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Article abstract

Several qualitative studies suggest that the sense of belonging to the scientific community is critical to the success of the doctoral journey. Although a few tools have been developed to capture some components of the sense of scientific community, no instrument is available to measure this construct in its entirety. The purpose of this study was to develop the Sense of Scientific Community Scale (SSCS) and to examine its psychometric qualities using a sample of 318 doctoral students in Canada. Five indicators of construct validity (exploratory, confirmatory, discriminant, predictive, and concurrent) and three indicators of reliability (internal consistency, test-retest and temporal stability) of the SCSS were examined. In sum, this scale comprises 18 items divided into three factors (perception of belonging, influencing, and benefiting from support) providing good internal consistency indices. The psychometric qualities of the SCSS justify its use in future studies.

Development and validation of a measure of social well-being during doctoral studies: The sense of scientific community scale[1]

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Key words: doctorate, scale development, scale validation, sense of scientific community, social wellbeing

Several qualitative studies suggest that the sense of belonging to the scientific community is critical to the success of the doctoral journey. Although a few tools have been developed to capture some components of the sense of scientific community, no instrument is available to measure this construct in its entirety. The purpose of this study was to develop the Sense of Scientific Community Scale (SSCS) and to examine its psychometric qualities using a sample of 318 doctoral students in Canada. Five indicators of construct validity (exploratory, confirmatory, discriminant, predictive, and concurrent) and three indicators of reliability (internal consistency, test-retest and temporal stability) of the SCSS were examined. In sum, this scale comprises 18 items divided into three factors (perception of belonging, influencing, and benefiting from support) providing good internal consistency indices. The psychometric qualities of the SCSS justify its use in future studies.

Mots clés : bien-être social, développement d'outil, doctorat, sentiment de communauté scientifique, validation d'outil

Plusieurs études qualitatives suggèrent que le sentiment de faire partie de la communauté scientifique est essentiel à la réussite du parcours doctoral. Bien que quelques outils aient été développés pour capter certaines composantes du sentiment de communauté scientifique, il n'existe aucun instrument pour mesurer ce construit dans sa globalité. La présente étude visait donc à développer l'Échelle du sentiment de communauté scientifique (ÉSCS) et à en examiner les qualités psychométriques auprès d'un échantillon de 318 doctorants au Canada. Cinq indicateurs de la validité de construit (exploratoire, confirmatoire, discriminante, prédictive et concourante) et trois indicateurs de fidélité (cohérence interne, test-retest et stabilité temporelle) de l'ÉCSC ont été examinés. En somme, cette échelle comporte 18 items répartis en trois facteurs (perception d'appartenir, d'influencer et de bénéficier de soutien) présentant tous de bons indices de cohérence interne. Les qualités psychométriques de l'ÉSCS justifient son usage dans des études ultérieures.

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Palavras-chave: desenvolvimento de ferramentas, doutoramento, qualidades psicométricas, sentimento de comunidade científica, validação de ferramentas

Vários estudos qualitativos sugerem que o sentimento de pertença à comunidade científica é essencial para o sucesso do percurso de doutoramento. Embora algumas ferramentas tenham sido desenvolvidas para capturar certas componentes do sentimento de comunidade científica, não há nenhum instrumento para medir este construto na sua globalidade. O presente estudo teve assim como objetivo desenvolver a Escala do sentimento de comunidade científica (ESCC) e examinar as qualidades psicométricas de uma amostra de 318 doutorandos no Canadá. Cinco indicadores de validade do construto (exploratória, confi rmatória, discriminante, preditiva e concorrente) e três indicadores de fidelidade (coerência interna, teste-reteste e estabilidade temporal) da ESCC. Em suma, esta escala compreende 18 itens divididos em três fatores (percepção de pertença, de influência e de benefício de apoios) apresentando todos bons índices de coerência interna. As qualidades psicométricas da ESCC justificam o seu uso em estudos ulteriores.

Introduction

Across all disciplines, a doctorate is increasingly regarded as the way to train qualified scientific researchers, since upon completing their training, doctoral graduates generally take on professional roles as scholars, whether in academia, industry or government (Holley, 2009). A growing body of research has been focusing on doctoral students' sense of scientific community, a concept defined as the perception of belonging to the scientific community not only by being part of it, but by benefiting from its support and contributing to it in some way (Stubb, 2012). Doctoral students' sense of scientific community therefore reflects their social wellbeing, i.e., positive functioning that involves a sense of integration, contribution, coherence, actualization and acceptance within a society (Keyes, 2014). The available data, mostly stemming from qualitative studies, suggest that feeling like one is part of the scientific community is an essential part of doctoral studies, in terms of both doctoral students' perseverance in their research and their psychological well-being (Cornér et al., 2017; Pyhältö & Keskinen, 2012). A quantitative study by Sverdlik et al. (2020) found perceived degree of belonging to the scientific community—one of the components of sense of scientific community—to negatively predict symptoms of depression, stress and illness in PhD students. These findings are worrying, given that deteriorating mental health is an important risk factor for the intention to drop out of doctoral studies (González-Betancor & Dorta-González, 2020; Litalien & Guay, 2015), which has a ripple effect on scientific progress and, ultimately, society at large (Gallea et al., 2021).

While these data show that researchers recognize the importance of sense of scientific community, it is striking to note the absence of a direct measure of this construct using an instrument capable of capturing its various components. The aim of the present study is to fill this gap by working toward developing and validating a new instrument for measuring sense of scientific community, specifically tailored to the doctoral context.

Theoretical context

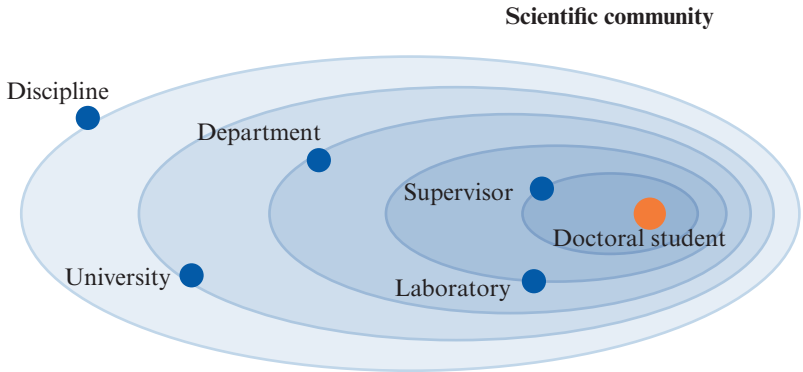
Conceptualizing and measuring scientific community

A community is defined as a group of people with a shared commitment to specific norms and values (Bucchi, 2014). Internally homogeneous groups such as these can form in different contexts, including geographic (Talò et al., 2014), professional (Boyd & Nowell, 2013) and academic (Boyd et al., 2022).

Scientific community

More specifically, in an academic context, the scientific (or scholarly) community is the complex entity made up of everyone who conducts scientific research within a given discipline (McAlpine & Norton, 2006). According to research by Merton (1973) and subsequent texts regarding the evolution of scientific community (Bucchi, 2014), the norms and values of researchers revolve around advancing scientific knowledge and adhering to rigorous practices to obtain a sufficient level of evidence before drawing definitive conclusions about any given research finding.

Figure 1
The scientific community for doctoral students



The scientific community constitutes doctoral students' main environment (Stubb, 2012) and comprises various academic sub-communities such as the dissertation supervisor, the dissertation supervisor's laboratory/research group, the department (including faculty members and students in their doctoral program), the university and the discipline. These relationships are illustrated in Figure 1, which is inspired by White and Nonnamaker (2008, p. 358).

Sense of scientific community

McMillan and Chavis' (1986) research on the concept of sense of community in a neighbourhood-group context is looked upon as a landmark contribution to the understanding of this concept. These researchers defined sense of community as a feeling of belonging to a group. According to their model, sense of community is determined by four components: membership, influence, fulfilment of needs, and emotional connection. Chavis and other collaborators devised a questionnaire to measure this construct, called the Sense of Community Index 2 (Chavis et al., 2008). This index includes 24 items designed to represent the four components using a Likert scale ranging from 1 = not at all to 4 = completely. The work of McMillan and Chavis has been widely cited in the literature and influenced a great deal of later research into the sense of community in various social groups.

Drawing on McMillan and Chavis's (1986) definition of sense of community, it can be inferred that, while scientific community refers to the entity comprising all scientists, the sense of scientific community designates the feeling of identifying with this group. Given the popularity of McMillan and Chavis' work, their four-component theory and the tool derived from it may help guide the development of a tool to measure the sense of scientific community in doctoral students.

Membership

The first element in defining sense of community is membership, i.e., the feeling of being part of the group and identifying with its members (McMillan & Chavis, 1986). To feel a sense of scientific community, doctoral students must feel belongingness, i.e., they must perceive themselves to be an integral part of the scholarly community (White & Nonnamaker, 2008). Thanks to a process of research socialization, they must feel relatedness, in other words, that they adhere to the dominant culture of the scientific community—whether in terms of values, priorities, needs or

goals—proudly and for an extended period of time (Boyd & Nowell, 2013; Holley, 2009). In terms of measurement, perceived membership to the scholarly community was assessed by Sverdlik et al. (2020) using a six-item self-reported scale entitled the "perceived scholarly belongingness" scale; examples of items included "I feel like I am a member of this scholarly community" and "I feel I have strong ties with members of this research community."

Influence

The second defining element of community is influence, i.e., the feeling of being important, of making a difference to the group through personal engagement (McMillan & Chavis, 1986). In the doctoral context, students must believe that they have some influence within the scholarly community thanks to their participation and involvement in various contexts (Vekkaila et al., 2013). In particular, engaging with their scholarly subcommunities (e.g., research groups) helps doctoral students find their unique role within them, and, more broadly, within the scholarly community in general (McAlpine & Amundsen, 2009). In their study with 669 doctoral students, Pyhältö and Keskinen (2012) measured doctoral students' sense of relational involvement in their academic community using the Sense of Relational Agency in Their Scholarly Communities Scale. Although no items are reported, the authors describe the construct as doctoral students' perception of their role as important members of the scholarly community and, more specifically, as active agents who have important ideas and contributions.

Fulfilment of needs

The third element necessary for a sense of community is meeting needs (in terms of integration and fulfillment). According to McMillan and Chavis (1986), sense of community will be enhanced if a person perceives that the members of their community can draw upon their skills to fulfil the person's needs. Along these lines, doctoral students benefit from several types of supervisory activities led by different players in the scholarly community (Cornér et al., 2017) who can fulfil the student's needs for training, safety and recognition (Boyd & Nowell, 2013). Considering that the needs of doctoral students relate more specifically to the support available to them in order to carry out their research and to develop professionally, Overall et al. (2011) developed a scale measuring doctoral students' perception of academic support. This scale has 16 items ($\alpha = 0.94$; 1 = strongly

disagree, 4 = neither agree nor disagree, 7 = strongly agree) that assess the extent to which a supervisor makes themselves available, offers support, gives feedback, offers advice and contributes to the doctoral student's professional success in general. Based on the definition of scholarly community proposed by White and Nonnamaker (2008), however, meeting the needs of doctoral students extends beyond the doctoral supervisor and also includes the influence of the context arising from the research group, the department, the discipline, and so on.

Emotional connection

The final element of sense of community according to McMillan and Chavis (1986) is shared emotional connection, in other words, members' perception that they spend time together in common spaces and develop bonds of friendship and mutual trust (Boyd & Nowell, 2013). This component can apply to a neighbourhood group or to other forms of proximal communities. In the doctoral context, a measure was developed for this concept by Terrell et al. (2009), who set forth a 17-item Doctoral Students' Connectedness Scale to assess doctoral students' perceived level of connection to the student body and faculty of their university department (α = 0.87; 1 = completely disagree to 5 = completely agree). Examples of items include: "I feel connected to other students" and "I feel I can trust the faculty while I am working on my dissertation." Emotional connection can therefore be assessed in a proximal scientific sub-community such as the department. However, it remains to be seen whether emotional connection has its place in the sense of scientific community, which involves an entity that may be too distant for developing meaningful intimate connections (Terrell et al., 2009; Vallières et al., 2022).

Based on the theoretical background outlined above, the objective of this study is to develop and empirically validate the Sense of Scientific Community Scale (SSCS) with a sample of doctoral students.

Methodology

This section sets forth the process of developing the SSCS based on the steps proposed by DeVellis and Thorpe (2021). This will be followed by information on the participants, the data collection procedure and the analyses performed.

Questionnaire development process

Clarification of the construct to be measured, generation of the item pool and selection of a measure format

In keeping with the four-component structure of sense of community, the SSCS items were developed in order to form four subscales. For this purpose, the items of the available scales (reported in the theoretical context) were recorded, translated into French and adapted to the context of the scientific community pertaining to doctoral students. To translate all the items, the double (or back) translation method (Vallerand, 1989) was used by two translators, in English and in French. The first author of this article translated the items from English into French. The second translator, who did not have access to the original scales, then retranslated the items from French into English. The two translations were then compared to identify any discrepancies between the original items and the back-translated items. Where necessary, modifications were made to ensure the semantic and conceptual equivalence of the translated items. In addition, the recommendations of DeVellis and Thorpe (2021) regarding item wording were followed in order to make sure that several items covered the content being measured and that all items were worded using the pronoun "I." As with the scale of Terrell et al. (2009), the SSCS proposes a five-point unipolar Likert scale: 1 = not at all, 2 = little, 3 = somewhat, 4 = very much and 5 = completely. The original instructions for the SSCS were adapted from Chavis et al. (2008) to determine the sense of community specific to the scholarly context: "How well do each of the following statements reflect how you feel about the scientific community?" As Pyhältö and Keskinen (2012) point out, doctoral students may interpret the definition of scientific community in different ways, ranging from the dissertation supervisor to the wider scholarly community. This is why the provided instructions included the following definition:

> In the broadest sense, scientific community refers to all researchers, including trainees (doctoral students), who carry out scholarly research. In what follows, please consider all the scholarly groups to which you belong, e.g., your dissertation supervisory committee, laboratory or research group, program cohort, research associations in your discipline, etc.

Review of the item pool by a panel of experts and administration of cognitive interviews

Consistent with the recommendations of DeVellis and Thorpe (2021), five researchers with expertise in the psychosocial aspect of higher education examined all the items to ensure that they covered the entire construct in terms of the subconcepts targeted in the SSCS (content validity). The SSCS was then piloted with 10 doctoral students from various disciplines and universities ("cognitive interviews" as designated by DeVellis and Thorpe, 2021). As potential study respondents, these participants offered feedback on how they interpreted and understood the items. This enabled us to make final changes to a few items that required clarification.

Inclusion of additional validation indices

DeVellis and Thorpe (2021) suggest including other scales in the survey to examine predictive validity, which is the ability of the new instrument to predict a different construct, and concurrent validity, which is the association between the new instrument and another validated instrument measuring a similar construct. Two scales validated in the Quebec context were therefore added to the survey. To examine the predictive validity of the SCCS, the doctoral psychological health scale (8 items, $\omega = 0.91$; Vincent et al., 2023) was included in the survey, given that it is a measure of anxiety, depression and psychological well-being at the doctoral level. Examples of items include "I feel preoccupied and anxious" (reversed item) and "I feel emotionally balanced." Next, to assess the concurrent validity of the SSCS, the Social Acceptance Scale (5 items, $\alpha = 0.89$; Richer & Vallerand, 1998) was chosen given its substantial popularity for examining sense of belonging to a community. The statement "In my relationships with other researchers, including doctoral students, I feel..." was followed by five terms, namely "supported," "valued," "trusted," "listened to," and "understood."

DeVellis and Thorpe (2021) also suggest examining the stability of participants' answers by looking at the test-retest reliability of the instrument. The same authors recommend examining the temporal stability of the instrument's structure according to a participant characteristic that can provide a different understanding of the construct being measured. Participants completed the questionnaire twice, three weeks apart. In

addition, a question was added to measure the stage of advancement in the doctorate, a variable that may influence not only sense of scholarly community, but also the structure of the SSCS.

Administration of the questionnaire

Consistent with the Research Ethics Board for student projects involving human subjects (ethics certificate number 20223687), we sent the recruitment poster and hyperlink to the questionnaire by email or via social media to numerous graduate student associations and a variety of doctoral programs at universities located primarily in Quebec, but also in Ontario. Following the recommendations of DeVellis and Thorpe (2021), we aimed for a sample of at least 300 respondents.

The LimeSurveyplatform was used to administer the online questionnaire between July 20 and September 30, 2022. It included the consent form, socio-demographic questions (age, gender, etc.) and academic questions (start date of doctoral studies, home university, discipline, etc.), as well as the aforementioned instruments, i.e., the SSCS, the Social Acceptance Scale and the Doctoral Psychological Health Scale and the Doctoral Psychological Health Scale. At the end of the survey, the participants were asked to leave their email address so that they could be contacted three weeks after Time 1 with a new link to the Time 2 questionnaire.

The participants

A total of 318 participants took part in the measurement at the first time point. No missing data were identified, as participants had to answer all items in order to move on to the next section of the questionnaire. Their sociodemographic characteristics are reported in Table 1. Of these participants, 265 (83.33%) completed the Time 2 questionnaire, designed to assess test-retest reliability.

Table 1 shows that the largest proportion of participants in the study was made up of people identifying as female and studying in BHASE, which is consistent with Statistics Canada's (2017) observations that more women study in these fields than men. Moreover, given the proportions of people belonging to minority groups, the sample appears well diversified. The average age of participants was 32.12 years (standard deviation 7.27).

Table 1
Socio-demographic characteristics of the participants (N = 318)

Socio-demographic characteristics	Percentage
Gender	
Female	79.9
Male	17.6
Other (non-binary, queer or fluid)	2.5
Discipline	
Business, humanities, health, arts, social science and education (BHASE)	91.8
Science, technology, engineering and mathematics (STEM)	8.2
Number of years in doctoral studies	
One year	17
Two years	22.6
Three years	18.6
Four years	14.5
Five years	12.6
Six years or more	14.8
Belonging to minority groups	
First-generation students	30.8
International students	23.6
Student parents	23
Indigenous, Black, Asian and Coloured	17.3

Source: This table was developed by the authors.

Analysis

We examined five forms of construct validity and three forms of reliability of the SSCS.

Construct validity

First, descriptive analyses, including mean, standard deviation, skewness, kurtosis and inter-item correlations were used to examine item performance.

Second, factorial validity was investigated using exploratory factor analysis (EFA). Beforehand, to ensure that the EFA's conditions of use were met, the Bartlett sphericity test and the Kaiser-Meyer-Olkin (KMO) index test were conducted. A statistically significant Bartlett's sphericity

test indicates that there are sufficient correlations between items to proceed. The KMO variable-sampling quality index estimates the extent to which the dimensions present in the data are supported by more than two items. The recommended minimum index is 0.6 (Achim, 2020). The EFA was used applying an Oblimin rotation, as suggested when factors are correlated with each other (Hair et al., 2019) as are the dimensions of sense of community (Chavis et al., 2008). In this EFA, a method of factor extraction by principal axis factoring (Achim, 2020) was used, since it makes it possible to determine the number and nature of the factors explaining the network of correlations among all the items under examination. In the present study, the EFA aimed to examine the structure of the SSCS in several subscales representing the theoretical components of sense of scientific community. As Hair et al. (2019) suggest, in each subscale, only items with a factor loading above the 0.40 threshold were selected. In addition, items that provided saturation in more than one factor were removed, as they were considered to be problematic. The elimination of items is encouraged when it results in a coherent and conceptually interpretable structure (Hair et al., 2019). Next, a second-order confirmatory factor analysis (CFA) was performed to validate the multidimensional structure of the SSCS, i.e., to confirm that the identified subscales do indeed represent the components of the sense of scientific community, while taking into account the variance not explained by the items (Hair et al., 2019). In this case, the instrument proves even more useful, since a total score can be derived from all the items selected. To interpret the CFA, the fit of the model to the data was assessed using chi-square (χ^2), the comparative fit index (CFI), the standardized root mean square (SRMR), and the root mean square error of approximation - RMSEA. According to Hair et al. (2019), in the case of a sample size of over 250 participants and a model comprising 12 to 30 variables (items or latent variables), a good fit of the model to the data results in a significant chi-square (χ^2), CFI or TLI > 0.94, SRMR < 0.08 and RMSEA < 0.07.

Third, to ensure that the SSCS subscales measured distinct components of sense of scientific community, discriminant validity was examined using the average variance extracted (AVE), i.e., the proportion of indicator variance that can be explained by its component (Fornell & Larcker, 1981). Thus, the AVE of each subscale must be greater than its correlation with the other subscales to provide empirical evidence of their discriminant validity (Hair et al., 2019).

Fourth, a correlation matrix was generated between the SSCS subscales, the Doctoral Psychological Health Scale and the Social Acceptance Scale. The aim was twofold: 1) to examine predictive validity and 2) to examine concurrent validity (DeVellis & Thorpe, 2021). Following the process adopted by Cabot and Facchin (2021), we wished to verify whether the SSCS could predict good psychological health during doctoral studies, since Sverdlik et al. (2020) reported a moderate correlation ($r = 0.26$) between mental health and sense of belonging during doctoral studies. Additionally, similar to the process carried out by Kindelberger and Picherit (2016), we wished to check whether the SSCS and the Social Acceptance Scale, two scales measuring similar constructs, were significantly correlated. To indicate satisfactory concurrent validity, we looked for a Pearson coefficient value greater than 0.40 (DeVellis & Thorpe, 2021).

Fidelity

Fifth, the internal consistency of each of the subscales was assessed using McDonald's omega fidelity index (ω) (Hayes & Coutts, 2020), recommending, as for Cronbach's alpha, a threshold of 0.70 to indicate good fidelity (Hair et al., 2019).

Sixth, following the same procedure as Kindelberger and Picherit (2016), test-retest reliability three weeks apart was assessed by measuring the correlation using Pearson's coefficient (r) between SSCS scores at the two administration times. Since a faithful psychometric instrument should produce the same results in the same person at two closely spaced points in time, it was expected for the scores obtained by each participant in a close interval to yield correlation coefficients above 0.70 (DeVellis & Thorpe, 2021).

Finally, to examine the temporal stability of the SSCS and ensure that its items had the same meaning for doctoral students during their studies as for doctoral students during their writing process, an invariance analysis was performed according to stage of doctoral advancement (binary variable). Configurational, metric, scalar and strict invariance models were tested by evaluating overall model fit using χ^2, CFI, RMSEA and SRMR. Furthermore, as suggested by Putnick and Bornstein (2016), metric, scalar and strict invariance models should be subject to a comparison of consecutive levels of invariance. To accept the invariance assumption, ΔCFI must not decrease by more than 0.01, ΔRMSEA must not increase by more than 0.02 and ΔSRMR must not increase by more than 0.03 for metric invariance and 0.015 for scalar invariance.

All analyses were performed using Statistical Package for the Social Sciences (SPSS) version 28 (IBM®, 2021-2022), with the exception of the CFA and the invariance analysis of SSCS according to the "stage of doctoral advancement" variable, which were conducted using M*plus* version 8.8.

Results

This section describes the psychometric qualities of the SSCS.

Item review: how does each item behave?

First, descriptive analyses were carried out. Table 2 below shows the mean (μ) out of 5, standard deviation (σ), asymmetry and kurtosis for each item.

The results indicate that the means were near the middle of the Likert scale, which is desirable in order to demonstrate good discrimination (DeVellis & Thorpe, 2021). As for the skewness and kurtosis of each item, the values ranged from -1 to 1, and are thus within the bounds suggested by Hair et al. (2019).

Table 3, in the appendix, shows the correlation matrix between items. Three items showed very strong correlations with each other, specifically item 16 with item 17 ($r = 0.90$) and item 19 ($r = 0.80$). Given the high degree of similarity between these three items, items 17 and 19 have been deleted to avoid redundancy in the SSCS. The other correlations were between 0.28 and 0.78.

Factor validity: does the structure of the SSCS conform to theory?

To answer this question, exploratory and confirmatory factorial validity were examined.

Exploratory factor structure

The results of Bartlett's sphericity test ($\chi^2 = 3482.30$; dl = 378; $p < 0.001$) and examination of the Kaiser-Meyer-Olkin index (KMO = 0.929) revealed satisfactory results, justifying the performance of the EFA. The pattern matrix for factorial analysis suggested four factors, as Table 4 shows. To simplify this presentation, only saturation coefficients above 0.40 are shown. In addition, coefficients associated with the theoretically expected component are written in bold and reported even if they are below the expected threshold.

Table 2
Means (μ), standard deviations (σ), skewness and kurtosis coefficients

Items		μ (σ)	Skewness	Kurtosis
1	Certain members of the scientific community care about fulfilling my professional needs.	3.30(1.01)	-0.30	-0.26
2	I've developed friendships with members of the scientific community.	3.51(1.15)	-0.34	-0.71
3	I'm useful in the scientific community.	3.07(0.97)	-0.31	-0.24
4	The members of the scientific community and I value the same things.	3.14(0.94)	-0.38	-0.19
5	I receive support from certain members of the scientific community.	3.58(0.99)	-0.46	-0.35
6	I feel connected to certain members of the scientific community.	3.42(1.06)	-0.34	-0.67
7	I feel assisted in my professional roles as a member of the scientific community.	3.11(1.03)	-0.23	-0.53
8	I benefit from the knowledge and experience of certain members of the scientific community.	3.76(1.06)	-0.64	-0.28
9	I can count on certain members of the scientific community to help me with my research.	3.62(1.07)	-0.46	-0.54
10	Certain members of the scientific community contribute to my professional success.	3.69(1.08)	-0.57	-0.46
11	I can trust the members of the scientific community.	3.51(1.00)	-0.52	-0.19
12	I am known to certain members of the scientific community.	2.98(1.16)	0.11	-0.76
13	I embrace the culture of the scientific community.	3.07(1.04)	-0.17	-0.43
14	Being a member of the scientific community is part of my identity.	3.01(1.15)	-0.14	-0.82
15	I contribute to the scientific community.	3.25(1.02)	-0.09	-0.54

Table 2 (continued)
Means (μ), standard deviations (σ), skewness and kurtosis coefficients

Items		μ (σ)	Asymétrie	Aplatissement
16	I help other members of the scientific community.	3.38(1.04)	-0.41	-0.37
17	I offer support to other members of the scientific community.	3.43(1.03)	-0.52	-0.15
18	I have my place in the scientific community.	3.23(1.08)	-0.19	-0.64
19	I share my knowledge and experience with other members of the scientific community.	3.42(1.06)	-0.43	-0.37
20	I enjoy spending time with certain members of the scientific community.	3.64(1.05)	-0.58	-0.26
21	I have a role to play in the scientific community.	3.39(1.05)	-0.35	-0.44
22	I'll be part of the scientific community for a long time to	3.41(1.14)	-0.44	-0.56
23	I identify with the members of the scientific community.	3.05(1.06)	-0.15	-0.52
24	I act as a leader in the scientific community.	2.36(1.12)	0.26	-0.96
25	I'm optimistic about the future of the scientific community.	3.23(1.11)	-0.33	-0.70

Source: This table was developed by the authors.

As shown in Table 4, the first factor, Influencing, included seven items with saturation coefficients above the desired threshold of 0.40 (Hair et al., (2019) However, it was expected that item 18 would be found in the membership factor. The second factor, Benefit, comprised eight items, all with a coefficient greater than 0.40. However, the last two items (items 11 and 6) also showed a theoretical mismatch with this factor, corresponding instead to emotional connection, in which a cosaturation was observed. The third factor had six items with saturation coefficients above 0.40. Finally, given the dispersion of its items in the other factors, the fourth factor, Connect, was composed of only two items (items 2 and 20) that also provided indices of saturation in another factor.

Table 4
Results of the rotated pattern matrix for the initial factorial analysis

Items		Influencing	Benefiting	Belonging	Connecting
15	I contribute to the scientific community.	**0.85**			
24	I act as a leader in the scientific community.	**0.80**			
3	I am useful in the scientific community.	**0.77**			
16	I help other members of the scientific community.	**0.76**			
21	I have a role to play in the scientific community.	**0.72**			
18	I have my place in the scientific community.	0.65		**0.31**	
12	I am known to certain members of the scientific community.	**0.59**			
8	I benefit from the knowledge and experience of certain members of the scientific community.		**-0.83**		
9	I can count on certain members of the scientific community to help me with my research.		**-0.80**		
10	Certain members of the scientific community contribute to my professional success.		**-0.78**		
5	I receive support from certain members of the scientific community.		**-0.74**		
7	I feel assisted in my professional roles as a member of the scientific community.		**-0.72**		

Table 4 (continued)
Results of the rotated pattern matrix for the initial factorial analysis

Items		Influencing	Benefiting	Belonging	Connecting
1	Certain members of the scientific community care about fulfilling my professional needs.		**-0.66**		
11	I can trust the members of the scientific community.		-0.63		**0.32**
6	I feel connected to certain members of the scientific community.		-0.48		**-0.48**
13	I embrace the culture of the scientific community.			**0.74**	
23	I identify with the members of the scientific community.			**0.73**	
14	Being part of the scientific community is part of my identity.			**0.59**	
4	The members of the scientific community and I value the same things.			**0.58**	
22	I will be part of the scientific community for a long time to come.			**0.50**	
25	I am optimistic about the future of the scientific community.			**0.49**	
2	I have developed friendships with members of the scientific community.		-0.36		**-0.50**
20	I like to spend time with certain members of the scientific community.			0.38	**-0.41**

Source: This table was developed by the authors.

Table 5
Results of the rotated pattern matrix for the final exploratory factorial analysis

Items	Influencing	Benefiting	Belonging
15	0,84		
16	0.77		
3	0.75		
24	0.74		
21	0.66		
12	0.62		
8		-0.82	
9		-0.80	
5		-0.79	
10		-0.79	
1		-0.71	
7		-0.69	
13			0.82
23			0.76
4			0.60
25			0.59
22			0.57
14			0.56

Source: This table was developed by the authors.

To improve the factor structure, problematic items (items 2, 6, 11, 18 and 20) were removed one by one, by systematically re-running an EFA. The same mismatches kept occurring, until all the said items were removed. The results of the final EFA, presented in Table 5, have been revised into a three-factor structure (Influencing, Benefiting and Belonging), each comprising six items consistent with the theory.

As expected, after removing the problematic items, the results showed that each item provided a high saturation coefficient only in the expected factor (between 0.56 and 0.84). In addition, the three factors explained 47.92%, 8.44% and 6.04% of the shared variance in the data respectively, for a total of 62.41%.

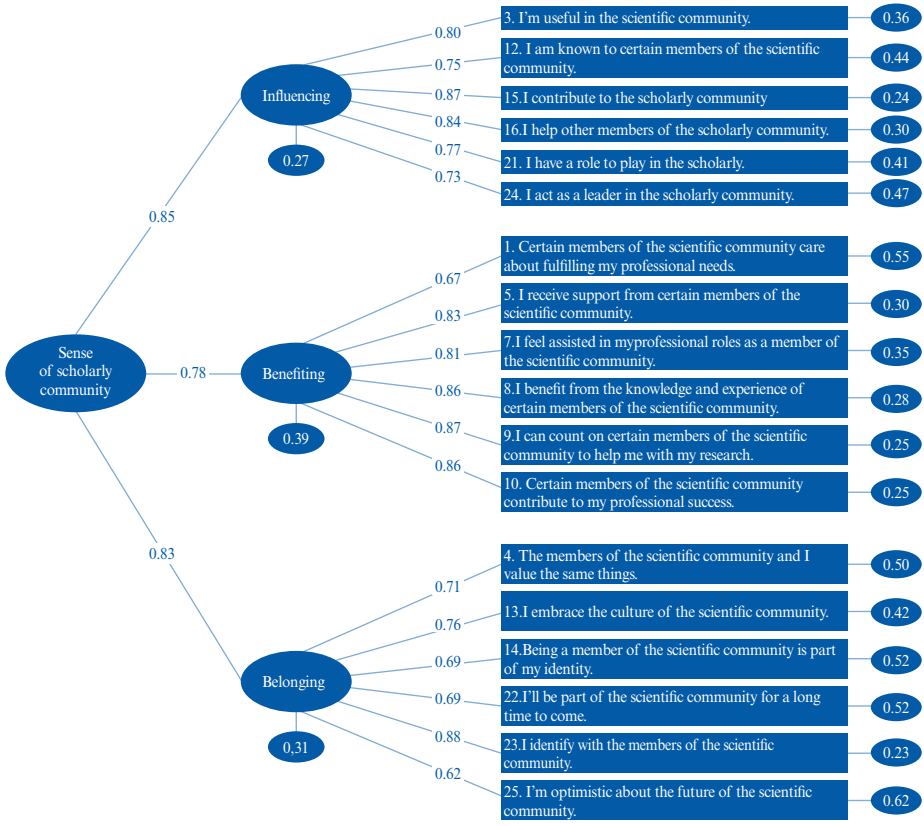
Confirmatory factor structure

To examine the empirical validity of the three-dimensional structure of the SSCS, a second-order CFA was conducted. These data are shown in Figure 2 below.

Figure 2 shows that the saturation coefficients were all quite high (< 0.62), which is close to the sought-after threshold of 0.70 (Hair et al., 2019). As for "the fit of the model to the data," all the indices were satisfactory (CFI = 0.94; SRMR = 0.05, RMSEA = 0.07) [0.0670.085], $\chi^2(132) = 371.77$, $p < 0.001$). These results confirm that the three subscales do indeed represent the components of the sense of scientific community, which can therefore be the subject of a composite score calculated by combining all the selected items.

Figure 2

Results of second-order confirmatory factor analysis



Discriminant validity: Do the SSCS subscales really measure three distinct components of sense of scientific community?

The AVEs for the Belonging (0.52), Influencing (0.62) and Benefiting (0.67) subscales were all higher than the squared correlation with the other subscales ($r^2_{\text{Belonging-Influencing}} = 0.41$, $p < 0.001$; $r^2_{\text{Belonging-Benefiting}} = 0.39$, $p < 0.001$ et $r^2_{\text{Influencing-Benefiting}} = 0.37$, $p < 0.001$). These results suggest that the SSCS subscales each explained a greater share of the variance associated with their own construct than that of other latent constructs, testifying to the discriminant validity of the tool (Fornell & Larcker, 1981).

Predictive and concurrent validity: What is the relationship between SSCS and other constructs?

Table 6 below shows the correlation matrix between the SSCS subscales, the doctoral psychological health scale (Vincent et al., 2023) and Social Acceptance (Richer & Vallerand, 1998).

Table 6

Average scale score, standard deviation and correlation matrix between scales

	Mean score	Standard	deviation	Belonging	Benefiting
Influencing	18.43/30	5.27	1		
Belonging	19.91/30	4.99	0.64	1	
Benefiting	21.06/30	5.3	0.61	0.59	1
Doctoral psychological health	32.71/40	7.42	0.28	0.36	0.25
Social acceptance	24.37/25	5.91	0.43	0.52	0.58

Note: All correlations are significant at the $p < 0.001$ threshold.
Source: This table was developed by the authors.

As expected, all three SSCS subscales are positively correlated with the Doctoral Psychological Health Scale, supporting their predictive validity. Additionally, as expected, correlations are higher between the SSCS subscales and the Social Acceptance Scale, a construct theoretically similar to sense of community. These last results therefore provide evidence of the concurrent validity of the SSCS subscales. It should also be noted that the correlations between the three SSCS subscales are positively correlated to each other (> 0.59). This result implies that the higher the perception of having support within the scientific community, the higher the perception of belonging to this entity and the perception of influencing other members thereof.

Fidelity (internal consistency): Do the items in each SSCS subscale consistently measure the same construct?

McDonald's omega fidelity indices (ω) (Hayes & Coutts, 2020) are high, with values of ω = 0.91 for the Influencing factor, ω = 0.92 for the Benefiting factor, ω = 0.87 for the Belonging factor, as well as ω = 0.94 for all items reflecting sense of scientific community. Internal consistency is therefore satisfactory for each subscale and for the overall scale.

Test-retest fidelity: Do scores on the SSCS subscales remain stable at three-week intervals?

Examination of the scores at three-week intervals revealed high correlations, as expected. First, the Influencing score at T1 with the Influencing score at T2 yielded a correlation of $r = 0.81$ $p < 0.001$. Second, the Benefiting score at T1 was strongly associated with the score at T2 on the same scale ($r = 0.77$, $p < 0.001$). Third, the Belonging score at T1 with the Belonging score at T2 revealed a correlation of $r = 0.81$, $p < 0.001$. Finally, the total SSCS score at T1 and T2 produced a correlation of $r = 0.84$, $p < 0.001$. Overall, these data reveal good test-retest reliability for the SSCS.

Temporal fidelity: Does the SSCS have the same structure depending on stage of advancement in the doctorate?

The results of the invariance analysis performed using stage of doctoral advancement as a binary variable (study period vs. writing period) are reported in Table 7 below.

Table 7
SSCS invariance test results by doctoral advancement

Models	χ^2	*ddl*	CFI	RMSEA	SRMR	ΔCFI	ΔRMSEA	ΔSRMR	Decision
Configural	507.35	264	0.94	0.08	0.06	N/A	N/A	N/A	N/A
Metric	527.12	119	0.94	0.08	0.06	-0.002	-0.001	0.007	Accepted
Scalar	565.04	294	0.93	0.08	0.07	-0.005	0.001	0.002	Accepted
Strict	582.55	312	0.93	0.07	0.07	0.000	-0.002	0.001	Accepted

Source: This table was developed by the authors.

As shown in Table 7, invariance is respected for all models, meaning that the three-dimensional structure of the SSCS does not differ significantly according to doctoral students' stage of advancement (Hair et al., 2019).

Discussion

This article has brought to light the process of developing a tool to measure sense of scientific community. To this end, the definition and characteristics of sense of scientific community were first identified using the available literature on the doctoral context. The establishment of this theoretical framework enabled the development of the SSCS, following the steps of Devellis and Thorpe (2021). Using a sample of 318 doctoral students, the present study then aimed to examine the psychometric qualities of the scale.

On the whole, the results showed that the SSCS had satisfactory psychometric qualities. Indeed, the data from the EFA and AFC showed that the SSCS had a three-factor structure, each possessing six items and good internal consistency. In addition, the data supported the predictive validity of the new tool with psychological health at the doctoral level (Vincent et al., 2023), as well as its concurrent validity with social acceptance (Richer & Vallerand, 1998). Moreover, the high correlation between SSCS scores obtained three weeks apart testified to the test-retest reliability of the instrument. The temporal stability of its structure also proved satisfactory. So, whatever the stage of doctoral advancement, the structure of the SSCS remained invariable. Discriminant validity was also considered to be satisfactory, with the SSCS subscales each explaining more of the variance associated with their own construct than with other latent constructs.

Given these data, it turns out that sense of scientific community translates into three interrelated subcomponents: 1) perception of belonging, in other words, of adhering to academic culture, of resembling and identifying with other scholars, and of being proud to belong to the scientific community; 2) perception of influence, i.e., having a leadership role, contributing, helping other members, being useful and being recognized within the scientific community; and 3) perception of receiving support, attention and advice from other members to support one's own professional success. In addition, the SSCS appears to be comprehensive in that it brings together the three key socio-professional aspects of the doctorate that had

previously been studied separately, namely 1) membership (Sverdlik et al., 2020) or identity fit with the scientific community (Emmioğlu et al., 2017; Gardner, 2008); 2) involvement (Gardner & Barnes, 2007, McAlpine & Amundsen, 2009; Pyhältö & Keskinen, 2012) or engagement in the scientific community (Vekkaila et al., 2013) and finally, 3) supervision (Cornér et al., 2017), guidance (Overall et al., 2011) and academic support in the scientific community (van Rooij et al., 2019).

In addition, all three subscales of the SSCS moderately predicted psychological health status during doctoral studies, replicating the findings of Sverdlik et al. (2020). Moreover, our study contributes to the advancement of knowledge regarding the association between the various components of sense of scientific community and psychological health during doctoral studies. First, the data from the present study are consistent with research by Cornér et al. (2017) establishing a link between sense of belonging to the scholarly community and the psychological well-being experienced during doctoral studies. Second, our results replicate the negative relationship between feelings of involvement (influence) and doctoral students' anxiety and depressive symptoms reported by Pyhältö and Keskinen (2012). Third, the results replicate the positive association between perceived support from members of the scientific community (Benefiting), particularly doctoral students' supervisors and peers, and their psychological health (Jackman et al., 2022).

Despite the conformity between the three factors of the SSCS and the literature surrounding sense of scientific community at the doctoral level, the emotional connection construct, a component included in McMillan and Chavis' (1986) original theory, proved problematic. Indeed, the items measuring this construct showed a high cosaturation in the other factors, a psychometric problem justifying their removal. Although these results may seem surprising at first glance, they may be explained by the particularities of the scholarly context, which is not necessarily based on friendly relationships. More specifically, among doctoral students, the quality of their sense of scientific community does not depend on the bonds of friendship they perceive—a finding consistent with the solitary nature of doctoral work. Indeed, doctoral students, who must work alone on their dissertation (Chao et al., 2015), have limited possibilities for developing friendships with other members of the scientific community (Terrell et al., 2009; Vallières et al., 2022). Even when carried out in collaboration, scholarly work does not necessarily require friendly relationships, but

rather high-quality relationships between peers. Such positive relationships rely more on the perceived support of community members, an aspect that is already captured by the Benefiting component of the SSCS. This interpretation is consistent with the fact that two items in the Emotional Connection component (items 6 and 11) were saturated in the Benefiting factor. This underlines the conceptual overlap between these two components in the context of a scientific community, as perceived by doctoral students. So, while there is reason to believe in the importance of developing friendships at the doctoral level, these data suggest that emotional connection is not inherent to sense of scientific community.

Overall, these findings underscore the importance of taking context into account when measuring sense of community. Indeed, McMillan and Chavis' (1986) theory was based on community between members of a neighbourhood, a context in which friendships between people are key. In contrast, other contexts, including professional ones, do not necessarily require such friendly relationships in order to generate a sense of community. This being said, it is interesting to note that the other three components seem more generalizable to different contexts. Just like sense of community between members of the same neighbourhood, sense of scientific community is defined by a group of people (Belonging) who can contribute to this community (Influencing) and obtain support from it (Benefiting).

Limitations

It should be pointed out that all the measures used in this study were based on self-reported data, which may artificially increase the strength of relationships between variables (Navarro-González et al., 2016). In particular, participants may have had misconceptions about their level of influence in the scientific community. To avoid this bias, one interesting avenue would be to verify the contribution to the research group perceived by other members of the scientific community (e.g., research supervisor or research group colleagues). The same observation applies to the perceived state of psychological health at the doctoral level. In this case, it would be possible to examine the extent to which the SSCS predicts more objective constructs, such as a physiological marker of mental health issues like blood cortisol levels. Another limitation lies in the use of a single sample for both exploratory and confirmatory analyses. Ideally, exploratory analyses are carried out on a first sample and confirmatory analyses on a

second independent sample (DeVellis & Thorpe, 2021). Thus, to ensure the generalizability of the results, further research involving varied samples will be necessary.

Conclusion

In conclusion, regarding the use of the SSCS and the interpretation of the results, the 18-item scale is quick to complete. This scale can be used to measure participants' perception of the three dimensions of sense of scientific community, or overall perception of sense of scientific community, by combining the 18 items to obtain a composite score. What is more, it may be used to assess membership to the scientific community as a whole, as well as to a scientific sub-community. In the first case, participants are simply asked to keep in mind that the scientific community designates all researchers who carry out academic research, as we have done in this study. In the second case, researchers distributing the questionnaire can invite respondents to target a specific scientific sub-community such as their doctoral program, department or faculty, a specific research team, etc.

Whatever the context of the targeted scholarly community, the SSCS can help paint a picture of the situation and, if necessary, implement improvements to address any problematic aspects that may arise. Researchers can also use the scale to explore relationships between the various components of the SSCS and other indicators of doctoral success, such as persistence in the program or participation in scientific activities. The SCSS may also be useful for measuring the effects of an intervention on doctoral students' sense of scholarly community. An example would be participation in a writing retreat, which is known to create a sense of community between doctoral students (Tremblay-Wragg et al., 2021). The retreat could be evaluated by comparing the change in SSCS subscale scores before and after the intervention, to examine whether it improves sense of scientific community. What is more, beyond doctoral students, the SSCS can easily be adapted to students at other education levels, as well as to current research professors. Future research could empirically test the SSCS in different contexts and with diverse populations. Ultimately, a better understanding of the role of the scientific community is likely to benefit all its members and therefore foster greater social well-being within the research profession.

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Appendix 1

Table 3

Means. standard deviations. skewness and kurtosis coefficients and correlations between items

Items	Pearson correlation																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	1																								
2	.40	1																							
3	.33	.51	1																						
4	.40	.36	.35	1																					
5	.67	.60	.50	.48	1																				
6	.52	.74	.54	.50	.76	1																			
7	.58	.47	.46	.51	.66	.60	1																		
8	.52	.49	.44	.47	.72	.64	.69	1																	
9	.56	.50	.43	.53	.70	.62	.69	.75	1																
10	.57	.51	.45	.48	.70	.67	.69	.74	.78	1															
11	.39	.38	.33	.55	.50	.44	.60	.60	.60	.58	1														
12	.32	.47	.57	.35	.49	.55	.48	.52	.47	.49	.35	1													
13	.25	.24	.35	.58	.34	.43	.43	.37	.40	.39	.50	.40	1												
14	.28	.40	.41	.46	.39	.48	.35	.30	.36	.37	.29	.44	.51	1											
15	.28	.46	.71	.36	.49	.54	.46	.46	.45	.47	.36	.63	.42	.50	1										
16	.33	.49	.66	.38	.52	.62	.48	.52	.48	.53	.33	.64	.37	.43	.74	1									
17	.33	.51	.62	.31	.53	.59	.48	.49	.48	.50	.29	.58	.31	.40	.69	**.90**	1								

Table 3 (continued)

Means, standard deviations, skewness and kurtosis coefficients and correlations between items

Items	Pearson correlation																								
18	.36	.45	.63	.47	.52	.59	.57	.47	.49	.52	.46	.57	.45	.52	.68	.67	.63	1							
19	.38	.51	.63	.40	.54	.63	.53	.51	.50	.55	.35	.57	.41	.49	.72	**.80**	**.79**	.68	1						
20	.38	.64	.46	.49	.59	.72	.51	.54	.51	.58	.46	.54	.45	.55	.51	.59	.59	.55	.57	1					
21	.28	.36	.63	.35	.40	.45	.44	.37	.44	.44	.36	.53	.43	.53	.67	.62	.58	.67	.68	.50	1				
22	.25	.25	.39	.40	.35	.41	.38	.33	.40	.35	.35	.38	.52	.51	.48	.48	.44	.59	.47	.44	.63	1			
23	.29	.40	.46	.63	.44	.51	.49	.44	.49	.46	.45	.52	.66	.64	.54	.49	.45	.64	.52	.61	.57	.60	1		
24	.29	.37	.59	.28	.39	.40	.41	.32	.33	.36	.25	.60	.31	.38	.62	.60	.61	.62	.60	.41	.56	.41	.47	1	
25	.23	.18	.33	.46	.31	.32	.45	.42	.40	.38	.57	.27	.56	.28	.34	.30	.25	.47	.28	.37	.36	.48	.52	.30	1

Note: Problematic correlations are shown in bold.

Source: This table was developed by the authors.