




Sense of belonging among first-year physics students in Germany: Exploring intergroup differences and correlations

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Abstract

Within the present study, we investigated first-year physics students' senses of belonging to physics and to their university given different backgrounds and prerequisites. Moreover, we explored whether, and to what extent, these two senses of belonging relate to characteristics that curtail students' academic success and impact the dropout rate from physics programs. For this purpose, we conducted a voluntary, anonymous online survey at 20 universities in Germany. A total of 238 first-year physics students participated. The results of the present study not only align with those of previous research (e.g., the correlative results) but also extend the current state of research (e.g., the revealed intergroup differences) and provide starting points for future research. Conclusions are drawn from these results at the end of the paper.

Keywords: sense of belonging, physics, higher education, first-year students, academic dropout, underrepresented student groups

INTRODUCTION

In the first few months of their studies, first-year students have to overcome numerous challenges: settling into a new place, making new friends, understanding how their university works and how courses are run, and settling into their field of study. Within STEM fields (science, technology, engineering, and mathematics), the number of students who drop out or change their course of study is high, especially among those studying physics (Albrecht & Nordmeier, 2011; Chen, 2013; Henriksen, 2015). Additionally, students who remain in physics programs tend to have a low level of diversity (Avraamidou, 2018; Bilimoria & Stewart, 2009; Rodriguez, & Blaney, 2021). Marginalized groups, such as women, first-generation students, students of color, students with a migration background, or students from families with low socio-economic or educational backgrounds, are more underrepresented in upper-level physics courses than in lower-level courses (Johansson & Larsson, 2022).

The causes of academic dropout, or so-called “leaky pipeline” (Blickenstaff, 2005), are manifold and have been intensively researched. However, constructs

describing students' individual characteristics, such as their prior knowledge (Binder et al., 2019; Buschhüter et al., 2017), interest (Bøe & Henriksen, 2015), academic self-concept (Ackerman et al., 2013), or self-efficacy in physics (Larson et al., 2015), explain this disparity only partially. Therefore, it seems reasonable to conceptualize academic dropout not only as an isolated, individual phenomenon but also as a phenomenon resulting from students' integration into the social environment of their study program (Suhlmann et al., 2018; Ulriksen et al., 2010).

Among physics students, the extent of their integration into the social environment of their study program is represented by two distinct senses of belonging (Feser, 2021; Kuchynka et al., 2019): belonging to their university and belonging to physics. Current studies indicate that students' success and academic dropout from physics programs are noticeably influenced by these two senses of belonging (see below). For example, as Strayhorn (2016) put it, “students who feel as if they belong [...] excel in higher education. Those who feel as if they do not belong [...] tend to perform poorly, transfer, drop out, or withdraw

Contribution to the literature

- First-year physics students' senses of belonging to physics and to their university are distinct constructs, although both senses of belonging are considerably correlated.
- Participants' satisfaction with their study program and their intention to drop out or change their study program correlate to different degrees, and (semi-)partially, with their senses of belonging to physics and to their university. Participants' physics-specific characteristics (e.g., their interest in physics or their physics-related self-concept) correlate (semi-)partially with their sense of belonging to physics but not their sense of belonging to their university.
- Within the German higher education system, first-year physics students' senses of belonging to physics and their university are impacted by different student characteristics (e.g., gender or migration background).

altogether" (p. 50). In the following sections, we elaborate upon this idea.

THEORETICAL BACKGROUND

Sense of Belonging to One's University and to Physics

At a general level, the term "sense of belonging" addresses individuals' drive for social behavior and meaningful interaction that is rooted in the fundamental, innate, and universal human need to be socially integrated—their need to belong (Allen et al., 2021; Baumeister & Leary, 1995; Hartung & Renner, 2014). Individuals' sense of belonging manifests in their emotional well-being and drive to participate in social contexts as well as their feelings of connectedness with others, their feelings of being relevant to others, and their trust in others (Cooper, 2009; Good et al., 2012; Strayhorn, 2019). Within this framework, individuals are not seen as isolated and self-sufficient entities, but as social beings involved in social interactions and relationships.

Given its rootedness in the fundamental human need to belong, it is reasonable to conceptualize students' sense of belonging and its possible correlates with academic outcomes at a general level (Slaten et al., 2016). However, since social embeddedness is specific to different contexts in one's life, Nunn (2021) points out that one's sense of belonging at a general level "does not automatically equate to feeling like one belongs [...] at the university" (p. 25). Moreover, with respect to physics students, it is possible to focus on university-related contexts (e.g., campus clubs or sports programs) and/or physics-specific contexts that are not necessarily related to their university studies (e.g., working for a planetarium or as a physics tutor for high school students).

Consequently, it is meaningful to distinguish between two different senses of belonging among physics students. As Lewis et al. (2016) state, "[university] belonging predicts general academic success, [whereas] domain-specific belonging predicts domain-specific outcomes" (p. 3). Physics students' sense of belonging to their university may be defined as

their "feeling or sensation of connectedness, and the experience of mattering or feeling cared about, accepted, respected, valued by, and important to the campus community or others on campus" (Strayhorn, 2019, p. 4). In contrast, students' sense of belonging to physics can be defined as their feelings of connectedness, acceptance, recognition, emotional well-being, and interpersonal trust within the physics domain (Feser, 2021; Kuchynka et al., 2019; Lewis et al., 2016). As indicated above, for physics students, social experiences related to physics are often, but not necessarily, intertwined with university-related contexts, like lectures. Therefore, it is plausible to presume that, although physics students' senses of belonging to their university and to physics are distinct constructs, both senses of belonging are considerably interrelated at an empirical level (Feser, 2021).

Current State of Research at a Glimpse

At a general level, previous research has shown that sense of belonging is associated with numerous cognitive and affective-motivational constructs that are crucial for academic success and persistence, such as physical and mental well-being, stress level, and memory skills (Hausmann, 2007; Nunn, 2021; Slaten et al., 2016). Particularly for student teachers, development of a salient sense of belonging during university-based teacher education seems essential to their professionalization (for details, see Feser & Michalik, 2023b; Feser & Plotz, 2023; Pendergast et al., 2020; Wolf et al., 2021). Within higher education classrooms, students' sense of belonging relates to their academic self-efficacy, intrinsic motivation, and task value (Freeman et al., 2007) as well as to their self-reported academic engagement (Wilson et al., 2015) and academic achievement (Zumbrunn et al., 2014).

There is evidence that students' sense of belonging to their university predicts their academic self-concept (Curtin et al., 2013) as well as their academic grades and competencies (Pittman & Richmond, 2007). Furthermore, this sense of belonging is positively correlated with students' satisfaction (Fischer, 2007) and

engagement within their study program (Gillen-O'Neel, 2021).

Several studies indicate that students' senses of belonging to their university and to their specific domain are correlated with each other at a moderate to high level (Feser, 2020; Findley-Van Nostrand & Pollenz, 2017; Hansen et al., 2023). Moreover, an increasing number of studies have investigated domain-specific challenges in higher education (e.g., the comparatively high academic dropout rates or gender imbalance in STEM fields) in relation to sense of belonging (e.g., Chen et al.; 2021, Lahdenperä & Nieminen, 2020; Lewis et al., 2016; Trujillo & Tanner, 2014; Ulriksen et al., 2015). Good et al. (2012) and Hansen et al. (2023) report that students' domain-specific sense of belonging is positively correlated with their intention to remain in their STEM study program. For example, mathematics students' domain-specific sense of belonging predicts their "intention to pursue math, as well as math-related variables, such as math anxiety, math confidence, and perceived usefulness of math" (Good et al., 2012, p. 712). Similarly, Findley-Van Nostrand and Pollenz (2017) report a negative correlation between university students' belonging to STEM and intention to leave their STEM academic program as well as a positive correlation between self-efficacy in STEM and positive expectations regarding a STEM career. A domain-specific sense of belonging seems to be pivotal for explaining the representation gap between men and women – or, more broadly, the limited representation of marginalized groups (underrepresented student groups) – in STEM (Good et al., 2012; Lewis, 2016; Rainey et al., 2018). Previous research suggests that, within STEM fields, a lack of sense of belonging is more consequential for women than for men (Lewis et al., 2017) and therefore contributes to the underrepresentation of women in these fields.

A considerable amount of research addresses the factors that influence students' sense of belonging and how a sense of belonging can be promoted. Within their literature review, Lewis et al. (2016) identified, among other things, students' number of peers and role models within their study program and stereotypical images of professionals in their field of study (e.g., the stereotype of physicists as white, nerdy men) as important influences on students' sense of belonging. Based on the results of Freeman et al. (2007), students' sense of belonging seems to be informed by the degree to which they perceive their lecturers as warm, open, and encouraging of participation. Students' sense of belonging can also be promoted by providing belonging-specific interventions (e.g., Hansen et al., 2023; Shnabel, 2013; Strayhorn, 2021; Walton & Cohen, 2011), by

fostering an inclusive and respectful campus culture (Locks et al., 2008), via peer mentoring programs (Zaniewski, & Reinholz, 2016), and by offering extracurricular activities that promote social integration on campus (e.g., university sports programs; Strayhorn, 2019).

Aim of the Study

Although interest in students' belonging to their university and to their domain has grown within STEM education research, several desiderata remain largely unaddressed to date (Feser, 2021).

Previous studies on students' sense of belonging in higher education mostly refer to STEM fields in general. Individual STEM disciplines, such as physics, are less frequently studied. Moreover, studies rarely distinguish between students pursuing different study programs¹, such as physics and physics teacher studies. To the best of our knowledge, there are no studies in which physics students' senses of belonging to their university and to physics are simultaneously surveyed and systematically related to each other.

In addition, previous studies have been predominantly conducted in Anglo-American contexts, especially in the United States of America. Studies on students' senses of belonging to their university and to their domain conducted in other regions around the globe, especially from European countries, are scarce. Thus, the transferability of the results of prior studies to higher education systems that substantially differ from the Anglo-American one has not been clarified. This is particularly true for the German higher education system and for the finding that, within STEM fields, students' senses of belonging to their university and to their domain tend to be lower among underrepresented student groups (Good et al., 2012; Lewis, 2016; Rainey et al., 2018), which consequently leads to a reduced chance of success in their studies and/or an increased risk of dropping out.

The aim of the present study is to explore physics students' senses of belonging to physics and to their university given different backgrounds and prerequisites for introductory courses at German universities. Furthermore, we aim to reveal whether, and to what extent, these two senses of belonging relate to other characteristics that curtail students' academic success and the rate of academic dropout from physics programs. Given that previous research indicates a substantial correlation between students' senses of belonging to their university and to their domain, we controlled for this correlation within the present study. As a result, we could rule out potential spurious

¹ In Germany, before students start their university studies, they decide whether to enroll in a general physics degree program or a teacher training program with a specialization in physics. In this paper, these two study programs are referred to as "physics" and "physics teacher studies," respectively.

associations and provide a clear picture of the unique relationships between students' senses of belonging to physics and to their university as well as students' characteristics.

We address the following three research questions² in the context of the German higher education system:

RQ1. Do first-year physics students' senses of belonging to physics and to their university correlate with each other, and if so, to what extent?

RQ2 a (b). If we control for the effect of first-year physics students' sense of belonging to their university (physics), to what extent does these students' sense of belonging to physics (their university) correlate with ...

... their interest in physics?

... their physics-related self-concept?

... their satisfaction with their study program?

... their intention to drop out or change their studies?

... the extent to which they perceive the physics courses in their study programs to be of high quality?

... how well they cope with distance learning due to the COVID-19 pandemic?

RQ3 a (b). If we control for the effect of first-year physics students' sense of belonging to their university (physics), do these students differ in their sense of belonging to physics (their university), depending on ...

... their study program (physics vs. physics teacher studies)?

... their gender?

... whether they are students with or without a migration background?

... whether they are first-generation students?

... whether their study program implemented distance learning due to the COVID-19 pandemic?

Below, we describe the context and design of our study. Subsequently, we report and discuss the results we obtained from our data analysis.

Context of the Study

Several characteristics of the German higher education system need to be considered when conducting research on physics students in this context (for more details on the German higher education system, see Hühner & Krücken, 2018; Ness & Lin, 2013). The number of private universities in Germany is insignificant. Students usually do not pay tuition fees for their first degree, and they are entitled to financial support from the state if they have low socio-economic status. For most study programs, if admission is regulated, it is based on applicants' average high school

graduation grade. Most universities are research universities with an option to continue up to a PhD. In addition, the vast majority of universities allow anyone with a high school degree to study physics. In contrast to other higher education systems around the globe, in Germany, students usually do not live on campus. There are far fewer clubs and sports activities that promote social integration on campus compared to, for example, Anglo-American universities.

METHODS

Data Collection

To collect data, a voluntary, anonymous student survey was administered at 20 universities in Germany—which also voluntarily participated in the present study—that offer a bachelor's degree program in physics and/or physics teacher studies. Ethical approval for the study was obtained from the ethics committee of the first author's institution. Physics students who started their bachelor's degree program in October 2021 were invited to participate via email, their physics lecturers, and/or promotional materials distributed by their university (e.g., flyers, online video clips about the study). To increase the participation rate, 30 bookstore vouchers were raffled off to the participants.

Data collection was carried out between April and June 2022 in accordance with the legal and ethical standards for educational research in Germany (Watteler & Ebel, 2019). In total, $n=238$ first-year physics students participated, which represents approximately 3% of all students in Germany who started their degree program in physics and/or physics teacher studies in October 2021 (minus those who matriculated for these degree programs without attending them; Düchs & Mecke, 2022). The main descriptive statistics of our sample are detailed in **Table 1**. In line with German legal and ethical standards for educational research, universities and students voluntarily participated in the present study (see above). Consequently, our surveyed sample is to be classified as a convenience sample.

Measures

The survey involved an online questionnaire, which took participants about 20 minutes to complete. The questionnaire was based on established items and scales, whose reliability and validity have been carefully examined and verified in previous studies and which were adapted to the context of the present study. The questionnaire was piloted at two German universities in 2021 with a total of $n=69$ first-year physics students in order to (re-)ascertain the reliability and validity of our

² Since our data collection was conducted during the COVID-19 pandemic and research indicates that physics students' academic success was heavily influenced by the COVID-19 pandemic (e.g., Ivanjek et al., 2022), we expanded **RQ2** and **RQ3** with corresponding sub-questions.

Table 1. Descriptive statistics of surveyed sample (n=238)

Variable & category	n	%
Study program		
Physics	175	73.5
Physics teacher studies	63	26.5
Gender identification		
Male	142	59.7
Female	90	37.8
Diverse or no gender	6	2.5
Migration background		
No	179	75.2
Yes	59	24.8
First-generation status		
No	131	55.0
Yes	107	45.0
Distance-based study program		
No	41	17.2
Yes	197	82.8

Note. n: Number of participants; Migration background: Participant, or one parent of participant was not born in Germany; First-generation status: No parent of participant has a higher education degree; & Distance-based study program: Participants whose study program at least partly included distance learning due to the COVID-19 pandemic

adapted items and scales (for more details, see Feser et al., 2022).

To measure first-year physics students' senses of belonging to physics and to their university, the questionnaire contained adapted versions of the scales developed by Feser (2020) and Baumert et al. (2009). In line with RQ2, the questionnaire included scales to measure participants' interest in physics (Frey et al., 2009), physics-related self-concept (Elsholz, 2019), satisfaction with their study program (Westermann et al. 2018), intention to drop out or change their study program (Apenburg, 1980; Klingsieck & Marker, 2019; Westermann et al., 1996), perception of the quality of physics courses in their study program (Trapmann, 2008), and ability to cope with distance learning implemented due to the COVID-19 pandemic (Feser & Michalik, 2023a).

Table 2 summarizes the psychometric properties of the scales. Within the present study, these scales were found to be viable for the present study, showing good to excellent internal consistency (reliability) within the sample ($.79 \leq \alpha \leq .91$) and a moderate to high selectivity coefficient for items ($.47 \leq r_{it} \leq .82$). Skewness and excess kurtosis lie within an acceptable range, allowing us to assume that their distributions do not markedly differ from a normal distribution ($|\text{skewness}| < 2$; $|\text{excess kurtosis}| < 3$; see Westfall & Henning, 2013). More information on these scales and the online questionnaire can be found in the technical report of the present study (see Feser et al., 2023).

Data Analysis

Quantitative data analysis was conducted using IBM SPSS Statistics version 29.0.0.0. Given that the size of our surveyed sample (n=238) of course restricted the possibilities for analyzing of our collected data, as does the fact that it is a convenience sample, we deliberately limited our data analysis to statistical methods whose prerequisites are fulfilled by our data.

To address **RQ1**, we determined the bivariate correlation between participants' senses of belonging to physics and to their university (Pearson's r). Before doing so, we used a scatterplot to check the relationship between both senses of belonging for linearity, and we used Q-Q plots to check whether they are both normally distributed (Bauer, 1984).

To control for the effect of first-year physics students' sense of belonging to their university and to physics while addressing **RQ2a** and **RQ2b**, we conducted partial and semi-partial correlation analyses. In a partial correlation analysis, the relationship of a third variable with two other variables is controlled (Field, 2009). In contrast, in a semi-partial correlation analysis, the relationship of a third variable is controlled for only one of the two other variables. Therefore, while both types of analysis examine the relationship between two variables while controlling for the effects of a third variable, they produce different results. While a partial correlation describes the relationship between the variation of two variables while taking a third variable into account, a semi-partial correlation describes the unique contribution of one variable (which is controlled for by a third variable) to the total variation of another variable (Cohen et al., 2003).

To address **RQ2a**, we calculated the partial and semi-partial correlations between participants' sense of belonging to physics and their interest in physics, physics-related self-concept, satisfaction with their study program, intention to drop out or change their study program, perception of the quality of the physics courses in their study programs, and ability to cope with distance learning implemented due to the COVID-19 pandemic. Participants' sense of belonging to their university was controlled within these partial and semi-partial correlation analyses. To address **RQ2b**, we determined the partial and semi-partial correlations between participants' sense of belonging to their university and the characteristics listed above. In these analyses, participants' sense of belonging to physics was controlled. To determine whether the prerequisites for partial and semi-partial correlation analyses were met, we examined the relationship between each pair of variables for linearity and determined whether each variable was normally distributed by using scatter plots and Q-Q plots (Bauer, 1984; Leonhart, 2022).

Table 2. Scales used within online questionnaire: Characteristics & psychometric properties

Construct	Origin	N _{item}	Response format	Exemplary item (approximate translation)	M (SD)	S	K	α	r _{it}
Sense of belonging to physics	Feser (2020)	21	Likert scale (range: 1 to 5)	I feel that I belong to the physics community.	3.70 (.66)	-.44	.22	.85	.52 to .77
Sense of belonging to one's university	Baumert et al. (2009)	6	Likert scale (range: 1 to 4)	My university is a place, where I feel that I belong.	3.09 (.64)	-1.02	.90	.88	.57 to .77
Interest in physics	Fey et al. (2019)	5	Likert scale (range: 1 to 4)	I am interested in learning something new in physics.	3.51 (.52)	-1.14	1.23	.89	.71 to .81
Physics-related self-concept	Elsholz (2019)	5	Bipolar scale (range: 1 to 7)	Solving problems within my physics study program is easy/difficult for me.	4.33 (1.00)	-.48	-.19	.90	.70 to .82
Satisfaction with the study program	Westermann et al. (2018)	3	Likert scale (range: 1 to 5)	All in all, I am satisfied with my physics study program.	3.97 (.85)	-.73	-.06	.84	.66 to .77
Intention to drop out or change studies	Apenburg (1980); Klingsieck and Marker (2019); & Westermann et al. (1996)	4	Likert scale (range: 1 to 4)	I am considering dropping out of my physics study program.	1.60 (.76)	1.52	1.70	.91	.77 to .81
Perceived quality of physics courses	Trapmann (2008)	6	Likert scale (range: 1 to 5)	The content structure of lectures in my physics study program is comprehensible.	3.94 (.60)	-.36	-.04	.79	.47 to .61
Ability to cope with distance learning	Feser and Michalik (2023a)	5	Bipolar scale (range: 1 to 7)	During COVID-19 pandemic, I find it very easy/very hard to learn content within distance-based lectures of my physics study program.	3.75 (1.28)	-.05	-.42	.84	.54 to .77

Note. N_{item}: Number of items; M: Arithmetic mean; SD: Standard deviation; S: Skewness; K: Excess kurtosis; α : Cronbach's alpha; & r_{it}: Range of items' selectivity coefficient

Table 3. Results of partial & semi-partial correlation analyses

Construct	Sense of belonging to physics			Sense of belonging to one's university		
	r	r _p	r _{sp}	r	r _p	r _{sp}
Interest in physics	.482***	.407***	.390***	.288***	-.055	-.049
Physics-related self-concept	.484***	.398***	.380***	.302***	-.036	-.031
Satisfaction with study program	.627***	.398***	.326***	.574***	.265***	.206*
Intention to drop out or change studies	-.541***	-.354***	-.314***	-.458***	-.152*	-.128*
Perceived quality of physics courses	.442***	.298***	.279***	.351***	.081	.073
Ability to cope with distance learning	.406***	.320***	.309***	.264***	-.013	-.012

Note. r: Bivariate correlation (Pearson's r); r_p: Partial correlation; r_{sp}: Semi-partial correlation; *p<.050; & *** p<.001

Finally, to address **RQ3**, we conducted a total of 4×2=8 one-way analyses of covariance in which participants' sense of belonging to physics was the dependent variable and participants' sense of belonging to their university was the covariate (**RQ3a**) or vice versa (**RQ3b**). Participants' study program, gender, migration background, first-generation status, and distance learning status were utilized as the independent categorical variables within these analyses. To evaluate the effect size of significant group differences, we calculated the partial η^2 coefficient and Cohen's d based on the adjusted means and standard deviations. To verify that our data met the prerequisites for a one-way analysis of covariance, we followed the approach of Plichta and Kelvin (2012) and checked for normal distribution of the dependent variable, a linear relationship with the covariate, equivalence of variances of groups, and homogeneity of regression slopes.

RESULTS

Correlation Analyses

In line with the results of previous studies, our data analysis revealed that first-year physics students' senses of belonging to physics and to their university are significantly correlated with each other at a high level ($r=.672$; $p\leq.001$) (**RQ1**). Therefore, we conducted partial and semi-partial correlation analyses to identify spurious correlations and examine the unique relationships between participants' senses of belonging to physics and to their university with the constructs listed in **RQ2a** and **RQ2b**. The results of these analyses are summarized in **Table 3**.

Participants' senses of belonging to physics and to their university (semi-)partially correlate with their intentions to drop out or change their study program

Table 4. Results of one-way analyses of covariance in which participants' sense of belonging to physics was dependent variable & their sense of belonging to their university was covariate

Variable & category	M	SD	M _{ad}	SD _{ad}	F	p	η ²
Study program							
Physics	3.73	.66	3.75	.49	3.99	.047	.017
Physics teacher studies	3.65	.65	3.61	.48			
Gender identification							
Male	3.73	.65	3.75	.48	5.03	.007	.043
Female	3.72	.63	3.69	.48			
Diverse or no gender	2.87	.82	3.07	.48			
Migration background							
No	3.72	.59	3.68	.48	2.23	.137	.010
Yes	3.67	.82	3.79	.49			
First-generation status							
No	3.80	.62	3.74	.49	1.12	.291	.005
Yes	3.62	.68	3.67	.48			
Distance-based study program							
No	3.67	.74	3.60	.49	2.63	.107	.012
Yes	3.72	.64	3.73	.48			

Note. M: Arithmetic mean; SD: Standard deviation; M_{ad}: Adjusted mean; SD_{ad}: Adjusted standard deviation; F: F value; p: p-value; η²: Partial η²; Migration background: Participant or one parent of participant was not born in Germany; First-generation status: No parent of participant has a higher education degree; & Distance-based study program: Participants whose study program at least partly included distance learning due to COVID-19 pandemic

($-.354 \leq r_p \leq -.152$; $-.314 \leq r_{sp} \leq -.128$). Moreover, the (semi-)partial correlation with participants' sense of belonging to physics is more than twice as high as the (semi-)partial correlation with their sense of belonging to their university. We found the same pattern for participants' satisfaction with their study program ($.265 \leq r_p \leq .398$; $.206 \leq r_{sp} \leq .326$). In this case, however, the (semi-)partial correlation with participants' sense of belonging to physics is about 1.5 times higher than the (semi-)partial correlation with their sense of belonging to their university.

Participants' interest in physics and physics-related self-concept correlate (semi-)partially with their sense of belonging to physics ($.398 \leq r_p \leq .407$; $.380 \leq r_{sp} \leq .390$), but not with their sense of belonging to their university ($-.055 \leq r_p \leq -.036$; $-.049 \leq r_{sp} \leq -.031$). Likewise, regarding the extent to which participants perceive the physics courses in their study programs to be of high quality and how well participants cope with distance learning implemented due to the COVID-19 pandemic, we found significant (semi-)partial correlations with participants' sense of belonging to physics ($.298 \leq r_p \leq .320$; $.279 \leq r_{sp} \leq .309$), but no (semi-)partial correlations with their sense of belonging to their university ($-.013 \leq r_p \leq .081$; $-.012 \leq r_{sp} \leq .073$). Based on these findings, it is reasonable to assume that the significant bivariate correlations between participants' sense of belonging to their university and their interest in physics, physics-related self-concept, perception of the quality of the physics courses in their study program, and ability to cope with distance learning implemented due to the COVID-19 pandemic (see **Table 3**) are spurious

correlations resulting from the strong correlation between participants' senses of belonging to physics and to their university.

Covariance Analyses

Table 4 and **Table 5** summarize the results of the covariance analyses conducted to address **RQ3a** and **RQ3b**.

We found a significant difference between physics students and student physics teachers after controlling for the effect of first-year physics students' sense of belonging to their university ($F[1, 227]=3.99$; $p=.047$; partial $\eta^2=.017$). Physics students' mean sense of belonging to physics was significantly higher than that of student physics teachers ($p=.047$, $\Delta M_{ad}=.14$; $d_{ad}=.29^3$).

Participants' sense of belonging to physics significantly differed based on gender ($F[2, 227]=5.03$; $p=.007$; partial $\eta^2=.043$). Post-hoc tests revealed a strong and significant difference between participants who identify as having diverse or no gender and participants who identify as male ($p=.002$, $\Delta M_{ad}=-.68$; $d_{ad}=-1.42$) and a strong and significant difference between participants who identify as having diverse or no gender and participants who identify as female ($p=.005$, $\Delta M_{ad}=-.62$, $d_{ad}=-1.29$). However, there was no significant difference between participants who identify as male and female ($p=.369$, $\Delta M_{ad}=-.06$; $d_{ad}=-.13$).

We found no statistically significant difference in sense of belonging to physics between students with and without a migration background ($F[1, 227]=2.23$; $p=.137$; partial $\eta^2=.010$). The same result emerged for students

³ d_{ad} represents Cohen's d based on the adjusted means and standard deviations (listed in **Table 4** & **Table 5**).

Table 5. Results of one-way analyses of covariance in which participants' sense of belonging to their university was dependent variable & their sense of belonging to physics was covariate

Variable & category	M	SD	M _{ad}	SD _{ad}	F	p	η ²
Study program							
Physics	3.06	.67	3.05	.48	3.91	.049	.017
Physics teacher studies	3.15	.57	3.19	.47			
Gender identification							
Male	3.07	.67	3.04	.48	1.56	.212	.014
Female	3.14	.59	3.13	.48			
Diverse or no gender	2.80	.66	3.36	.48			
Migration background							
No	3.15	.61	3.14	.47	7.73	.006	.033
Yes	2.91	.71	2.94	.47			
First-generation status							
No	3.15	.59	3.10	.48	.35	.553	.002
Yes	3.00	.69	3.07	.47			
Distance-based study program							
No	3.20	.65	3.22	.47	4.02	.046	.018
Yes	3.06	.64	3.06	.48			

Note. M: Arithmetic mean; SD: Standard deviation; M_{ad}: Adjusted mean; SD_{ad}: Adjusted standard deviation; F: F value; p: p-value; η²: Partial η²; Migration background: Participant or one parent of participant was not born in Germany; First-generation status: No parent of participant has a higher education degree; & Distance-based study program: Participants whose study program at least partly included distance learning due to COVID-19 pandemic

with and without first-generation status ($F[1, 227]=1.12$; $p=.291$; partial $\eta^2=.005$) and for participants whose study program was or was not distance-based due to the COVID-19 pandemic ($F[1, 227]=2.63$; $p=.107$; partial $\eta^2=.012$).

After we controlled the effect of first-year physics students' sense of belonging to physics, we also found a significant difference between physics students' and student physics teachers' sense of belonging to their university ($F[1, 227]=3.91$; $p=.049$; partial $\eta^2=.017$). However, in contrast to the findings above, physics students' mean sense of belonging to their university was lower than that of student physics teachers ($p=.049$, $\Delta M_{ad}=-.14$, $d_{ad}=-.29$). Sense of belonging to one's university also differed significantly between students with and without a migration background ($F[1, 227]=7.73$; $p=.006$; partial $\eta^2=.033$). The mean sense of belonging to one's university among participants with a migration background was significantly lower than that among participants without a migration background ($p=.006$, $\Delta M_{ad}=-.20$, $d_{ad}=-.43$). Moreover, we found that sense of belonging to one's university significantly differed between participants whose study programs were and were not distance-based due to the COVID-19 pandemic ($F[1, 227]=4.02$; $p=.046$; partial $\eta^2=.018$). In line with our expectations, the mean sense of belonging to one's university among participants in a distance-based study program was significantly lower than that among participants in a non-distance-based study program ($p=.046$, $\Delta M_{ad}=-.13$, $d_{ad}=-.27$). Similar to the findings above, we found no statistically significant difference between students with and without first-generation status in terms of their sense of belonging to their university ($F[1, 227]=.35$; $p=.55$; partial $\eta^2=.002$).

Furthermore, sense of belonging to one's university did not significantly differ between participants of different genders ($F[2, 227]=1.56$; $p=.212$; partial $\eta^2=.014$).

DISCUSSION AND CONCLUSIONS

Within the present study, we explored the magnitude of first-year physics students' senses of belonging to physics and to their university given different backgrounds and prerequisites. Moreover, we investigated whether, and to what extent, these two senses of belonging relate to other characteristics that impact students' academic success and the academic dropout rate of physics programs. The results provide important insights into the role of physics students' senses of belonging to physics and to their university as they navigate the introductory phase of their study program.

Some limitations of the present study have to be considered. First, since the present study was conducted in the German higher education system, its new findings, analogous to those from previous studies conducted in the Anglo-American region, cannot (yet) be transferred to other higher education systems. To do so, future research is needed that systematically compares higher education systems across different countries. However, the findings of the present study, which correspond with those from previous studies that were not conducted in Germany (see below), strongly indicate that they may be generalizable. Second, the present study is based on a convenience sample of 238 first-year physics students who voluntarily participated. As physics students with a low sense of belonging to physics and/or their university may be less inclined to participate in a voluntary survey addressing senses of

belonging, such students might be underrepresented within the sample. Third, only students who had been studying physics or physics teacher studies for about half a year were surveyed in the present study. Therefore, the results do not allow for conclusions about advanced physics students or physics students at the very beginning of their undergraduate studies. Fourth, since data collection was conducted during the COVID-19 pandemic and our data analysis revealed that the pandemic influenced physics students' sense of belonging to physics and/or their university (see Results), it is conceivable that our research questions may yield further results if our study is replicated with first-year physics students whose studies are not affected by a pandemic. More generally, the transferability of the findings of the present study within post-pandemic contexts should be addressed in future research. Fifth, given the exploratory design of the present study, we deliberately chose to not adjust the global α -level within our data analysis. Consequently, when the term "significance" is used in the aforementioned sections, it only refers to the occurrence of a non-adjusted but conspicuously small p-value (Victor et al., 2010).

With these just mentioned limitations in mind, the results of the present study both align with the results of previous research and extend current research by providing starting points for future studies. In the following sections, we outline this in depth by summarizing the results of the present study, relating them to the current state of research and the limitations of our study, and derive implications for future physics education research based on these syntheses. To ensure reader-friendliness we ordered the following sections in accordance with the ordering of our research questions **RQ1** to **RQ3**. Consequently, this way of ordering should not be interpreted as a ranking or hierarchy of different results and implications as more or less important.

Correlation Between Both Senses of Belonging

RQ1 can be answered positively. Our data analysis revealed a positive, strong correlation between first-year physics students' senses of belonging to physics and to their university ($r=.672$). This result is consistent with the results of previous studies (Feser, 2020; Findley-Van Nostrand & Pollenz, 2017; Hansen et al., 2023). It is also consistent with the theoretical expectation that both constructs are closely related but empirically distinct, thus contributing to the replication of previous research findings. It is plausible to presume that this result may be transferable to students in STEM disciplines other than physics (e.g., biology, chemistry, or mathematics). However, this presumption requires empirical verification in future research.

(Semi-)Partial Correlations with Other Students' Characteristics

While controlling for sense of belonging to one's university, we consistently found significant, medium-sized (semi-)partial correlations between participants' sense of belonging to physics and other characteristics that impact academic success and academic dropout (**RQ2a**). In contrast, while controlling for sense of belonging to physics, we found (semi-)partial correlations only between participants' sense of belonging to their university and their intention to drop out or change their study program and between participants' sense of belonging to their university and their satisfaction with their study program (**RQ2b**). Again, these results are consistent with existing theory since physics-specific constructs (i.e., students' interest in physics and physics-related self-concept) are only correlated with students' sense of belonging to physics (i.e., the belonging construct that involves domain specificity).

The substantial correlations between students' sense of belonging to physics and their interest in physics and physics-related self-concept ($.482 \leq r \leq .484$; $.398 \leq r_p \leq .407$; $.380 \leq r_{sp} \leq .390$) raises the suspicion that these constructs could be traced back to a superordinate construct. To this end, it might be fruitful to conceptualize students' sense of belonging to physics, interest in physics, and physics-related self-concept as proxies of their professional identity as physicists or respectively as physics teachers (Feser & Haak, 2023; Hazari et al., 2010). In other words, the question arises: Can students' sense of belonging to physics, their interest in physics, and their physics-related self-concept be jointly conceptualized as features of their professional identity? Empirical approaches to address this question can already be found in recent physics education research, especially research with a quantitative methodology (e.g., Hazari et al., 2020; Kalender et al., 2019; Kuchynka et al., 2019; Nieswandt et al., 2013). However, since these approaches are mostly exploratory in nature, further research should address this concept both theoretically and empirically (i.e., qualitatively as well as quantitatively).

Within the present study, participants' satisfaction with their study program and intention to drop out or change their study program show a notably stronger (semi-)partial correlation with their sense of belonging to physics compared to their sense of belonging to their university. Additionally, participants' perceptions of the quality of their physics courses and their ability to cope with distance learning implemented due to the COVID-19 pandemic are only (semi-)partially correlated with their sense of belonging to physics. These correlative findings align with the results of previous research indicating that students' senses of belonging to physics and to their university are considerably associated with other constructs that are crucial for academic success and persistence. However, the correlative findings of the

present study do not allow us to make conclusions regarding the direction of effects. For example, it is reasonable to assume that students' sense of belonging to physics will increase if they perceive their physics courses to be of high quality, or vice versa, that students' sense of belonging to physics leads them to perceive their physics courses to be of higher quality. Similar considerations apply to the other characteristics mentioned previously. Based on the findings of the present study, further research should examine the direction of effects for students' senses of belonging to physics and to their university.

Intergroup Differences

The present study provides strong evidence that students' senses of belonging to physics and to their university may differ for certain student groups (RQ3), without yet being able to uncover cause-and-effect relationships. Thus, the results of the present study provide a basis to further elucidate these group differences in future research:

With respect to students' study program, our data analysis revealed a significantly higher sense of belonging to physics among physics students compared to student physics teachers ($d_{ad}=.29$). A somewhat different picture emerged for students' sense of belonging to their university. Within our surveyed sample, physics students showed a significantly lower sense of belonging to their university compared to student physics teachers ($d_{ad}=-.29$). This result is probably caused by the fact that, in Germany, physics students' study program comprises considerably more physics courses compared to the study program of student physics teachers. Consequently, physics students typically engage with a greater number of people in the physics community (especially lecturers), spend more time with other physics students, and share more formal and informal encounters with each other (e.g., within learning groups). As a result, physics students have more social interactions within the physics community, which, presumably, results in stronger social identification with this community. This, in turn, manifests in a stronger sense of belonging to physics among physics students compared to student physics teachers. In contrast, student physics teachers in Germany usually take courses in several departments, including the physics department, the department of the second subject they study, and the educational research department. Therefore, it seems plausible that student physics teachers develop a stronger sense of belonging to the overall institution, i.e., their university, than physics students.

Students with a migration background showed a significantly lower sense of belonging to their university compared to students without a migration background ($d_{ad}=-.43$). A plausible explanation for this result could

be the existence of specific barriers in the German higher education system for students with a migration background (e.g., cultural or social factors that differ from the majority population). Such barriers could cause these students to struggle with social integration on campus and thus develop a distinct sense of belonging to their university (see Janke et al., 2023; Wolf et al., 2021). Similarly, students in a distance-based study program showed a significantly lower sense of belonging to their university compared to students whose study program was not distance-based ($d_{ad}=-.27$). This result suggests that a lack of physical interaction and face-to-face support may substantially affect students' sense of belonging to their university. Both of these findings emphasize the need to create inclusive environments that foster a sense of belonging to one's university among diverse student populations, including those with migration backgrounds and those enrolled in distance-based study programs. Addressing the lower sense of belonging among students with a migration background and those in distance-based study programs may contribute to a more equitable and supportive higher educational system in Germany that benefits all students. Consequently, future research should explore the specific factors that contribute to a lower sense of belonging to one's university among these student groups within the German higher education system in order to inform targeted interventions and support strategies (for an overview of ways to increase students' sense of belonging that have been successfully demonstrated in previous research, see Theoretical Background).

Regarding students' gender identification, our data analysis revealed a significantly lower sense of belonging to physics among students who identify as having diverse or no gender ($-1.42 \leq d_{ad} \leq -1.29$) compared to male and female students. Given the masculine, heteronormative connotation carried by the culture of physics (Danielsson, 2009; 2013; Götschel, 2017), and given that many LGBTQ+ physicists—especially gender-nonconforming physicists—experience exclusionary behavior within their departments (Atherton et al., 2016; Bilimoria & Stewart, 2009), our finding is not surprising. However, since a very small number of students identifying as having diverse or no gender participated in our study ($n=6$), further research (e.g., individual case studies) is needed to verify this finding and uncover its potential origins.

Finally, within our sample, there were no additional differences between students of different genders—especially between male and female physics students—regarding their senses of belonging to physics or to their university. We also observed no significant differences for students with and without first-generation status. The finding that there are no significant differences between male and female students in terms of their sense of belonging to their university aligns with the results of

previous research (e.g., Pákozdy et al., 2023). However, previous research conducted in Anglo-American contexts indicates that, within STEM fields, women (e.g., Rainey et al., 2018) and first-generation students (e.g., Blaney & Stout, 2017) tend to show a comparatively lower domain-specific sense of belonging, and first-generation students tend to show a comparatively lower sense of belonging to their university (e.g., Stebleton et al., 2014). On the one hand, these results may indicate that the physics community and higher education system in Germany may be comparatively successful in socially integrating women and first-generation students. On the other hand, differences between women and first-generation students' senses of belonging to physics or their university may have been masked in this study due to additional confounding constructs (e.g., the big five personality traits, which previous research has shown to be associated with students' sense of belonging to their university; Lounsbury et al., 2003). Consequently, future research conducted in the context of the German higher education system should clarify whether students' senses of belonging to physics and to their university differ for certain groups if other potentially confounding constructs are controlled for.

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