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Interest, learning opportunities and teaching experience as predictors of professional vision in gender-sensitive physics education

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ABSTRACT
To promote gender equity in physics education, it is essential to understand the factors that influence how even pre-service teachers perceive, interpret and make decisions when gender inequities arise in the classroom. This means that we need to pay particular attention to teachers' professional vision of gender-sensitive physics teaching. The following study examines pre-service teachers' interest in gender-sensitive teaching and learning, as well as their learning opportunities and teaching experiences as potential predictors of their professional vision. A questionnaire and a vignette test were used for a cross-sectional survey of 586 pre-service teachers in Switzerland. Structural equation modeling (SEM) was used to analyse the predictors. The results contribute to the current research on gender-sensitive physics education, highlighting the importance of interest as the strongest predictor, followed by teaching experience and number of learning opportunities. The results are discussed in terms of their relevance for teacher training programs in gender-sensitive science education.

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Professional vision; physics education; gender equity

Introduction

In 34 out of 43 OECD[1] countries, female students are in the minority in the field of science, technology, engineering and mathematics (STEM). In Switzerland, where this study took place, the country exhibits a lower percentage of female STEM graduates, with only 23%, compared to the OECD average of 32%. Notably, there is a significant gender segregation, particularly evident in the field of physics (OECD, 2016, 2018). Internationally, there is a broad consensus in research and policy domains that additional efforts are required to broaden and enhance participation in STEM, especially in physics (Archer et al., 2020; Mujtaba & Reiss, 2013). Also, the Agenda 2030 gives special importance to Sustainable Development Goals (SDGs) 4 and 5, focusing on quality, inclusive, and fair education, along with gender equality and empowering

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girls (United Nations, 2021). It urges countries to boost their investment in STEM education, ensuring equal opportunities for girls.

Identifying barriers that contribute to gender segregation and implementing support measures to eliminate these obstacles are central goals in gender-sensitive physics education (McCullough, 2007). In physics, a multitude of barriers for girls within various facets of physics education have already been identified (Atanasova et al., 2023, for an overview). For instance, these encompass competitive learning styles that are typically promoted in physics classrooms (Riegle-Crumb et al., 2019; Zohar & Sela, 2003), as well as unequal participation in experimentation within mixed-gender groups (Benke & Stadler, 2008; Jahnke-Klein, 2013), the dissemination of physics content through stereotypically male examples (Murphy & Whitelegg, 2006), the use of gender-biased teaching materials (Makarova et al., 2021), or the phenomenon in which teachers call on and pose less challenging questions to female students less frequently (McCullough, 2002).

It is important to understand how gender-related differences can arise and which aspects of classroom teaching should be taken into account by teachers (Lesperance et al., 2023). In the quest to promote gender equity in physics education and advance the cause of gender-sensitive education, teachers play a pivotal and enduring role as facilitators (Kollmayer et al., 2020; Murphy & Whitelegg, 2006). They can contribute to greater gender equity by reducing barriers that girls often encounter in physics classrooms, enabling all students to realise their full potential (Zohar & Bronshtein, 2005).

In order for teachers to engage in this, it is crucial for them to initially perceive relevant aspects in the classroom that are not in line with gender equity in physics education and derive actions that promote gender-sensitive teaching Bartsch and Wedl (2015, p. 20). This so-called professional vision of teachers (Blömeke et al., 2015) —comprising perception, interpretation, and decision-making regarding aspects crucial for gender-sensitive education— plays a decisive role in promoting gender equity in the field of physics education.

Identifying and understanding the relevant factors that influence professional vision is of particular importance. It allows us to explore how we can foster this key competence in teachers, so that learners can benefit from gender-sensitive teaching. These considerations are already particularly relevant in teacher education and form the context of this study.

Pre-service teachers should already be trained in how to design gender-sensitive lessons and be made aware of non-gender-sensitive aspects in the classroom. Therefore, the professional vision of teachers is of particular interest during teacher training. Stürmer et al. (2014) emphasise both individual characteristics of pre-service teachers (e.g. interest) and formal and informal learning opportunities within teacher education as important factors contributing to the development of professional vision.

Despite the wealth of research on professional vision in different subject-specific teaching dimensions (e.g. mathematics, Kersting, 2008) or in general teaching dimensions such as classroom management (Gold et al., 2021; Stahnke & Blömeke, 2021) or inclusion (Keppens et al., 2019; Roose et al., 2022), knowledge about professional vision in the context of gender-sensitive physics teaching is still limited (Atanasova et al., 2023; Brovelli et al., 2019).

This study aims to contribute to addressing this research gap and focuses on investigating predictors of pre-service teachers' professional vision.

Theoretical background

The professional vision of gender-sensitive physics teaching

Professional vision describes the ability to perceive and interpret relevant features of classroom situations (Meschede et al., 2017; Santagata & Yeh, 2016; van Es & Sherin, 2002). As shown in Figure 1, it is understood as a situation-specific skill that mediates between teachers' dispositions and performance and involves *perceiving (P)* specific classroom situations relevant to students' learning, knowledge-based *interpretation (I)* of these events, and *making decisions (D)* about how to respond to these situations, also known as the PID structure (Blömeke et al., 2015). In pedagogical contexts characterised by the concurrent occurrence of multiple events vying for the teacher's attention, the significance of the concept of professional vision is accentuated, as emphasised by Heinonen et al. (2023). Consequently, teachers must initially cultivate the capacity to notice relevant aspects before they can proficiently comprehend and facilitate student learning within such complex scenarios.

Professional vision regarding gender-sensitive physics teaching includes perception, interpretation and decision-making relating to aspects that are crucial for gender-sensitive teaching (Atanasova et al., 2023; Brovelli et al., 2019). Perception, as a component of professional vision, includes selective attention, which enables teachers to identify aspects that promote or hinder gender-sensitive teaching, so-called gender-relevant aspects. Teachers utilise their prior knowledge, structured within schemas, to construct a cognitive representation of the situation during perception (König et al., 2015). Thus, knowledge of typical gender inequities within different facets of gender-sensitive physics teaching can help to perceive these aspects in the classroom. Interpretation is a cognitive process that involves deriving meaning from perceived and relevant elements (Seidel & Stürmer, 2014). Decision-making, as the final component of professional vision, involves either anticipating a response to students' activities or proposing alternative instructional strategies to improve students' learning opportunities (Blömeke et al., 2015; Santagata & Yeh, 2016). In the context of the professional vision regarding gender-sensitive physics

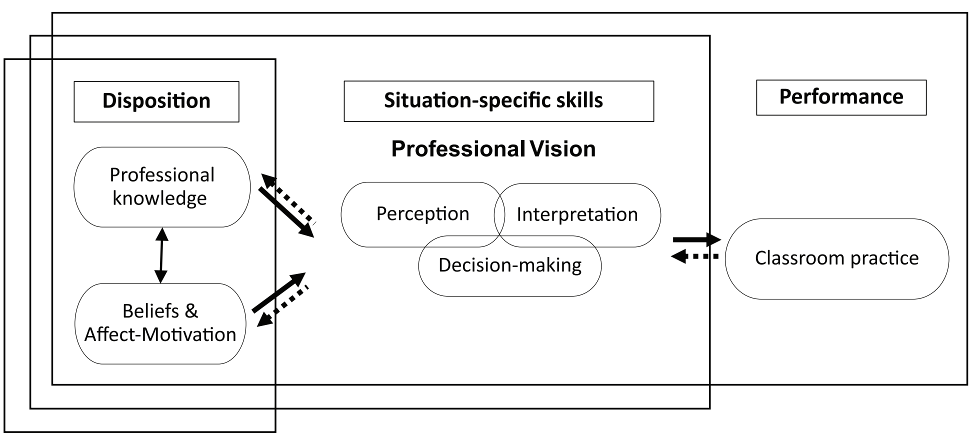

Figure 1. Competence model based on Meschede et al. (2017), Blömeke et al. (2015) and Santagata and Yeh (2016).

teaching, this means the process of making informed decisions about actions or taking measures that, when put into practice, lead to a gender-sensitive educational environment (Atanasova et al., 2023). Relevant aspects regarding gender-sensitive physics teaching that need teachers' attention can occur within different facets of teaching. Based on the framework of situation-specific skills in the context of gender-sensitive physics education (Atanasova et al., 2023), the present study explores the professional vision through four facets that are essential for ensuring gender-sensitive physics education: gender-sensitive *forms of instruction* and *teaching of physics content*, as well as *teaching materials* and *feedback and interactions*, which will now be discussed in more detail.

The first facet *form of instruction* underlines the importance of the active participation of all genders in the classroom (Labudde et al., 2000; Zohar & Sela, 2003). Previous studies have confirmed that girls in particular may withdraw from classroom activities in physics during certain practices and thus be disadvantaged. These include, for example, the negative emotional feelings of girls in competitive situations in physics classes (Buser et al., 2017; Riegle-Crumb et al., 2019; Zohar & Sela, 2003), or stereotypical work when experimenting in gender-mixed groups, where girls often write the protocol and leave the activities to the boys (Benke & Stadler, 2008; Heinicke et al., 2017). Teachers should be attentive to gender differences in participation and be able to counteract them with appropriate strategies. To this end, the design of lessons should be analysed and reflected in terms of the extent to which prevailing gender inequities are manifested by classroom structures (Kollmayer et al., 2020; Kreienbaum & Urbaniak, 2006).

The second facet of *teaching physics content* is geared toward ensuring that the chosen content is oriented toward the interests, previous experiences and everyday life of all genders in order to arouse the interest of as many learners as possible in physics (Hoffmann, 2002; McCullough, 2004). If mainly boys' interests are taken into account or only male-dominated examples are used in physics lessons (such as cars, motors or cranes), the stereotype that girls are not intended for this subject area is reinforced (Murphy & Whitelegg, 2006; Wenger & Makarova, 2019; Wheeler & Blanchard, 2019). Girls' perceived barriers to accessing physics content through contexts stereotypically aimed at boys hinder their full exploration, learning and immersion in the subject (Wheeler & Blanchard, 2019).

In Switzerland, where the study took place, the curriculum gives teachers significant freedom in how they teach physics content. The Swiss curriculum focuses on competencies rather than fixed content. For example, in the area of mechanics, the following competency is required: students should be able to analyze movements and the effects of forces (D-EDK, 2016). This approach gives teachers considerable freedom in how they develop specific content and in the contexts in which they present physics-related topics in their lessons, allowing them to tailor their teaching and ensure that students achieve the required competencies with considerable flexibility. Teachers should make use of this freedom and therefore pay close attention to how they counteract male perceptions of physics and how they develop approaches to physics content that are relevant to both girls and boys.

Another important facet is the *teaching materials* utilised in the classroom. In addition to subject content, teaching materials also convey social norms and values and offer learners opportunities for identification through language and images (Good et al., 2010; Moser & Hannover, 2014). Studies of physics teaching materials with regard to gender equity in Germany and Switzerland demonstrate a qualitatively and quantitatively unbalanced representation of genders. In the teaching materials analysed, women are clearly underrepresented in both text and illustrations compared to men. They are still depicted in stereotypical gender roles in which they are mainly active in domestic and social areas of life, and their scientific achievements remain unmentioned, which means that practically no female physicists are represented in the teaching materials (Herzog et al., 2019; Jenderek, 2015; Makarova et al., 2021). Students who are predominantly confronted with such teaching materials unconsciously adopt the message that physics is a male domain (Elsen, 2020; Makarova et al., 2021). Teachers should identify such non-gender-sensitive teaching materials on both a formal and a content level. Teachers' sensitivity toward gender-sensitive teaching materials is particularly important considering the fact that teachers do not only use textbooks in the classroom, but also create teaching materials and documents themselves (Jenderek, 2015).

The last facet focuses on *feedback and interactions* and thus on how teachers contribute to gender differences in physics education through their interactions and feedback toward girls and boys (Hoffmann, 2002; Murphy & Whitelegg, 2006). Studies from physics lessons show that teachers call on boys more often than girls and ask them more challenging questions (McCullough, 2002). They more frequently praise girls for their neatness and orderliness, whereas they focus on content aspects with boys (Schmirl et al., 2012) and encourage girls significantly less often than boys (Mujtaba & Reiss, 2013). Awareness of these usually unconscious structures is essential for the design of successful gender-sensitive physics teaching and the promotion of gender equity.

As outlined, gender inequities can manifest themselves in various aspects of the classroom and, due to their complexity, may perpetuate gender disparities in physics education. To surmount obstacles to gender equity in physics classrooms, numerous formal and informal initiatives have been established to address the gender disparity in STEM (Buck et al., 2020). The aim of these interventions is to improve the correspondence between (a) the cognitive, personal, or perceived characteristics of girls and women and (b) the requirements or opportunities present in STEM (Liben & Coyle, 2014, p. 91–92). In their discussion of making physics more equitable, Archer et al. (2020, p. 379) emphasise 'interventions might most usefully be directed at changing the field of physics and the physics classroom, rather than focusing on trying to change students (particularly girls), as many currently do.' Many of these formal and informal approaches focus on individualised efforts to enthuse students, especially girls, about physics and spark their interest. However, they often overlook the crucial role of teachers, who interact with countless students and can serve as a sustainable starting point by indirectly influencing students (Kollmayer et al., 2020) Teachers should understand how gender differences in the classroom emerge (e.g. in motivation, performance, interest), recognise how they may contribute to these differences, and learn strategies and methods for implementing gender-sensitive teaching (Kollmayer et al., 2020). In their book chapter 'Practical Strategies for Detecting and Correcting Gender Bias in Your Classroom,' Sadker and Zittlemann (2007) describe an approach that involves carefully observing one's own teaching, first describing it before interpreting it, and then using strategies to address and correct gender bias. A promising approach is to sensitize teachers to gender-sensitive teaching during their initial teacher education and later through professional development, so they develop an awareness of classroom challenges (Archer et al., 2020; Kollmayer et al., 2020).

In summary, solutions to the gender gap in STEM should involve interventions in the context of science education, and teachers should engage with the issue and reflect on their practice.

Possible predictors of professional vision in gender-sensitive teaching

Research indicates that professional vision is a crucial component of effective teaching, as it allows teachers to understand what is happening in the classroom and respond appropriately to students' needs (Seidel et al., 2021). The factors within university-based teacher education that influence pre-service teachers' professional vision are of particular interest for the further development of this skill (Bastian et al., 2024; Stürmer et al., 2014). A key component is the learning opportunities provided during the program, which pre-service teachers can use as sources for knowledge acquisition. These formal learning opportunities are organised by the teacher education program at universities and follow an internal curriculum.

In addition to formal learning opportunities, practical teaching experience through internships is a significant part of teacher education, providing chances to reflect on practice and develop professional vision (Bastian et al., 2024; Stürmer et al., 2014). Both pre-service teachers' teaching experiences and the learning opportunities during their studies are potential predictors and are important from a teacher education perspective (Bastian et al., 2024; König et al., 2014; Stürmer et al., 2013, 2014; Todorova et al., 2017).

Furthermore, it can be deduced from theoretical competence models that teachers' dispositions, which include both cognitive (e.g. knowledge) and affective-motivational elements (e.g. beliefs, attitudes and interests), are related to teachers' professional vision (Blömeke et al., 2015; Meschede et al., 2017; Santagata & Yeh, 2016). Stürmer et al. (2014) view interest as an important indicator of the individual characteristics of pre-service teachers and a significant predictor of professional vision, thus explaining learning outcomes in university-based teacher education.

With the aim of examining the predictors of interest, learning opportunities, and teaching experience in the specific context of professional vision regarding gender-relevant aspects, we expect to gain a better understanding of these predictors. They should help to identify how pre-service teachers develop their ability to recognise and respond to gender inequities in the classroom. This knowledge is crucial for creating equitable and inclusive learning environments that support the success of all students. In the following, we present the three possible predictors (interest, learning opportunities and teaching experience) and discuss them with regard to their significance for the professional vision of gender-sensitive physics teaching.

Interest

In the context of classroom practice, teacher interest has been identified as a significant influencing factor. For instance, Schiefele et al. (2013) have demonstrated that teachers' interest serves as a crucial predictor of their instructional practices, which foster student learning and motivation. The stronger their interest in didactic issues, the more likely they are to employ methods involving internal differentiation and cognitive stimulation. However, there has been limited research on the extent to which teachers' interest influences the preliminary stage of classroom practice, i.e. their professional vision. One of the few studies examining this relationship is that of Stürmer et al. (2014), which revealed a positive correlation between the professional vision of pre-service teachers ($N = 443$) in domains such as goal clarity, teacher support, and the learning climate, and their interest in teaching and learning related to a generic pedagogical content area.

So far, there is limited knowledge regarding pre-service teachers' interest in gender-sensitive teaching and learning. Preliminary findings from a study in Switzerland suggest that pre-service teachers ($N = 548$) are generally highly interested in the topic, with female pre-service teachers exhibiting a significantly higher level of interest, albeit with only a small effect ($r = 0.18$) (Atanasova et al., 2024a). Whether there is a relationship between the pre-service teachers' interest in gender-sensitive teaching and learning and their professional vision has, to our knowledge, not been investigated thus far. Based on the findings of Stürmer et al. (2014) we anticipate that interest in gender-sensitive teaching and learning plays a pivotal role in pre-service teachers' professional vision, given that this particular element explicitly pertains to aspects of teaching that foster gender equity.

Hypothesis 1 (H1). Interest in gender-sensitive teaching and learning is a significant predictor of pre-service teachers' professional vision of gender-sensitive teaching.

Learning opportunities

Formal learning opportunities within teacher education programs serve the purpose of preparing future teachers for effective classroom practices, thereby providing a source for acquiring knowledge across various domains (Stürmer et al., 2014). Learning opportunities for gender-sensitive teaching enable pre-service teachers to address gender stereotyping in society and the related gender differences in students (e.g. in interest or self-efficacy) and to reflect on how the school as an institution or teachers contribute to gender inequities in teaching. The demand for competent teachers, able to create gender-sensitive science education is high, emphasising the need for universities of teacher education to provide learning opportunities for this purpose (Atanasova et al., 2024a, 2024b; Langfeldt & Mischau, 2011; Merayo & Ayuso, 2022). The relationship between the number of learning opportunities during teacher training and the professional vision of pre-service teachers has been examined in previous studies. Stürmer et al. (2013, 2014) demonstrated a positive correlation between the number of pedagogical courses where theories of teaching and learning are taught and pre-service teachers' professional vision (Stürmer et al., 2013, 2014).

Building upon these results we assume that the number of learning opportunities that pre-service teachers attend during their training on this topic will have an influence on their professional vision.

Hypothesis 2 (H2). The quantity of learning opportunities for gender-sensitive teaching are a significant predictor of pre-service teachers' professional vision of gender-sensitive teaching.

Teaching experience

To facilitate the application of theoretical knowledge in practical contexts, internships are integrated into all university teacher education programs (Stürmer et al., 2014). Practical experiences in school serve as crucial opportunities for pre-service teachers to develop their expertise (König et al., 2014). Complementary to formal learning opportunities in teacher education, which are often aimed at acquiring theoretical knowledge, classroom experiences'give future teachers the chance to connect their knowledge to practical situations in the classroom' (König et al., 2014, p. 79). In this respect, teaching experiences are also important to consider in relation to pre-service teachers' professional vision. Research examining the impact of practical experience on professional vision is limited and yields contradictory results. The outcomes of a study by Stürmer et al. (2013) indicate that pre-service teachers who participated in a seminar combining theoretical and practical elements had a positive change in their professional vision. Similarly, Bastian et al. (2024) examined the impact of teaching internships on pre-service teachers' perception, interpretation, and decision-making within the context of secondary mathematics education. They assessed pre-service teachers' situation-specific skills before and after the internships using t-tests, revealing significant improvements with small but significant effect sizes ($d = 0.31–0.39$). In contrast, other works showed that the amount of practical experience does not explain the differences in pre-service teachers' professional vision (Simpson et al., 2018; Stürmer et al., 2014; Todorova et al., 2017).

We assume that classroom experiences serve as valuable resources and provide opportunities for pre-service teachers to confront and address specific gender inequities in the educational setting, such as the underrepresentation of female scientists in teaching materials. As pre-service teachers engage with diverse learning opportunities during teaching, we posit that these experiences play a crucial role in shaping their understanding and sensitivity to gender-related dynamics within the classroom. Therefore, we believe that these teaching experiences can significantly influence pre-service teachers' professional vision regarding gender-relevant aspects.

> **Hypothesis 3 (H3).** Teaching experience is a significant predictor of pre-service teachers' professional vision of gender-sensitive teaching.

To advance the scientific understanding of pre-service teachers' professional vision of gender-sensitive physics teaching, we investigated these possible predictors of professional vision: pre-service teachers' interest in gender-sensitive teaching and learning, learning opportunities regarding gender-sensitive teaching and teaching experience.

Research method

Based on our research purposes, this study adopted a cross-sectional survey design. In this section, the sample, the different instruments, and the data analysis steps used are described in detail.

Participants

The study was conducted with pre-service teachers who will teach at the secondary education level after completing their training ($N = 586$). In Switzerland, the secondary education level succeeds the six-year primary level, typically spanning from the seventh to the ninth school year and catering to students aged 12 to 16. In secondary school, all pupils must take the subject 'sciences', which includes areas such as physics, biology and chemistry.

Data were collected from September 2021 until June 2022 at the five largest universities of teacher education in the German-speaking region of Switzerland. Universities from different regions of Switzerland, all in the German-speaking area, were surveyed. These universities usually follow a 4.5-year (nine semesters) curriculum program (270 European Credit Transfer System (ECTS), master's degree) to become a secondary teacher. In Switzerland, teacher education for secondary level I is a combined bachelor-master's degree program. Pre-service teachers typically choose between three and four different subjects to teach at the secondary level I, with science being one of the options. The curriculum includes educational sciences, subject-specific education and practical vocational training with internships. Pre-service teachers were notified of the survey by their professors and given the opportunity to participate in their modules, allowing for the survey of entire class cohorts. Pre-service teachers from all semesters ($M = 4.7$, $SD = 2.7$) were surveyed, all of whom majored in science and are allowed to teach science (biology, chemistry, physics) at the secondary level after graduation. The age of the pre-service teachers ranged from 18 to 55 years, with an average of 24.3 years ($SD = 4.9$). The average age of students at the universities of teacher education in Switzerland at secondary level I is 23.4 years, which is slightly lower than in our study (SKBF, 2023). In our study, 49.5% reported being female, 49.5% male, 0.5% indicated a non-binary gender and 0.5% did not provide their gender. According to the Swiss Education Report 2023, the proportion of female pre-service teachers at the surveyed universities for secondary level I ranged between 51% and 56%, slightly higher than the female proportion in our survey (SKBF, 2023).

Instruments

In addition to a questionnaire to assess interest, teaching experience and learning opportunities, a text-based vignette test was utilised to assess the pre-service teachers' professional vision. The entire survey was configured as an online format, and the participants received a link through which they could respond.

Professional vision of gender-sensitive physics teaching. Vignettes show classroom scenes and often highlight critical issues that require specific competencies in teachers to be successfully mastered (Rehm & Bölsterli, 2014, p. 215). In recent years, vignettes have been increasingly used to assess and promote teachers' professional vision (Alwast & Vorhölter, 2022; Atanasova et al., 2024b; Brovelli et al., 2014; Gippert et al., 2022; Keppens et al., 2019; Stürmer et al., 2014; Todorova et al., 2017). When using vignettes to assess teachers' competencies, Rehm and Bölsterli (2014) found that it was easier to agree on deficiencies in teaching than on examples of successful teaching.

To assess teachers' professional vision, vignettes often include critical situations that may overlap in time and space, reflecting the complexity that may arise during teaching (Wöhlke & Höttecke, 2022). Both text-based and video-based vignette formats are used for this purpose. While video vignettes provide a particularly realistic portrayal of classroom events, they also carry the risk of exposing participants to higher cognitive load due to the simultaneous visual and auditory processing of impressions (Friesen & Feige, 2020; Syring et al., 2015). Furthermore, scripted videos may be perceived by participants as less authentic, potentially affecting a test person's willingness to seriously participate in the study (Wöhlke & Höttecke, 2022). An advantage of text vignettes is their ability to reduce the complexity of simultaneously occurring processes while still allowing for the presentation of longer, coherent teaching sequences (Brovelli et al., 2014). Consequently, Vogt and Schmiemann (2020) also use text-based vignettes to assess pre-service teachers' professional vision. Regardless of the format chosen for the vignettes, it is to be expected that the participants will engage equally with the presented teaching sequences and content (Friesen & Feige, 2020; Herbst et al., 2013).

In this study a validated online-based vignette test consisting of four text vignettes was used to assess the professional vision of pre-service teachers of gender-sensitive physics teaching in a standardised yet contextualised way. The test used contained a total of 16 critical gender-relevant aspects from four facets (i.e. gender-sensitive forms of instruction, teaching of physics content, teaching materials and feedback and interactions) which are considered fundamental in the context of gender-sensitive physics teaching and were elicited based on the literature (Table 1). Evidence of the instrument's validity has been established in previous research, including the pilot study and expert survey. The construction and validation of the instrument are detailed in Atanasova et al. (2023). This study provides additional findings by analyzing the predictors of professional vision.

The instrument, which had an open-response format, required the pre-service teachers to read through the individual vignettes and provide feedback on the teaching sequence by (a) noting critical aspects with regard to gender-sensitive teaching, (b) giving reasons why the aspects mentioned are critical and (c) deriving alternative actions or suggestions for improvement that would lead to more gender-sensitive physics teaching. For example, in one vignette, the teacher explained the lever principle but exclusively used technical examples or objects with a male connotation (e.g. excavator, crane, crowbar), thus neglecting to consider the diverse interests of the class. Incorporating additional and less stereotypical objects such as scissors, nutcrackers, or seesaws can address this oversight. This neglect may contribute to an increased perception of the subject as male-dominated, which could lead girls to withdraw or shy away from this

Table 1. Overview of the four facets and examples of critical aspects in the vignette test

Facet of gender-sensitive physics teaching	Example of a critical gender-relevant aspect
Gender-sensitive forms of instruction (FOI) (4 items)	FOI3*:* In the mixed-gender group, a stereotypical division of labor takes place where the girl writes the protocol and the boy carries out the experiment. Due to the lack of organization by the teacher, roles within the group are also not changed.
Gender-sensitive teaching of physics content (TPC) (4 items)	TPC2: The examples predominantly employed for the subject of energy conversion fail to consider the diverse experiences and interests of the students, instead aligning with a stereotypically male context (e.g. motors, generators, weapons, cars).
Gender-sensitive teaching materials (TM) (4 items)	TM2: Only male scientists are highlighted in connection with the discovery of nuclear fission, thus omitting the representation of women in physics.
Gender-sensitive feedback and interactions (FI) (4 items)	FI2: Despite comparable performance, the teacher provides stereotypical feedback by praising girls for their neat presentation on worksheets and boys for the content they have developed.

field. Based on the PID structure (Blömeke et al., 2015), participants must first perceive that this specific classroom situation involves a critical gender-related aspect (Perception). After perceiving the situation, teachers interpret the observed aspects. They analyze and evaluate the situation based on their professional knowledge (Interpretation) and make decisions about appropriate pedagogical actions and strategies to respond to the classroom situation, leading to a gender-sensitive educational environment (Decision-making).

In order to keep the processing time constant and thus enable comparability, a time limit of 15 min was set for each vignette. After this time, the pre-service teachers were automatically forwarded to the next vignette.

The participants' responses were evaluated using qualitative content analysis (Mayring, 2015) and then subsequently quantified employing a coding manual derived deductively based on the literature. It was supplemented with responses from the pilot study ($N = 41$) and from a previous survey of experts ($N = 6$). The experts were distinguished by their extensive tenure in science education, profound expertise in the assessment of (pre-service) teachers' competencies, and intensive engagement in research projects specifically targeting gender-sensitive science education.

For each of the 16 critical gender-relevant aspects, between zero and three points could be achieved, depending on the quality of the answer. Zero points were distributed if the critical aspect was not perceived, one point if it was recognised, an additional point if a correct interpretation was noted and, again, one point if a suitable suggestion for improvement was given. The responses were scored by two independent raters. Of the total 6097 response segments, 33.89% were double-coded. The interrater reliability was 0.84, which corresponds to an almost perfect agreement (Cohen, 1960).

Learning opportunities. Regarding learning opportunities, we evaluated the number of pre-service teachers' formal learning opportunities that they had used thus far. Participants could indicate the total number of lessons devoted to the topic of gender-sensitive teaching and learning in their studies up to that point. In Switzerland, where the study took place, there are no overarching guidelines for gender-sensitive teaching, which is why the number of learning opportunities can vary widely.

Teaching experience referred to the general teaching experience that the pre-service teachers had during (e.g. in the context of study-integrated internships) or outside their studies (e.g. working as a substitute teacher). Based on the experiences noted in the pilot study with pre-service teachers ($N = 41$), different categories based on the number of lessons were defined in order to make it easier for the participants to choose a category corresponding to the number of lessons. The participants could choose between four categories (1 = 0-20 lessons, 2 = 21-50 lessons, 3 = 51-100 lessons, 4 = more than 100 lessons).

Interest in gender-sensitive teaching and learning was assessed with a scale from Atanasova et al. (2024a) containing four items rated on a six-point Likert scale (1 = completely disagree, 6 = completely agree). Higher scores on the scale indicate that teachers report more interest in gender-sensitive teaching and learning (Table 2).

Data analysis

In the first step, we examined the validity of the measurement model on professional vision using confirmatory factor analysis (CFA). Based on theoretical considerations,

Table 2. Scale on interest in gender-sensitive teaching and learning from Atanasova et al. (2024a).

Int1	Ich würde gerne mehr darüber erfahren, welche Unterrichtsmethoden sowohl Jungen als auch Mädchen besonders ansprechen. *I would like to learn more about teaching methods that appeal to both boys and girls.*
Int2	Ich würde gerne Möglichkeiten kennenlernen, wie die Vermittlung von Lerninhalten für alle Geschlechter ansprechend gestaltet werden kann. *I would like to explore ways to make the delivery of educational content engaging for all genders.*
Int3	Ich würde gerne erfahren, wie Unterrichtsmaterial hinsichtlich Geschlechtergerechtigkeit untersucht wird. *I would like to understand how teaching materials are examined in terms of gender equality.*
Int4	Ich würde gerne Strategien kennenlernen, um in der Interaktion alle Geschlechter gleichermassen zu fördern. *I would like to learn strategies to equally promote interaction among all genders.*

Note: The original items are in German, and the translated items in English are in italics.

we assumed that the professional vision of gender-sensitive physics teaching is a higher-order factor encompassing the four sub-factors gender-sensitive forms of instruction, teaching of physics content, teaching materials and feedback and interactions (model 3). Alternatively, we considered two other theoretically plausible possibilities: first, that there is only one factor and all items load onto a single factor (model 1); second, that there is a four-factor solution, taking into account the four distinct facets form of instruction, teaching of physics content, teaching materials and feedback and interactions (model 2) (Figure 2).

In the second step, we examined the relationships between professional vision and the proposed variables (interest, learning opportunities, teaching experience) and tested our hypotheses. A structural equation modeling (SEM) analysis approach was used to analyse the relationships between the variables. Due to the categorical nature of the data (categorical ordinal data in the measurement of professional vision) the weighted least squares estimator (WLSMV) was utilised (Finney & DiStefano, 2013, p. 454; Muthén & Muthén, 1998-2017). The analyses were carried out with Mplus version 8.3 (Muthén & Muthén, 1998-2017).

Results

The descriptive results for the three predictors examined, interest, learning opportunities, and teaching experience, are shown in Table 3. Interest in gender-sensitive teaching is relatively high among pre-service teachers, with a mean score of 4.92. Learning opportunities for gender-sensitive teaching range from 0 to 15 lessons, with pre-service teachers having attended an average of four lessons during their studies. In terms of teaching experience, 16.4% ($n = 96$) of the pre-service teachers reported 0–20 lessons, 21.2% ($n = 124$) 21–50 lessons, 23.9% ($n = 140$) 51–100 lessons and 37.7% ($n = 221$) more than 100 lessons of teaching experience.

Before examining the relationship between the possible predictors and professional vision, we first analysed the measurement model of professional vision. Based on theoretical assumptions, three models were compared: model 1 with one factor (PV), model 2 with four factors and model 3 as a second-order model (Figure 2).

All the models were analysed using confirmatory factor analysis. The descriptive examination of the items revealed three conspicuous items. FOI1, TPC1 and TPC3 were addressed by less than 20% of the participants and were therefore viewed as too difficult. They were thus not utilised in further analysis. This meant that a total of 13

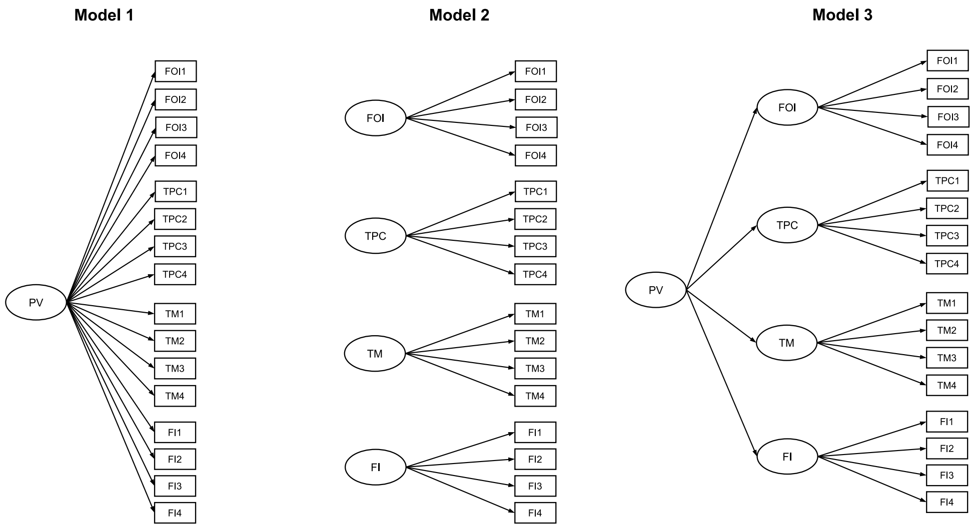

Figure 2. Overview of the three evaluated measurement models for professional vision *Note*: PV = Professional vision; FOI = Forms of instruction; TPC = Teaching of physics content; TM = Teaching Materials; FI = Feedback and Interaction.

items out of the original 16 items were included. In Table 4, we present goodness-of-fit statistics for all three measurement models. It should be noted that the *p*-value for the chi-square test is significant for all the models. However, since the sample contains more than 500 participants and the *p*-value is thus very likely to become significant even with good model fit values, other fit measures (such as the robust comparative fit index (CFI) or root mean square error of approximation (RMSEA)) are more strongly considered for the model evaluation.

Model 1 with one factor showed unsatisfactory values and was therefore not considered for further analyses ($CFI < 0.96$, $TLI < 0.95$, $RMSEA > 0.06$), which is why models 2 and 3 were evaluated. For models that incorporate categorical variables and employ the WLSMV estimator, Asparouhov and Muthén (2010) introduced a secondary assessment known as the DIFFTEST procedure, which is integrated into Mplus. The results of the DIFFTEST comparing the two models demonstrate that the *p*-value is not significant ($\chi^2 = 4.845$, $df = 2$, $p = .09$), indicating that the restrictions do not worsen the model. The confirmatory factor analysis of the second order model thus explains the data similarly well and can be retained. This aligns with our theoretical

Table 3. Descriptive statistics of the analysed variables.

	n	%	*M*	SD	Min	Max	α
Interest[a] (4 items)	548		4.92	1.10	1	6	0.88
Learning opportunities[b]	585		4.08	3.95	0	15	–
Teaching experience	581	(100%)	–	–	–	–	–
0–20 lessons	96	(16.4%)					
21–50 lessons	124	(21.2%)					
51–100 lessons	140	(23.9%)					
More than 100 lessons	221	(37.7%)					

Note: [a] Likert scale: 1 = do not agree at all, 2 = do not agree, 3 = somewhat disagree, 4 = partially agree 5 = , agree, 6 = totally agree, [b] number of lessons.

Table 4. Goodness-of-fit statistics for the three models.

Model	χ^2	df	*p*	CFI	TLI	RMSEA	SRMR
Model 1	224.611	65	0	0.89	0.87	0.067	0.065
Model 2	105.913	59	0	0.97	0.96	0.038	0.045
Model 3	110.691	61	0	0.97	0.96	0.038	0.046

Note: in all models the three items FOI1, TPC1 and TPC3 were excluded.
Abbreviations: χ^2 = chi-square, df = degree of freedom, CFI = comparative fit index, TLI = Tucker–Lewis index, RMSEA = the root mean square error of approximation, SRMR = standardised root mean square residual.

assumption that the professional vision of gender-sensitive physics teaching is a higher-order factor encompassing the four sub-factors gender-sensitive forms of instruction, teaching of physics content, teaching materials and feedback and interactions. Therefore, the second-order model (model 3) was utilised for further analysis in the structural equation model.

After confirming the measurement model for professional vision, we analysed the correlations and our structural equation model in terms of the three variables, namely interest, learning opportunities and teaching experience, and evaluated their relationships according to our expected hypotheses. Gender was included as a control variable.

The results in Table 5 reveal significant correlations at the $p < 0.001$ level between professional vision and the other variables: Interest, Learning opportunities, Teaching experience, and Gender.

The results of the SEM, illustrated in Figure 3, show that our proposed research model is a relatively good fit with the observed data (with $\chi^2 = 222.763$; df = 159; $p = 0.001$; RMSEA = 0.026; CFI = 0.965; and TLI = 0.959; SRMR = 0.046). A good level of fit is suggested when the CFI and TLI values surpass .95 and when RMSEA is under .06. The model's fit remains acceptable if the CFI and TLI are in the range of .90 to .95, and the RMSEA is below .08 (Hu & Bentler, 2009).

Based on the structural equation model, we can conclude that pre-service teachers' experience, interest and learning opportunities have direct effects on their professional vision (PV) (Figure 3). Among the three predictors, we found that the strongest one is interest ($\beta = .32$, $p < 0.01$) with a medium effect, followed by teaching experience ($\beta = .24$, $p < 0.001$) and learning opportunities ($\beta = 0.11$, $p < 0.05$) with a small effect. These results support our three hypotheses that interest (H1) as well as learning opportunities (H2) and teaching experiences (H3) are predictors of pre-service teachers' professional vision of gender-sensitive physics teaching.

In terms of the control variable gender, female pre-service teachers were found to have a significantly higher professional vision ($\beta = .26$, $p < 0.001$) with a medium effect, and a considerably greater interest in gender-sensitive teaching and learning ($\beta = .19$, $p < 0.001$)

Table 5. Correlation matrix for the analysed variables.

	1	2	3	4	5
1. Professional vision	–				
2. Interest	.39***	–			
3. Learning Opportunities	.18***	.02	–		
4. Teaching Experience	.32***	.03	.38***	–	
5. Gender	.34***	.19***	−.03	.09*	-

*$p < 0.05$; **$p < 0.01$, ***$p < .001$.

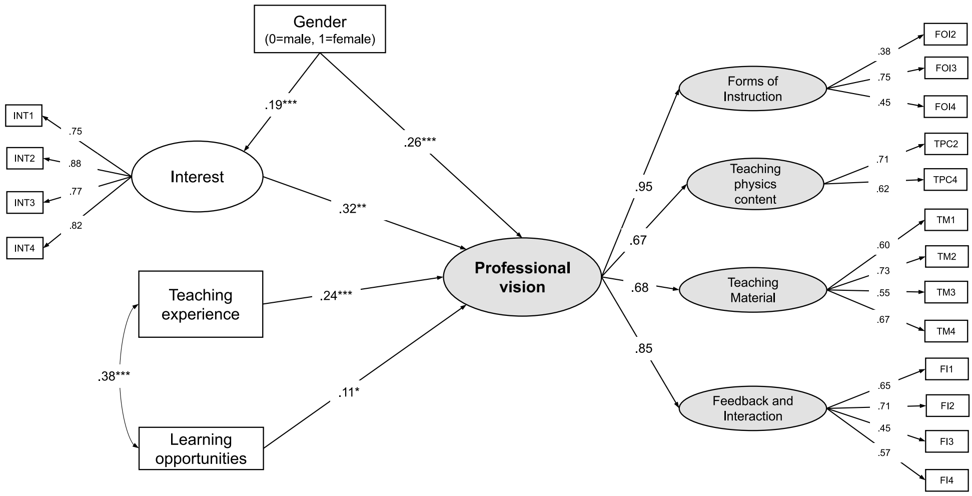

Figure 3. Structural equation model to explain professional vision of gender-sensitive physics teaching (N = 580) Note: Statistics are standardised coefficients. Only significant relations are shown; $^*p < 0.05$; $^{**}p < 0.01$, $^{***}p < .001$.

with a small effect. With the structural equation model presented and predictors listed, 31% of the variance in professional vision can be explained.

Discussion

The aim of this study was to advance the scientific understanding of pre-service teachers' professional vision regarding gender-sensitive physics. In pursuit of this objective, this study successfully validates a model we outlined by elucidating significant predictors of pre-service teachers' professional vision. The findings of our work indicate a systematic relationship between pre-service teachers' professional vision and their level of interest in this subject area, the number of lessons attended related to gender-sensitive teaching, and their teaching experiences. More importantly, we were able to demonstrate this relationship for the first time in relation to their professional vision of gender-sensitive physics teaching. Using this model, 31% of the variance in pre-service teachers' professional vision can be explained. Our results confirm that the predictors of professional vision, namely interest, teaching experience and learning opportunities, identified in previous studies, are also relevant in the context of gender-sensitive physics teaching.

As noted by Stürmer et al. (2014), interest plays a central role in the professional vision of pre-service teachers and thus represents an 'important individual source for developing integrated knowledge'. In our work, interest was the strongest predictor, ahead of learning opportunities and teaching experience. It is worth mentioning that interest in gender-sensitive teaching and learning is significantly higher among female pre-service teachers than male ones, albeit with a small effect. This could be related to the fact that gender inequities in science education often affect girls and young women, and they may have experienced gender inequities in their school career, which might make them more interested in this topic. The focus on teachers' interests during teacher training is essential as it is consistent with the idea that personal interests play a central role in the teaching practice of teachers (Schiefele et al., 2013). Therefore, an approach that starts with teachers' interests can increase the effectiveness of training programmes and could help pre-service teachers to develop their professional vision in the area of gender-sensitive teaching.

Stürmer et al. (2014) previously highlighted the connections between professional vision and learning opportunities. The results of our structural equation model support the hypothesis that the greater the number of lessons that pre-service teachers have attended during their training on gender-sensitive teaching, the higher their professional vision of the concept. How, and whether, learning opportunities for gender-sensitive science teaching are offered during teacher training often depends on the instructors' perspective (Atanasova et al., 2024b). However, it seems that, based on the way learning opportunities are structured during teacher education, they are an important resource, as evidenced by the fact that more learning opportunities were positively associated with a higher level of professional vision. This result is important because in Switzerland, as in other countries, pre-service teachers are inadequately trained through teacher education programs to acquire the competencies necessary for conducting gender-sensitive (physics) teaching (Atanasova et al., 2024b; Grünewald-Huber & von Gunten, 2009; Langfeldt & Mischau, 2011). This underscores the need to raise awareness among pre-service teachers regarding the topic. It seems that even a few learning opportunities during their studies (the maximum number of lessons reported was 15, corresponding to approximately 0.2% of the number of lessons in the master's program) are related to a higher professional vision.

Practical experience is also seen as important in the context of professional vision, which is why this relationship has been investigated in previous studies, but with contradictory results (Bastian et al., 2024; König et al., 2014; Simpson et al., 2018; Stürmer et al., 2013, 2014; Todorova et al., 2017). Our outcomes suggest that teaching experiences, measured by the number of lessons taught during internships or substitute teaching, appear to be important predictors of the professional vision of gender-sensitive physics teaching. This aligns with the findings of Bastian et al. (2024), where internships had a significant impact on pre-service teachers' perception, interpretation, and decision-making abilities, but the effect sizes were also small. Pre-service teachers are already challenged to address gender equity in different areas of teaching during their internships. The selection of contexts or examples in physics lessons (facet: teaching physics content) and the participation of all genders in the lessons within the chosen teaching format (facet: forms of instruction), as well as classroom interactions (facet: feedback and interaction) and teaching materials (facet: teaching material), provide opportunities to reflect on gender equity in the classroom and to activate knowledge previously acquired in academic contexts. Presumably, such teaching experiences provide valuable opportunities for addressing specific gender inequities and reflecting on one's own teaching practice. The question is how such experiences can be enhanced during teacher training or mentoring. Mentors, supervisors, experienced teachers, lecturers or school principals who accompany pre-service teachers in their practice have a high influence on the design of such practice experiences. They can support pre-service teachers in reflecting on their own teaching in relation to gender equity, thus creating additional learning opportunities for pre-service teachers. The effectiveness of internships and practice and, consequently, the experiences gained by teachers in schools can naturally vary significantly. Nevertheless, a clear trend emerges that the number of lessons taught by pre-service teachers has a significant impact on their professional vision of gender-sensitive physics teaching. For this reason, such placements should be better monitored. Moreover, it would make sense to systematically and explicitly (and not only implicitly, for example, in dealing with heterogeneous classes) list gender-sensitive teaching as a quality criterion in teacher practice.

Limitations and future directions

While the current study reveals that learning opportunities, teaching experiences, and pre-service teachers' interest in gender-sensitive teaching and learning are elements within university-based teacher education that contribute to explaining pre-service teachers' professional vision, it is essential to acknowledge certain limitations.

Professional vision is crucial for teachers because it enables them to perceive and interpret classroom dynamics and make decisions based on their pedagogical knowledge on how to respond to these situations (Blömeke et al., 2015). Enhancing professional vision empowers teachers to anticipate teaching scenarios, make informed decisions, and cultivate gender-sensitive learning environments. Professional vision is considered the foundation of teachers' classroom practice. Therefore, the identified predictors potentially play an important role in shaping teachers' classroom practices. However, our study did not specifically investigate teachers' classroom practices regarding gender-sensitive issues; thus, further research is needed.

It is worth noting that in our analysis, professional vision is considered a combination of interconnected processes of perception, interpretation, and decision-making (Blömeke et al., 2015), and the three individual processes were not examined independently. While the vignette test we used captured what pre-service teachers might spontaneously notice, it did not address the prerequisites for the other processes of professional vision. This means that if pre-service teachers did not perceive critical gender-relevant aspects, they could not interpret them, suggest improvements, or derive actions. In future research, tests utilising a combination of open-ended questions (to assess perception) and closed-ended ones (for interpretation and decision-making) could be employed to capture the sub-processes involved in professional vision more accurately and economically.

In addition, the vignette test used to assess professional vision used only critical, non-gender-sensitive classroom situations. While other studies have used this approach (e.g. Wöhlke & Höttecke, 2022) and Rehm and Bölsterli (2014) emphasise that focusing on critical examples is more straightforward, it is important to consider that professional vision in gender-sensitive teaching does not only include critical aspects. For future research, it might be interesting to use sequences that are specifically relevant to gender-sensitive teaching and to include both positive examples and negative components.

Although our findings support the hypothesis that the greater the number of lessons on gender-sensitive teaching attended by pre-service teachers during their training, the higher their professional vision, it should be noted that in our study, only the quantity of learning opportunities was assessed. The quality of these opportunities, including the specific content covered during teacher education, remains undetermined. Future research should also look at the quality of learning opportunities in relation to the number of learning opportunities in order to identify the best conditions for pre-service teachers to develop their professional vision of gender-sensitive physics teaching.

When assessing teachers' interest in gender-sensitive teaching, it is important to consider the impact of social desirability bias. Social desirability bias is the tendency of individuals to respond in a manner that is socially acceptable rather than providing accurate responses based on their true beliefs or attitudes (Crowne & Marlowe, 1960). Although the survey was anonymous and the pre-service teachers had no reason to fear discrimination, it cannot be ruled out that their responses may have been influenced by social desirability, potentially reflecting socially acceptable views rather than their genuine opinions.

Our results highlight the importance of teacher education programs as a source of knowledge acquisition related to gender-sensitive teaching and learning, as well as professional vision. Serving as a starting point for the initial professional development process, additional to pre-service teachers' interest, learning opportunities during the teacher training form a central foundation to prepare pre-service teachers for their later professional endeavours. In order to promote the development of a professional vision of gender-sensitive physics teaching among pre-service teachers, it seems reasonable to include teaching experiences, to promote interest and to offer sufficient learning opportunities on various aspects of gender-sensitive teaching during teacher training.

Note

1. Organization for Economic Co-operation and Development

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

The data that support the findings of this study are available from the corresponding author (Sanja Atanasova) upon reasonable request.

Ethics statement

Before the survey began, participants were informed about the data collection process, the type of data processing and the individuals who would have access to the data as part of the project. Informed consent to the use of their data was obtained from all participants. Participation was voluntary and anonymous. Participants had the option of withdrawing from the survey at any time without giving reasons and without incurring any disadvantage. In accordance with the regulations of the University of Teacher

Education St.Gallen and the University of Teacher Education Lucerne, the head of the ethics committee confirmed that no formal approval was required for this study.

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