*	-.07	1												
5. Peer support	5.13	1.40	-.06	-.06	-.09	.44**	1											
6. Teacher support	5.26	0.99	-.00	-.08	-.00	.29**	.42**	1										
7. Study advisor	4.97	1.24	-.05	.02	-.05	.20**	.25**	.36**	1									

support																		
8. Corona worry: falling behind	4.19	1.84	.15**	-.03	.02	-.01	-.17**	-.24**	-.13*	1								
9. Corona worry: less enjoya ble study period	5.40	1.50	-.02	-.02	.06	-.19**	-.13*	-.15**	-.11*	.30**	1							
10. Corona worry: financi al concer ns	3.24	1.80	.26**	.11*	.26**	-.09	-.17**	-.10	-.09	.26**	.17**	1						
11. Corona worry: value diplom	3.25	1.89	.17**	-.03	.11*	.14**	-.05	-.05	-.06	.36**	.24**	.25**	1					

a																		
12. Academic satisfaction	5.53	1.10	.01	-.09	-.08	.26**	.43**	.42**	.20**	-.28**	-.26**	-.15**	-.09	1				
13. Academic Study belonging	5.14	1.25	-.01	-.13*	-.08	.31**	.52**	.40**	.15**	-.20**	-.14**	-.19**	-.13*	.70**	1			
14. Academic efficacy	4.42	1.39	.03	-.20**	-.05	.32**	.25**	.25**	.11*	-.26**	-.14**	-.06	-.09	.41**	.43**	1		
15. Academic persistence	5.68	1.37	.11*	-.04	.12*	.30**	.37**	.32**	.16**	-.24**	-.20**	.01	-.01	.62**	.48**	.39**	1	
16. Student Dropout	0.21	0.41	-.03	.09	.01	.03	-.12*	-.15**	-.04	.16**	.13*	.02	.07	-.43**	-.34**	-.18**	-.44**	1

Note. $N = 353$. All items were measured on 7-point scales, except Dropout (i.e., Since starting your study, have you seriously considered quitting your study?) which was measured dichotomous (0 = No, 1 = Yes)

S8. Exploratory factor analyses: Academic well-being outcomes

In this study, an exploratory factor analysis (EFA) was conducted to assess the validity of our academic well-being measurements (i.e., to see if they really assessed different aspects of academic well-being as intended). The EFA revealed a clear factor structure, with four distinct factors identified, corresponding to our hypothesized well-being measurements: academic satisfactions, academic belonging, academic efficacy and academic persistence. Factor loadings were substantial (above 0.45) for all items on their respective factors (see Table S8). One of the reasons why we analyzed the two items of persistence intentions separately, was because of the low factor loadings of one item (i.e., "Since starting your study have you seriously considered quitting your study") and relatedly, this item answer scale was dichotomous in contrast to the other items that had a 7-point likert scale, therefore we decided not to merge the two items but analyze them separately.

Table S8.

Factor Loadings for Oblique Rotated Four-Factor Solution for 10 Academic Well-Being Items.

	Factor loadings				
	Factor 1: Academic Satisfaction	Factor 2: Academic Belonging	Factor 3: Academic Efficacy	Factor 4: Persistence intentions	Communality
1. I am satisfied with my choice of the study program	**0.89**	-0.04	-0.02	0.05	0.78
2. So far, I enjoy my study program	**0.75**	0.08	0.06	-0.01	0.67
3. So far, I feel at home in my study program	0.38	**0.48**	0.08	-0.01	0.68

4. I feel like I belong in my study program	-0.02	**0.96**	<0.01	0.02	0.91
5. I'm certain I can understand the most difficult material presented in my study texts	<0.01	-0.03	**0.83**	0.02	0.69
6. I'm confident I can understand even the hardest things taught by the lecturer	0.01	-0.01	**0.95**	-0.06	0.86
7. I'm confident I can do an excellent job on difficult assignments and tests	-0.03	0.07	**0.67**	`0.16	0.59
8. I will definitely complete this study	0.01	<0.01	0.01	**0.99**	0.99
9. Since starting your study, have you seriously considered quitting your study?	-0.29	-0.11	0.02	-0.21	0.26

Note that we a priori also performed separate exploratory factor analyses and reliability analyses on the items hypothesized to represent the scales: academic satisfaction, academic belonging, academic efficacy and academic dropout. This led to the removal of two items. For the belonging scale the item “I feel accepted by my fellow students in my study program” was removed because of lower intercorrelation and reliability improved if item was dropped. Furthermore, the item “I have thought about quitting this study more than once” was dropped because it only moderately correlated with the item “I will definitely complete this study” (r = -0.45). We chose to remove this first item because of the larger overlap it had with the other indicator of persistence: “Since starting your study have you seriously considered quitting your study?”.

S9. Exploratory factor analyses: Academic Support

In this study, an exploratory factor analysis (EFA) was conducted to assess the validity of our sources of support measurements. The EFA revealed a clear factor structure, with three distinct factors identified, corresponding to our hypothesized sources of support measurements: peer support, teacher support and academic advisor support. Factor loadings were substantial (above 0.70) for all items on their respective factors (see Table S9).

Table S9.

Factor Loadings for Oblique Rotated Four-Factor Solution for 9 Sources of Support Items

	Factor loadings			
	Factor 1: Peer support	Factor 2: Faculty support	Factor 3: Advisor support	Communality
1. I've already made some friends within my study program	**0.73**	-0.06	0.03	0.50
2. I expect I can count on my fellow students if I have problems in my study	**0.75**	0.13	-0.03	0.66
3. I think I will be able to talk about my study with my fellow students	**0.93**	-0.03	<0.01	0.84

4. The teachers take their time to respond to my needs	-0.03	**0.84**	<0.01	0.68
5. The teachers help me to resolve problems	-0.02	**0.84**	<0.01	0.68
6. The teachers make an effort to also accommodate my wishes as far as possible	0.09	**0.70**	0.04	0.59
7. Study advisors offer the support that I need	-0.02	<0.01	**0.94**	0.87
8. Study advisors offer the resources that I need	0.01	<0.01	**0.96**	0.93
9. Study advisors offer the advice that I need	0.01	<0.01	**0.88**	0.78

Note that we à priori also performed separate exploratory factor analyses (EFA; one EFA per hypothesized scale) and reliability analyses on the items hypothesized to represent the scales: peer support, faculty support and study advisor support. This led to the removal of several items. For peer support the item “Most of the friends I have now as a student are from within my study program” was removed because this improved reliability. For faculty support three items (i.e., “I have a feeling that the teachers are hostile towards me.”, “I feel neglected compared to how other students are treated.”, “My particular efforts are often overlooked by my teachers.”) were removed because they loaded on a different factor that seemed to represent more a teacher hostility construct instead of a teacher support construct. Finally, for study advisor support thwo items were removed (“Study advisors are easily accessible”, “Study advisors are sufficiently available”) because they loaded on a different factor that seemed to represent availability while our interest was in experienced support.