Abstract: It can be suggested that pre-service primary school teachers’ sense of belonging to science may be influential to their professionalization within university-based teacher education programs, which intend to prepare them for teaching natural sciences in primary school. Nevertheless, because only few studies have examined teachers’ sense of belonging to science so far, further research in this regard seems both reasonable and necessary. To this end, there is a need for instruments enabling a valid assessment of pre-service primary school teachers’ sense of belonging to science. However, existing sense-of-belonging-to-science instruments require a comparatively long time on task due to their significant number of items. Consequently, the applicability of these instruments within research is limited because surveys in educational contexts must often be brief and economical. The research we present in this article aims to tackle this issue by examining on an exploratory level whether and to what extent pre-service primary school teachers’ sense of belonging to science can be validly assessed using a single-item instrument. In doing so we report qualitative, as well as quantitative, findings that provide evidence regarding the validity of our instrument. Implications of the present study for future research are outlined at the end of this article.

Keywords: sense of belonging, primary school teachers, pre-service teacher education, science teacher education

1 Introduction

Belongingness is a fundamental human need (Baumeister & Leary, 1995), and a growing number of research studies students’ sense of belonging as a prerequisite for their professionalization during higher education – especially within teacher education (Pendergast, Ronksley-Pavia, & Dewhurst, 2020) and natural science education (Lewis, Stout, Pollock, Finkelstein, & Ito, 2016). To measure students’ and/or pre-service teachers’ sense of belonging to science, several researchers have developed instruments that typically comprise a substantial number of items (e.g., Feser, 2020; Findley-Van Nostrand & Pollenz, 2017; Rattan et al., 2018; Thoman, Arizaga, Smith, Story, & Soncuya, 2014). However, due to practical limitations within higher education research (e.g., time restrictions for surveys), a shorter alternative to these instruments with similar psychometric properties would be particularly useful. To address this issue, the present study investigates, on an exploratory level, whether and to what extent pre-service primary school teachers’ sense of belonging to science can be validly assessed during university-based teacher education using a single-item instrument (overarching research question). To this end, inspired by the Inclusion of Other into the Self Scale by Aron, Aron, and Smollan (1992), we developed a single-item instrument for assessing pre-service primary school teachers’ sense of belonging to science (see Section 3.3, Figure 1) and explored its validity based on a convenience sample of pre-service primary school teachers from Austria and Germany.

In this article we present, on one hand, qualitative findings in terms of our instrument's content validity that we obtained through the open-ended questioning of pre-service primary school teachers’ regarding their response to our developed instrument. These qualitative findings are based on the following research question:

1. In what ways do pre-service primary school teachers reason their response to our developed instrument?

On the other hand, we also report quantitative findings on the convergent, discriminant, and concurrent validity of...
our developed single-item instrument based on the following research questions:

2. Convergent validity: To what extent does our developed instrument (partially) correlate with a previously validated multiple-item instrument for the assessment of pre-service primary school teachers’ sense of belonging to science?

3. Discriminant validity: To what extent does our developed instrument (partially) correlate with pre-service primary school teachers’ (3.1) interest in science, and (3.2) their science-related self-concept?

4. Concurrent Validity: Compared to a multiple-item instrument for the assessment of pre-service primary school teachers’ sense of belonging to science, to what extent does our developed instrument predict the extent to which pre-service primary school teachers’ feel (4.1) self-doubt, (4.2) aversion, and (4.3) anxiety when thinking about teaching natural sciences to primary school children?

In Section 2, the theoretical background of the present study is presented in more detail. Subsequently, the methods and the results of the study are presented and discussed.

2 Theoretical Background

2.1 The Importance of Teacher Professionalization for Primary Science Education

Researchers have made a compelling case that a major concern of school-based education should be the promotion of a basic understanding of natural sciences to all students (e.g., Marquant-Mau, 2001; Schuck & Feser, 2022; Thomas & Durant, 1987). In this regard, primary school...
education is of central importance. For many students, primary education offers an initial exposure to natural sciences (Harlen & Qualter, 2018). Moreover, educational standards around the globe specify primary school as the place where education in natural sciences should begin and students should be prepared for science education at the secondary level (e.g., Gesellschaft für Didaktik des Sachunterrichts (GDSU), 2003; NGSS Lead States, 2013). Consequently, one of the key responsibilities of primary school teachers is to provide the first and most essential education in natural sciences to their students. To meet this requirement, primary school teachers themselves require proper professionalization in teaching science, which should be integrated within their university-based teacher education (Gesellschaft für Didaktik des Sachunterrichts (GDSU), 2019; Loughran, 2007). However, “significant numbers of primary school teachers avoid teaching science, are not knowledgeable about science, and lack confidence to teach it” (Appleton, 2003, p. 1; see also Epstein & Miller, 2011; Jarvis, Pell, & Hingley, 2018; Kazempour, 2014). It is therefore reasonable to assume that, to date, many university-based teacher education programs, which intend to prepare pre-service primary school teachers for teaching sciences, have only been successful to a limited extent (Appleton & Kindt, 2002; Möller, 2004).

The causes of, as well as potential solutions to, this challenge regarding university-based teacher education has already been widely discussed and empirically investigated (see, e.g., Appleton, 2006; Ubú, Vaas, Krass, & Sikkal, 2021). There is a consensus among researchers and teacher educators (Loughran, 2007; Mellado, Blanco, & Ruiz, 1998) that a university-based education designed to meet the needs of pre-service primary teachers regarding their professionalization in teaching science must take into account their prior knowledge of science, their interest in science, and their science-related self-concept. In this regard, in line with Krapp and Prenzel (2011), interest in science is conceptualized as “a phenomenon that emerges from an individual’s interaction with his or her environment… An interest represents a specific and distinguished relationship between a person and an object. An object can refer to concrete things, a topic, a subject-matter or an abstract idea, i.e. a certain part of the cognitively represented environment” (p. 31). In contrast, the term “science-related self-concept” refers to the overall cognitive representations of one’s own abilities in science-related performance situations (for details, see, e.g., Dickhäuser, Schöne, Spinath, & Stiensmeier-Pelster, 2002; Elsholz, 2019; Shavelson, Hubner, & Stanton, 1976).

2.2 Primary School Teachers’ Sense of Belonging to Science – State of Research and Instruments for its Assessment

Additionally, current research indicates that, besides prior knowledge in science, interest in science, and science-related self-concept, pre-service primary school teachers’ sense of belonging to science may also need to be considered:

(P)re-service teachers’ sense of belonging [...] is context-specific and embedded in the social, cultural and professional conditions of [their professional development and learning.] [...] [F]ailure to resolve belonging tensions can have damaging consequences on pre-service teachers’ development. (Pendergast et al., 2020, p. 59)

Simply put, sense of belonging to science is defined as individuals’ feeling or sensation of social affiliation within the natural sciences (Kuchynka, Findley-Van Nostrand, & Pollenz, 2019). More precisely, it refers to one’s personal feelings of connectedness to, recognition and acknowledgement by, emotional wellbeing around, and interpersonal trust in people involved and engaged in the natural sciences (Feser, 2021).

Within educational research, sense of belonging to science is often considered as a suitable proxy for specific aspects of the broader and very multifaceted construct of (science) teachers’ professional identity (Feser & Haak, 2022; Nieswandt, Barrett, & McEneaney, 2013; Pedretti, Bencze, Hewitt, Romkey, & Jivraj, 2008; Wang, 2020). Analogously, this applies to (science) teachers’ interest in science and their science-related self-concept. Not surprisingly, quantitative studies have found that these three constructs are substantially correlated, yet distinguishable from one another (e.g., Feser, 2020; Findley-Van Nostrand & Pollenz, 2017; Wang & Sneed, 2019). Beyond that, qualitative research conducted by Anna Daniellson and colleagues indicates that pre-service primary school teachers’ sense of belonging to science is “affected by their potential feelings of alienation in relation to previous experiences of science classrooms” (Daniellson, Andersson, Gullberg, Husénius, & Scantlebury, 2016, p. 1130) and that pre-service primary school teachers “who express a strong belonging in science [...] construct school science as practical, experimental and related to technology [in a way that] can be understood as closely associated with the enactment of a particular, classed masculinity” (Daniellson, 2013, pp. 146–152). Moreover, in-service teachers with a low sense of belonging to science report stronger intentions to abandon their teaching of science subjects (Balgopal, Weinberg, Sample McMeeking, Lin Hunter, & Wright, 2022) and tend to struggle to act as representatives...
of the natural sciences in front of their classes (Fejes & Köpsén, 2014), which in turn may negatively affect their students' identification within the science classroom (Chung-Parsons & Bailey, 2019).

In summary, the results of previous studies suggest that pre-service primary school teachers’ sense of belonging to science may be influenced to the quality of their science teaching and to their professionalization regarding teaching science on the affective-motivational level (Danielsson, 2013; Pendergast et al., 2020). However, because sense of belonging is a relatively new area of interest in higher education research (Nunn, 2021, Strayhorn, 2019), only a few studies have examined pre-service teachers’ sense of belonging to science so far. Given this, it seems both reasonable and necessary to further investigate pre-service primary school teachers’ sense of belonging to science. To this end, suitable instruments are needed that enable a valid assessment of pre-service primary school teachers’ sense of belonging to science.

Unfortunately, existing instruments for assessing sense of belonging to science are predominantly designed in an ad hoc fashion (e.g., Rattan et al., 2018; Thoman et al., 2014), and only rarely has their validity been critically evaluated (e.g., Fejer, 2020; Findley-Van Nostrand & Pollenz, 2017; Stachl & Barranger, 2020). Moreover, existing sense-of-belonging-to-science instruments require a comparatively long time on task on the part of participants because they consist of a significant number of items. Therefore, these instruments are not entirely suitable for assessing pre-service primary school teachers’ sense of belonging to science in a brief and highly economical manner. However, a brief instrument for assessing sense of belonging to science would be highly beneficial for educational research:

The need for brief, efficient measures has increased dramatically in the past decade. [...] For example, much of the current research uses longitudinal studies (e.g., daily diary studies), mass-testing sessions (e.g., participant prescreening), and field research (e.g., organizational settings). Researchers have met this need by developing efficient versions of popular [...] measures. (Nichols & Webster, 2014, p. 50)

One way to tackle this issue is to use a single-item instrument instead of a multiple-item instrument for the assessment of pre-service primary school teachers’ sense of belonging to science. Although some authors have been critical of single-item instruments in terms of their psychometric quality in general (e.g., Loo, 2002), research has provided cogent evidence demonstrating that single-item instruments can be as valid as multiple-item instruments (Nichols & Webster, 2013), especially if they are intended to assess constructs that are well distinguishable and mentally present for the respondents (Rost, Sparfeldt, & Buch, 2008). It is reasonable to assume that, within the context of university-based teacher education programs for teaching natural sciences, pre-service primary school teachers’ sense of belonging to science meets these requirements. Due to their scope, such teacher education programs encourage pre-service primary school teachers to maintain an ongoing and conscious engagement with the natural sciences not only on a cognitive level but also on an affective-motivational level, which includes their sense of belonging to science. Furthermore, some studies have already successfully used single-item instruments to assess students’ sense of belonging in university contexts (e.g., Nichols & Webster, 2013; Zander & Höhne, 2021). Even though these studies do not address sense of belonging to science and, instead, focus on students’ belonging within their university or study program, these studies give further credence to the assumption that a single-item instrument may be a valid way to assess pre-service primary school teachers’ sense of belonging to science. Nevertheless, such a single-item instrument requires a particularly thorough development and empirical examination of its psychometric quality, especially because various authors strongly recommend doing so (e.g., Loo & Kelts, 1998; Loo, 2002; Warren & Landis, 2007).

3 Method

In this section, we initially outline our expectations and hypotheses for research questions 1–4 regarding the validity of our developed single-item instrument. Following that, we describe the methodological procedures we applied in the present study.

3.1 Expectations and Hypotheses

As stated in Section 1, the present study qualitatively and quantitatively explores whether and to what extent pre-service primary school teachers’ sense of belonging to science can be validly assessed during university-based teacher education using a single-item instrument.1 Regarding
question cannot be answered by the present study as it solely focuses on pre-service primary school teachers' sense of belonging to science and its assessment. Therefore, this question should be addressed by future research.

H2.1 Our developed single-item instrument correlates, if at all, positively but at most moderately ($r \leq 0.50$; Cohen, 1988; ICC(A,1) $\leq 0.60$; Cicchetti, 1994) with pre-service primary school teachers'...

H2.1.1 interest in science.

H2.2.1 interest in science

H2.2.2 science-related self-concept

H3.1 self-doubt

H3.2 aversion

H3.3 anxiety

...when thinking about teaching natural sciences to primary school children.

Hypotheses H3.1–H3.3 is based on the assumption that, because results of previous studies suggest that pre-service primary school teachers' sense of belonging to science may be influential to their professionalization regarding teaching science on an affective-motivational level (see Section 2), a valid single-item instrument for the assessment of sense of belonging to science should positively predict pre-service primary school teachers' feelings of self-doubt, aversion, and anxiety when thinking about teaching natural sciences to primary school children. Analogously, this should be the case for
a previously validated multiple-item instrument used for assessing pre-service primary school teachers’ sense of belonging. Moreover, both predictions (using a single-item instrument versus a multiple-item instrument) should lead to comparable results.

3.2 Participants and Procedure

To provide empirical evidence, at an exploratory level, regarding the validity of our developed single-item instrument for assessing pre-service primary school teachers’ sense of belonging to science (see Section 3.3, Figure 1), we administered it to a convenience sample of pre-service primary school teachers within their university-based teacher education programs at the Universität Hamburg (Germany) and the University College of Teacher Education of Christian Churches Vienna/Krems (Austria). We conducted the study at these two universities for pragmatic reasons (the authors of the present study work for these two universities) and since the teacher education programs for teaching natural sciences that are implemented at the Universität Hamburg and at the University College of Teacher Education of Christian Churches Vienna/Krems are quite similar. In addition, the science education curriculum for primary schools in Austria and Germany are relatively similar compared to other education systems around the globe (Blaseio, 2021).

Data collection was conducted between December 2021 and February 2022 and carried out in accordance with the legal and ethical standards for educational research in Germany and Austria (Watteler & Ebel, 2019). Within the courses on natural sciences and science education for third-semester students, students were invited to participate in our study. Participants filled out an online questionnaire anonymously and voluntarily.

Table 1 summarizes the central descriptive statistics of our surveyed sample. In total, \( N = 91 \) of pre-service primary school teachers participated in our study. Participants were distributed approximately evenly between both universities (Hamburg: 52.75%; Vienna/Krems: 47.25%). Participants’ age distributions were comparable between both universities (Hamburg: \( M = 22.80, SD = 4.53 \); Vienna/Krems: \( M = 22.42, SD = 3.70 \)). Levene’s test for equality of variances was not violated for participants’ age distribution (\( F(1, 88) = 0.098; p = 0.755 \)) and their mean age did not differ significantly between both universities (Student’s \( t \)-test, \( t(88) = 0.367, p = 0.715 \)). On a descriptive level, within the subsample collected at the Universität Hamburg, the share of male participants is notably higher as compared to participants from the University College of Teacher Education of Christian Churches Vienna/Krems (10.42% versus 6.98%), as is the share of pre-service primary school teachers who participated in a teacher education program regarding teaching students with special educational needs (22.92% versus 11.63%). However, the results of Fisher’s exact tests indicate no significant differences between both subsamples regarding participants’ gender (\( p = 0.717 \)) or their study program (\( p = 0.177 \)). Furthermore, due to a technical error, no open-ended responses could be obtained from the participants from the University College of Teacher Education of Christian Churches Vienna/Krems. Therefore, only 36 open-ended answers obtained from participants from the Universität Hamburg regarding their responses to our developed instrument were recorded.

### Table 1: Descriptive statistics of the sample

<table>
<thead>
<tr>
<th></th>
<th>Hamburg</th>
<th>Vienna/Krems</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>( N )</td>
<td>48</td>
<td>43</td>
<td>91</td>
</tr>
<tr>
<td>( N_{\text{open}} )</td>
<td>36</td>
<td>0</td>
<td>36</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( M )</td>
<td>22.80</td>
<td>22.42</td>
<td>22.61</td>
</tr>
<tr>
<td>SD</td>
<td>4.53</td>
<td>3.70</td>
<td>4.11</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>85.41%</td>
<td>93.02%</td>
<td>89.01%</td>
</tr>
<tr>
<td>Male</td>
<td>10.42%</td>
<td>6.98%</td>
<td>8.79%</td>
</tr>
<tr>
<td>Training in special education</td>
<td>22.92%</td>
<td>11.63%</td>
<td>17.58%</td>
</tr>
</tbody>
</table>

Note. \( N \) = number of participants; \( N_{\text{open}} \) = number of participants who responded to the open-ended question on our developed instrument; \( M = \) arithmetic means; SD = standard deviation; training in special education = pre-service primary school teachers who do (not) participate in a teacher education program on teaching students with special education needs.

3.3 Measures

Table 2 summarizes the key characteristics of the instruments we used in our online questionnaire. In the following sections, we describe these instruments and their characteristics in more detail.

#### 3.3.1 Single-Item Instrument for Assessing Sense of Belonging to Science

Inspired by the research of Zander and Höhne (2021), as well as McDonald, Zeigler-Hill, Vrabel, and Escobar (2019), the starting point for our development of a single-item instrument for assessing pre-service primary school teachers’ sense of belonging to science was the Inclusion of...
Table 2: Descriptive statistics for instruments used based on our survey sample

<table>
<thead>
<tr>
<th>Instrument</th>
<th>N item</th>
<th>M</th>
<th>SD</th>
<th>min</th>
<th>max</th>
<th>Skew</th>
<th>Kurt</th>
<th>α</th>
<th>df</th>
<th>Differences between both universities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belonging-m</td>
<td>88</td>
<td>3.27</td>
<td>0.60</td>
<td>1.40</td>
<td>4.55</td>
<td>-0.36</td>
<td>-0.01</td>
<td>0.74</td>
<td>37–66</td>
<td></td>
</tr>
<tr>
<td>Belonging-s</td>
<td>90</td>
<td>2.14</td>
<td>0.74</td>
<td>1</td>
<td>4</td>
<td>0.26</td>
<td>-0.19</td>
<td>0.74</td>
<td>(88)</td>
<td>1.77, p = 0.19 (86) 1.51, p = 0.13</td>
</tr>
<tr>
<td>Interest</td>
<td>90</td>
<td>2.90</td>
<td>0.62</td>
<td>1.40</td>
<td>4.00</td>
<td>-0.24</td>
<td>-0.38</td>
<td>0.87</td>
<td>1.71–0.78</td>
<td></td>
</tr>
<tr>
<td>Self-concept</td>
<td>88</td>
<td>4.22</td>
<td>1.26</td>
<td>1.00</td>
<td>7.00</td>
<td>-0.06</td>
<td>0.03</td>
<td>0.93</td>
<td>0.77–0.87</td>
<td></td>
</tr>
<tr>
<td>Self-doubt</td>
<td>91</td>
<td>3.30</td>
<td>1.42</td>
<td>1</td>
<td>7</td>
<td>-0.45</td>
<td>-0.12</td>
<td>0.74</td>
<td>(89)</td>
<td>1.66, p = 0.20 (89) 0.26, p = 0.79</td>
</tr>
<tr>
<td>Anxious</td>
<td>91</td>
<td>2.55</td>
<td>1.38</td>
<td>1</td>
<td>6</td>
<td>-0.77</td>
<td>0.08</td>
<td>0.87</td>
<td>(89)</td>
<td>8.55, p &lt; 0.01 (69.10) 1.71, p = 0.09</td>
</tr>
</tbody>
</table>

Note. belonging-s = single-item instrument for assessing sense of belonging to science; belonging-m = multiple-item instrument for assessing sense of belonging to science; interest = interest in science; self-concept = science-related self-concept; self-doubt/aversion/anxiety = feelings of self-doubt/aversion/anxiety when thinking about teaching natural sciences to primary school children; N = number of participants who responded to all items of the instrument; N_item = number of items; M = arithmetic means; SD = standard deviation; min = minimum score; max = maximum score; skew = skewness; kurt = excess kurtosis; α = Cronbach’s alpha; r_it = range of the items’ selectivity coefficient; Levene-test = results of Levene’s test for equality of variance between both universities; t-test = results of Welch’s/Student’s t-test between both universities.

Other into the Self Scale, created by Aron et al. (1992). The Inclusion of Other into the Self Scale is a single-item instrument that prompts respondents to select from among a set of diagrams, with each representing different degrees of overlap between two circles, the one that best describes their interpersonal connectedness in general. We translated this scale into German and thereby revised it substantially. In this revision, we added an instructional text that specifies the item on belonging to the natural sciences, revised the labeling of the diagrams, provided each diagram with a descriptive text, and added an open-ended question that prompts respondents to reason regarding why they chose a particular diagram (Figure 1). Through this procedure, our single-item instrument – in contrast to the instrument of Aron et al. (1992), which measures one’s generic interpersonal connectedness – presumably assesses the extent to which a person perceives a sense of belonging to sciences.

3.3.2 Multiple-Item Instrument for Assessing Sense of Belonging to Science

To evaluate the convergent validity of our developed instrument, we used the instrument developed by Feser (2020) as an alternative and multiple-item instrument for the assessment of pre-service primary school teachers’ sense of belonging to science. This instrument is a translated, adapted, and refined version of the instrument created by Good et al. (2012) for assessing sense of belonging to mathematics that has already been successfully validated for the assessment of pre-service teachers’ sense of belonging to science (for more details, see Feser, 2020). It consists of 21 items, which participants are asked to respond to on a five-point Likert scale. Three examples of these 21 items are: “I feel connected to the natural science community,” “I feel valued by people involved and engaged in the natural sciences,” and “I feel comfortable around people involved and engaged in the natural sciences.”

As detailed in Table 2, in our surveyed sample, a noticeable mean difference between our developed single-item instrument and Feser’s (2020) multiple-item instrument was evident (M = 2.14 versus M = 3.27). In our judgment, the most likely reason for this difference is that Feser’s (2020) multiple-item instrument uses Likert scales for responses (approximate translation of the labeling: 1 = disagree, 2 = slightly disagree, 3 = neither disagree nor agree, 4 = slightly agree, 5 = agree), whereas our developed single-item is based on a five-point response scale labeled in a way that it is not equivalent to the Likert scale used in Feser’s (2020) instrument. Especially the mid-point labeling of this scale differs in its meaning (“I feel that I belong to the natural sciences community for some part” versus “neither disagree nor agree”; Figure 1). Consequently, a mean score of M = 2.14 on our developed instrument indicates that, on average, participants felt that they “belong to the natural science community just a little” (labeling of scale point 2 of our developed instrument; Figure 1). Conversely, a mean score of M = 3.27 on Feser’s (2020) instrument indicates that, on average, participants felt that they neither feel a sense of belonging nor of not belonging to science, but with a slight tendency toward a sense of belonging, which is fairly consistent to the interpretation of the mean score of our developed instrument.
3.3.3 Interest in Science and Science-Related Self-Concept

To evaluate our developed instrument’s discriminant validity, we administered instruments that assess constructs related to but distinguishable from sense of belonging to science. More specifically, we assessed participants’ interest in science and their science-related self-concept. On the one hand, we assessed participants’ interest in science using the scale that was developed by Rau (2017) for assessing early career primary school teachers’ interest in science based on the interest-in-science-scale employed within the PISA 2006 study (number of items: 5; scale range (Likert scale): 1 to 4; exemplary item: “For me, learning new things about natural sciences is easy/difficult”). On the other hand, we used the instrument created by Elsholz (2019), originally designed for assessing preservice physics teachers’ self-concept in physics which we adapted to natural science in general, to assess participants’ science-related self-concept (number of items: 5; scale range (bipolar scale): 1 to 7; exemplary item: “I am interested to learn something new about natural sciences”). On the other hand, we used the instrument created by Elsholz (2019), originally designed for assessing pre-service physics teachers’ self-concept in physics which we adapted to natural science in general, to assess participants’ science-related self-concept (number of items: 5; scale range (bipolar scale): 1 to 7; exemplary item: “I am interested to learn something new about natural sciences”).

Due to test economy reasons, we limit ourselves to preservice teachers’ interest in science and their science-related self-concept for evaluating the discriminant validity of our developed single-item instrument. Consequently, it may be fruitful for future research to explore correlational relationships between our developed single-item instrument and instruments assessing further constructs related to, but distinguishable from sense of belonging to science (e.g., science-related self-efficacy scales; see also Suprapto & Chang, 2015).

3.3.4 Feelings of Self-Doubt, Aversion, and Anxiety When Thinking About Teaching Natural Sciences to Primary School Children

Within our online questionnaire, we adapted the three-item instrument that was developed by Konen and Horton (2000) as a shortened version of the Science Teaching State-Trait Anxiety Inventory (Westerback, 1979, 1984). To evaluate our developed instrument’s concurrent validity, we use this adapted version of the instrument by Konen and Horton (2000) to assess participants feelings of self-doubt, aversion, and anxiety when thinking about teaching natural sciences to primary school children. It consists of three bipolar scales, ranging from 1 (self-confidence/curious/calm) to 7 (self-doubt/averse/anxiety). Participants are asked to rate their own feelings using these three bipolar scales as they relate to the (approximately translated) sentence “When I think about the fact that, as a primary school teacher, I am supposed to teach science to my students, I feel....”

Similar to our approach to evaluate the discriminant validity of our developed single-item instrument, we limited our exploration of its concurrent validity to our adapted version of the instrument by Konen and Horton (2000) for test economy reasons. Accordingly, it may also be profitable for future research to examine the extent to which our developed single-item instrument predicts additional affective-motivational attributes related to pre-service primary school teachers’ professionalization regarding teaching science (e.g., additional affective-motivational attributes assessed by Westerback’s (1979; 1984) original Science Teaching State-Trait Anxiety Inventory).

3.4 Data Analysis

3.4.1 Qualitative Data Analysis

Participants’ open-ended answers regarding their responses to our developed instrument (N = 36) were qualitatively analyzed using summarizing qualitative content analysis (Flick, 2009). In doing so, we deductively–inductively developed a coding scheme by applying the code development strategies of progressively summarizing and contrasting (Schreier, 2012, 2014). This coding scheme consists of three categories (see Section 4, Table 3), each capturing a different reason participants gave to explain why they chose a particular diagram in our developed instrument. Participants’ open-ended answers were coded in their entirety using our developed coding scheme. Thereby, each open-ended answer was coded with one up to all three of these categories because some participants expressed only one reason for choosing a particular diagram in our developed instrument while others expressed several reasons. The initial coding was performed by the second author of this article. Subsequently, 100% of participants’ answers were double-coded by a co-worker, who was not otherwise involved in this study, and through extensive discussion and reconciliation of the double-coding, we were able to resolve all coding disagreements (Steinke, 1999). Finally, based on our coding, open-ended answers were double-coded by a co-worker, who was not otherwise involved in this study, and through extensive discussion and reconciliation of the double-coding, we were able to resolve all coding disagreements (Steinke, 1999). Finally, based on our coding.

Table 3: Results of the summarizing qualitative content analysis

<table>
<thead>
<tr>
<th>Reasoning content</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sense of belonging to science</td>
<td>25</td>
<td>69.44</td>
</tr>
<tr>
<td>Scientific knowledge</td>
<td>15</td>
<td>41.67</td>
</tr>
<tr>
<td>Interest and personal value of sciences</td>
<td>7</td>
<td>19.44</td>
</tr>
</tbody>
</table>

Note. N = number of open-ended responses; % = percentage share of open-ended responses.
participants’ open-ended answers regarding their responses to our developed instrument were summarized and evaluated.

### 3.4.2 Quantitative Data Analysis

Quantitative data analysis was conducted using R Version 4.2.1 (The R Foundation for Statistical Computing, 2022). Due to missing values in the participants’ responses to our online questionnaire, we needed to reduce the dataset to \( N = 85 \) for this data analysis. As detailed in Table 2, except for the variance in participant’s interest in science and the variance in their aversion when thinking about teaching natural sciences to primary school children, the variances and means of the instruments we used in our online questionnaire did not show significant differences between both universities. Therefore, and because no further differences between participants from both universities were found (e.g., for their age, gender, study program; see earlier discussion), a differentiated analysis of participants from the Universität Hamburg and the University College of Teacher Education of Christian Churches Vienna/Krems was omitted for the quantitative data analysis.

To examine hypotheses H1.1 and H2.1, we performed correlation analyses (Pearson’s \( r \)) between participants’ responses to our developed single-item instrument, their scores on the multiple-item instrument for assessing sense of belonging to science, their interest in science, and their science-related self-concept. Based on the standardized scores,\(^2\) we also determined the degree of absolute agreement of these instruments (ICC(A,1); see McGraw & Wong, 1996) as an alternative benchmark for examining both hypotheses. In addition, we determined partial correlations (based on Pearson’s \( r \)) between our developed instrument and the three mentioned instruments, following hypotheses H1.2, H2.2.1, and H2.2.2.

Participants’ ratings regarding their feelings of self-doubt, aversion, and anxiety when thinking about teaching natural sciences to primary school children serve as dependent variables within several multiple regression models (hypotheses H3.1–H3.3). More precisely, we included each rated feeling into two multiple regression models as the dependent variable. Each regression model includes participants’ sense of belonging to science as an independent variable. Additionally, because participants’ interest in science and science-related self-concept are both constructs that can be distinguished from their sense of belonging to science (see earlier discussion), we also included these constructs as independent variables in our regression models. Beyond that, the two regression models we calculated for each rated feeling differ according to which of our instruments for assessing sense of belonging to science was used as an independent variable: in one of the two models, we used the multiple-item instrument to assess participants’ sense of belonging to science (Models 1-I, 2-I, 3-I; see Section 4, Table 5), whereas in the other model, we used our single-item instrument (Models 1-II, 2-II, 3-II; see Section 4, Table 5). To determine whether our data meet the assumptions for multiple-regression modeling, we followed the procedure detailed by Veith, Girnat, and Bitzenbauer (2022).

## 4 Results

### 4.1 Qualitative Results

As summarized in Table 3, our qualitative data analysis revealed three ways in which participants reasoned regarding their response to our developed instrument. First, the vast majority of participants explained their response behavior on our developed instrument based on their limited sense of belonging to science, which, in turn, strongly supports the content validity of our instrument. More precisely, participants based their reasoning on their personal feelings of connectedness to science itself (e.g., “I am not a scientist but a teacher with scientific knowledge”; “as a primary school teacher, I am a representative of the natural sciences, exposing children to them”) and to people involved in the natural sciences (e.g., “I have very little connection to members of the natural sciences community”). Furthermore, recognition and acknowledgement by others within science-related contexts (e.g., “I don’t feel others see me as a full-fledged science person”; “[from my science lecturers] I sometimes feel treated too much like a primary school student”) play an important role in participants’ reasoning. Sense of belonging to science is the most frequently expressed reason (69.44% of the open-ended responses) participants use to explain why they chose a particular diagram in our developed instrument.

A minority of the participants (41.67%) explained their response to our developed instrument by associating not belonging to science with a lack of scientific knowledge. In this regard, participants consider scientific knowledge, on one hand, to be a prerequisite for belonging to science itself (e.g., “I struggle with understanding physics and chemistry, which is why I don’t see myself belonging to

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\(^2\) Given that the response scales of the instruments we used in the present study differed in their scale range (see Section 3.3), standardization of the scores was necessary to determine the degree of absolute agreement between these instruments.
the natural sciences”). On the other hand, some participants also regard scientific knowledge as a prerequisite for the ability to communicate regarding science, which, in turn, represents a barrier to them belonging to science (e.g., “Currently, I lack sufficient knowledge to talk with others about scientific issues”).

Finally, some participants also explained why they chose a particular diagram in our developed instrument based on their interest in science (e.g., “I find many topics covered in the natural sciences, especially biology, quite interesting”) and/or the extent to which they personally value the natural sciences (“I find natural sciences exciting, and my world view is based on them”). In this regard, it is noteworthy that, except for the response of a single participant (“my personal interests have no intersections with natural sciences”), all corresponding open-ended responses indicated a positive attitude toward the natural sciences. However, having an interest in and/or personally valuing science is, by far, the reason participants least commonly use to explain their response to our developed instrument (19.44%).

Overall, the qualitative analysis of participants’ open-ended answers regarding their response to our developed instrument revealed that most of the responses tended to be negative and detailed on why participants do not feel they belong to science. However, this indication is reversed if the participants also included their interest in science in their reasoning.

### 4.2 Quantitative Results

#### 4.2.1 Convergent and Discriminant Validity

Table 4 summarizes the results of the correlation analyses we conducted in order to evaluate the convergent and the discriminant validity of our single-item instrument. In line with hypothesis H1.1, our developed instrument is positively and strongly correlated with the administered multiple-item instrument for assessing sense of belonging to science ($r = 0.62; p < 0.001$; ICC(A,1) = 0.63; $p < 0.001$). Moreover, our data analysis revealed a positive and moderate partial correlation between these two instruments ($r_{\text{part}} = 0.43; p < 0.001$) when we control for the relationships between our developed single-item instrument and pre-service primary school teachers’ interest in science, as well as their science-related self-concept. Therefore, based on our data analysis, hypotheses H1.1 and H1.2 were confirmed, which, in turn, provides a strong indication regarding the convergent validity of our developed instrument.

Equivalently, this applies to the results of our data analysis regarding our developed instrument’s discriminant validity (hypotheses H2.1 and H2.2). Our instrument correlates only moderately with participants’ interest in science ($r = 0.46; p < 0.001$; ICC(A,1) = 0.48; $p < 0.001$) and science-related self-concept ($r = 0.50; p < 0.001$; ICC(A,1) = 0.50; $p < 0.001$). Furthermore, when we control for the relationships between our single-item instrument and the administered multiple-item instrument for assessing sense of belonging to science, as well as the relationships between our single-item instrument and participants’ science-related self-concept, there is no partial correlation between our instrument and participants’ interest in science ($r_{\text{part}} = 0.14; p = 0.22$). Analogously, there is no partial correlation between our developed single-item instrument and participants’ science-related self-concept ($r_{\text{part}} = 0.06; p = 0.61$).

In this case, we controlled for the relationships between our instrument and the administered multiple-item instrument for assessing sense of belonging to science, as well as the relationship between our developed instrument and participants’ interest in science.

#### 4.2.2 Concurrent Validity

To explore our developed instrument’s concurrent validity (hypotheses H3.1–H3.3), we calculated a total of $3 \times 2 = 6$

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Correlation (Pearson’s $r$)</th>
<th>Intraclass correlation ICC(A,1)</th>
<th>Belonging-s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belonging-m</td>
<td>0.62***</td>
<td>0.63***</td>
<td>0.43***</td>
</tr>
<tr>
<td>Interest</td>
<td>0.46***</td>
<td>0.48***</td>
<td>Controlled</td>
</tr>
<tr>
<td>Self-concept</td>
<td>0.50***</td>
<td>0.50***</td>
<td>Controlled</td>
</tr>
</tbody>
</table>

Note: belonging-s = single-item instrument for assessing sense of belonging to science; belonging-m = multiple-item instrument for assessing sense of belonging to science; interest = interest in science; self-concept = science-related self-concept; $p = p$-value; ***: $p < 0.001$; controlled = controlled variables within the partial correlation analysis; following the rules of thumb provided by Cohen (1988) and by Cicchetti (1994) Pearson’s $r > 0.50$ indicates a strong correlation and an intraclass correlation $>0.60$ qualifies as “good.”
multiple regression models (see Section 3). As indicated in Table 5, for each of these multiple regression models, an F-test was used to verify its statistical significance. Furthermore, according to a common rule of thumb ($R^2 > 0.30$; Mehmetoglu & Mittner, 2022), with $0.44 \leq R^2 \leq 0.54$, these models explain a high degree of variance in their dependent variable (participants' feelings of self-doubt/aversion/anxiety when thinking about teaching natural sciences to primary school children). As detailed in the following, in summary, the results of these multiple regression analyses support the concurrent validity of our developed instrument.

Focusing on the regression models using our developed single-item instrument for assessing sense of belonging to science as an independent variable (Table 5, Models 1-II, 2-II, and 3-II), we find that it highly significantly predicts participants' feelings of self-doubt and anxiety while thinking about teaching natural sciences in primary school, while it is (narrowly; $p = 0.080$) not a significant predictor of

Table 5: Result of multiple regression analysis and bivariate correlations

<table>
<thead>
<tr>
<th>Variable</th>
<th>Feeling self-doubt when thinking about teaching natural sciences in primary school</th>
<th>Feeling aversion when thinking about teaching natural sciences in primary school</th>
<th>Feeling anxious when thinking about teaching natural sciences in primary school</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td></td>
<td>Model 1-I</td>
<td>Model 2-I</td>
<td>Model 3-I</td>
</tr>
<tr>
<td></td>
<td>Model 1-II</td>
<td>Model 2-II</td>
<td>Model 3-II</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>SE</td>
<td>$\beta$</td>
</tr>
<tr>
<td><strong>Constant</strong></td>
<td>8.27</td>
<td>0.61</td>
<td>***</td>
</tr>
<tr>
<td><strong>Belonging-m</strong></td>
<td>-0.62***</td>
<td>-0.80</td>
<td>0.24</td>
</tr>
<tr>
<td><strong>Belonging-s</strong></td>
<td>-0.52***</td>
<td>-0.12</td>
<td>0.25</td>
</tr>
<tr>
<td><strong>Interest</strong></td>
<td>-0.53***</td>
<td>-0.48</td>
<td>0.12</td>
</tr>
<tr>
<td><strong>Self-concept</strong></td>
<td>-0.68***</td>
<td>0.84</td>
<td>-0.27</td>
</tr>
<tr>
<td></td>
<td>$R^2 = 0.54, R^2_{adj} = 0.53$</td>
<td>$F(3, 81) = 32.18, p &lt; 0.001$</td>
<td>$R^2 = 0.51, R^2_{adj} = 0.49$</td>
</tr>
</tbody>
</table>

Note. (1), (2), (3) = results of multiple regression analysis and bivariate correlations regarding participants' feelings of self-doubt, aversion, and anxiety when thinking about teaching natural sciences to primary school children; negative coefficients result from the scaling of the instrument we used to assess participants' feelings of self-doubt, aversion, and anxiety (see Section 3.3); belonging-m = multiple-item instrument for assessing sense of belonging to science; belonging-s = single-item instrument for assessing sense of belonging to science; interest = interest in science; self-concept = science-related self-concept; $R^2 = $ coefficient of determination; $R^2_{adj} = $ adjusted coefficient of determination; Model I = Model using the multiple-item instrument to assess participants' sense of belonging to science; Model II = Model using the single-item instrument to assess participants' sense of belonging to science; constant = regression constant; $B = $ regression coefficient; $SE = $ regression coefficient standard error; $\beta = $ standardized regression coefficient; $F = $ F-statistic, $p = $ p-value; *: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$. 


participants’ feelings of aversion. Analogously, these results also apply to the regression models that use the multiple-item instrument for assessing sense of belonging to science as an independent variable (Table 5, Models 1-I, 2-I, and 3-I).

Beyond that, comparing the models including our single-item instrument versus the models including the multiple-item instrument for assessing sense of belonging to science reveals predominantly similarities but also a notably difference. There are similarities when we compare Models 1-I and 1-II and Models 2-I and 2-II. In both cases, the rank order of the standardized regression coefficients of the independent variables is identical. However, this is not the case when we consider Models 3-I and 3-II. Within Model 3-I, as compared to the other two independent variables (interest in science and science-related self-concept), a sense of belonging to science is the strongest predictor of participants’ feelings of anxiety while thinking about teaching natural sciences in primary school, while in Model 3-II, it is merely the second-strongest predictor. In our view, a reasonable explanation for this shift in the rank of the standardized regression coefficients of Models 3-I and 3-II is that the multiple-item instrument for assessing sense of belonging to science includes items that address feelings of anxiety in science-related contexts (e.g., “I feel uncomfortably tense around people involved and engaged in the natural sciences”). In contrast, our developed single-item instrument does not encompass such anxiety-related aspects, which is presumably why the multiple-item instrument better predicts participants’ feelings of anxiety when thinking about teaching natural sciences to primary school children (β = −0.40 versus β = −0.21). Similarly, the multiple-item instrument for assessing sense of belonging to science also includes items that address feelings of self-doubt in science-related contexts (e.g., “When I am surrounded by people involved and engaged in the natural sciences, I wish to be invisible”), which reasonable explains why the standardized regression coefficients for sense of belonging in Model 1-I is higher than in 1-II (β = −0.35 versus β = −0.21).

5 Discussion and Conclusion

This article presented the results of an exploratory study that investigated whether pre-service primary school teachers’ sense of belonging to science can be validly assessed during university-based teacher education using a single-item instrument. To this end, we substantially revised the Inclusion of Other into the Self Scale, created by Aron et al. (1992), into a single-item instrument that assesses the extent to which a person perceives a sense of belonging to sciences and administered this single-item instrument to a sample of N = 91 pre-service primary school teachers within their university-based teacher education programs at the Universität Hamburg (Germany) and the University College of Teacher Education of Christian Churches Vienna/Krems (Austria).

By analyzing the surveyed data qualitatively and quantitatively, we were able to identify cogent evidence that our developed single-item instrument enables a valid assessment of primary school teachers’ sense of belonging to science. On the one hand, our qualitative data analysis revealed that the vast majority of participants who responded to our open-ended question in our developed instrument explained their response behavior on their sense of belonging to science. On the other hand, the results of the quantitative data analysis are consistent with the hypotheses based on which we examined the convergent, discriminant, and concurrent validity of our developed single-item instrument: our developed instrument is strongly correlated with a previously validated multiple-item instrument for the assessment of pre-service primary school teachers’ sense of belonging to science. In addition, it is only moderately correlated with other constructs related to but distinguishable from pre-service primary school teachers’ sense of belonging to science, like their interest in science and their science-related self-concept. Similarly, we obtained a significant partial correlation between our developed instrument and the administered multiple-item instrument for assessing sense of belonging to science but not between our developed instrument and participants’ interest in science or science-related self-concept. Beyond that, by calculating several multiple regression models, our data analysis revealed that our single-item instrument significantly predicts the extent to which pre-service primary school teachers feel self-doubt or anxiety when thinking about teaching natural sciences to primary school children, while it does not predict participants’ corresponding feelings of aversion. Furthermore, we found that regression models using our developed single-item instrument as an independent variable and regression models that, instead, use the administered multiple-item instrument for the assessment of pre-service primary school teachers’ sense of belonging to science lead predominantly – with some reasonable exceptions (see Section 4, Table 5) – to comparable result.

Apart from these quite promising results, our study also revealed some validity limitations of our developed instrument, which researchers should take into account when considering using our developed instrument within their research. Although our developed instrument is strongly correlated with a previously validated multiple-item instrument for the assessment of pre-service primary
school teachers’ sense of belonging to science, this correlation does not qualify as very strong or excellent ($r = 0.62; ICC(A,1) = 0.63$). This, in turn, indicates that using our developed instrument within empirical research should not be considered as a complete equivalent to the use of a multiple-item instrument for the assessment of pre-service primary school teachers’ sense of belonging to science, but rather as a reasonable and valid proxy. In addition, our qualitative data analysis showed that a minority of our participants explained their response to our developed instrument based on other constructs than their sense of belonging to science (e.g., their interest in science). This suggests that, to a minor extent, our developed instrument may also cover constructs related to but distinguishable from pre-service primary school teachers’ sense of belonging to science, which could lead to spurious effects within future research that addresses these constructs and uses our developed instrument.

As a final note, due to our methodological approach, there are several limitations regarding the results of our study, which should also be considered. We administered our developed instrument only to pre-service primary school teachers in their third semester of university-based teacher education programs at the Universität Hamburg and the University College of Teacher Education of Christian Churches Vienna/Krems. Therefore, based on our results, it is not yet possible to draw conclusions about whether our developed instrument validly assesses pre-service teachers’ sense of belonging to science within university-based teacher education programs significantly differing from the primary school teacher education programs in Hamburg and Vienna/Krems or when administering it to pre-service teachers in other semesters of university-based teacher education. Hence, it might be particularly fruitful for future research to repeat the present study, for example, with pre-service primary school teachers at the beginning/end of their university-based teacher education, or with pre-service high-school science teachers. Furthermore, given the fact that the present study is exploratory in nature, we refrained from adjusting the global significance level within our quantitative data analysis (e.g., via Bonferroni correction). Therefore, when the term “significance” is used in the article, it only refers to the occurrence of noticeably small $p$-values, which should be confirmed in future studies (Victor, Elsäßer, Hommel, & Blettner, 2010). Finally, because in this study, we recorded only a relatively small number of open-ended reasoning responses to our developed instrument, future research should provide further insight regarding the validity of our developed instrument on a qualitative level. For example, a larger sample of open-ended responses could be used to examine whether and to what extent participants who show different response behavior on our developed instrument also differ in terms of the reasons they express regarding their response behavior.

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**Author contributions:** Both authors contributed to all stages of this research, including data collection, analysis, and the writing of the present article. MF supervised the project. All authors have read and approved the manuscript.

**Conflict of interest:** The authors state no conflict of interest.

**Ethical Statement:** The study presented in this article was carried out following the legal and ethical standards for educational research in Germany and Austria (see Section 3). Participants were informed about the aim of this study and participated in the study voluntarily and anonymously.

**References**


Chung-Parsons, R., & Bailey, J. M. (2019). The hierarchical (not fluid) nature of preservice secondary science teachers’ perceptions of


