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Do gender and science success moderate the effects of science learning self-efficacy on science identity?

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Introduction: This study investigates the relationship between science learning self-efficacy and science identity, examining how gender and science success moderate this relationship.

Methods: Using a quantitative approach with Partial Least Squares Structural Equation Modeling, data from high school students in Moscow, Almetyevsk, Khabarovsk cities from Russia were analyzed.

Results: The research highlights the significant positive impact of integrative science competence, practical science application, and science communication efficacy on science identity. Interestingly, gender did not significantly influence the efficacy-identity relationship, suggesting its minimal role in this context. Conversely, science success, particularly in conjunction with science communication efficacy, played a notable role, indicating a complex interplay that could affect students' science identity.

Discussion: These findings emphasize the need for educational strategies that bolster students' self-efficacy in science, catering to the development of a strong science identity. Future research should explore the nuanced effects of success and communication efficacy on science identity, aiming to inform interventions that support diverse and equitable participation in science education and careers.

KEYWORDS

science learning self-efficacy, science identity, gender moderation, academic success in science, PLS-SEM

Introduction

Building a strong science identity is about seeing oneself as knowledgeable, involved, and valuing about science. This is important for sparking interest and ensuring ongoing commitment and success in science (Carlone and Johnson, 2007; Stets et al., 2017). People with a high science identity tend to be more motivated, persistent, and successful in science education and their future careers (Shanahan, 2009; Hazari et al., 2017; Chen et al., 2021). Encouraging such an identity is especially crucial for inviting students from different backgrounds into the sciences (Fraser et al., 2014).

Researchers have pointed out that self-efficacy, or confidence in one's ability to complete specific tasks, plays a significant role in developing a science identity (Lebeck et al., 2018; Syed et al., 2019; Miles and Naumann, 2021). Science learning self-efficacy, the belief in one's ability to learn and do well in science tasks, is seen as having several components. These include skills in carrying out science experiments, applying scientific concepts in practical situations, and communicating scientific information effectively (Lin and Tsai, 2013; Wang and Tsai, 2019; Sezgintürk and Sungur, 2020; Tan et al., 2021).

Being well in science courses also shapes one's science identity. When students perform well and their abilities are recognized, they start to see themselves as competent in science (Carlone and Johnson, 2007; Master and Meltzoff, 2020). Additionally, studies have looked at how factors like gender may affect the connection between self-efficacy, success in science, and the development of a science identity. Some research finds differences between genders (Desy et al., 2011; Wang and Yu, 2023), while other studies note that cultural and social elements may influence these differences (Sachdev, 2018; Chan et al., 2019).

Within the framework of Russia education, it is necessary to analyze the elements that impact students' science identity and self-efficacy. Although Russia has traditionally placed great importance on science and technology education, recent research has revealed a decrease in students' enthusiasm and engagement in scientific-related disciplines (Pentin et al., 2018; Masalimova et al., 2024). This tendency is especially alarming considering the significance of a people that is knowledgeable in science for Russia's economic and technical progress (Moiseev and Chernyh, 2019). Furthermore, there is an ongoing presence of gender discrepancies in the involvement and achievement of females in the field of science. This is shown by the underrepresentation of female students in advanced science courses and careers, as highlighted by Antoshchuk (2021). Science teaching approaches in Russian schools currently predominantly utilize traditional, lecture-based methods, which offer limited scope for hands-on learning and practical applications in real-world scenarios (Lisichkin and Leenson, 2013; Glebova, 2023). To tackle these issues and provide valuable insights for educational changes, it is essential to do research on the intricate dynamics of elements that influence the science identity and self-efficacy of Russian students. The current study centers on three distinct cities—Moscow, Almetyevsk, and Khabarovsk—to obtain a representative sample of Russian high school pupils. The selection of these locations was based on their ability to represent the many geographical, socio-economic, and cultural aspects of the Russian education system. This choice enables a thorough investigation of the research topics in different settings.

The present study aimed to address the following research questions:

1. Do the dimensions of science learning self-efficacy affect science identity?
2. Does gender have a moderating role on the effect of science learning self-efficacy on science identity?
3. Does science success have a moderating role on the effect of science learning self-efficacy on science identity?

By examining these research questions, this study sought to contribute to the understanding of the complex interplay between self-efficacy beliefs, academic achievement, demographic factors, and the development of a robust science identity among students. The findings have the potential to inform educational strategies and interventions aimed at nurturing positive science identities and broadening participation in Science Technology Engineering and Mathematics (STEM) fields.

Literature review

Science identity

The study of science identity has become crucial in the field of science education. It significantly influences students' involvement, determination, and achievements in science areas (Carlone and Johnson, 2007). Science identity is about how individuals see themselves as understanding, engaging in, and appreciating science (Stets et al., 2017). A strong sense of science identity is linked to higher motivation, resilience, and success in science (Shanahan, 2009; Hazari et al., 2010; Chen et al., 2021).

Several factors work together to shape a student's science identity. These include the learning environment and the broader historical and social context. This is especially true for young people from diverse backgrounds (Fraser et al., 2014). For educators in science, reflecting on their teaching methods and dealing with challenges can lead to a deeper understanding of their professional identity (Mansfield et al., 2022). Using an intersectionality approach, the importance of acknowledgment and emotional responses is highlighted. This approach also points out issues related to power, inequality, and exclusion (Avraamidou, 2020). Engaging in real science activities can help build a science identity. It does so by making individuals feel they belong and are recognized, interested, and skilled in science (Huffmyer et al., 2022). Thus, developing a science identity involves both personal and societal aspects. These include relationships, the broader context, self-reflection, acknowledgment, emotions, and professional viewpoints.

Research has pinpointed key elements that help form a strong science identity. One significant element is self-efficacy, or the belief in one's ability to accomplish certain tasks (Kim, 2018; Syed et al., 2019; Miles and Naumann, 2021). Studies have emphasized various aspects of science self-efficacy. These aspects include understanding integrated science concepts, applying science practically, and effectively communicating scientific ideas (Britner and Pajares, 2006; Wang and Tsai, 2019; Hu et al., 2022).

Success in science topics also plays a vital role in forming science identity (Hazari et al., 2017; Chen et al., 2021). When students do well in science, they more strongly identify with it. Their successes make them feel capable and competent in this field (Carlone and Johnson, 2007; Shanahan, 2009; Master and Meltzoff, 2020). Moreover, studies have examined how factors like gender and socioeconomic status might influence the link between self-efficacy, academic success, and science identity (Robnett et al., 2015; Miles and Naumann, 2021). While some research shows clear gender differences in science identity formation (Desy et al., 2011; Wang and Yu, 2023), other studies suggest these differences may depend on various social and cultural factors (Sachdev, 2018; Chan et al., 2019). Having a strong science identity can greatly affect students' academic and career paths. Those with a well-developed science identity are more likely to choose science-related fields, overcome obstacles, and take part in science activities and groups (Jackson et al., 2016; Stets et al., 2017).

Recognizing the vital role of science identity, experts have suggested specific teaching methods and interventions. These strategies aim to nurture a positive science identity among all students (Vincent-Ruz and Schunn, 2018; Rushton and Reiss, 2021; Sandrone, 2022). Possible actions include showing students a variety of scientist roles, offering real science experiences, and creating supportive educational settings. Such settings help students feel competent and valued in the science community (Meyer and Crawford, 2015; Sheffield et al., 2021). Research on science identity underscores its importance in encouraging students to engage, achieve, and persist in science fields. By understanding how self-efficacy, academic performance, and other factors interact, educators can design strategies and interventions. These efforts aim to build a strong science identity among diverse student groups. Strengthening science identity is key to widening participation in STEM fields and preparing future scientists and innovators.

Science learning self-efficacy

Self-efficacy beliefs, which refer to an individual's confidence in their ability to perform specific tasks or activities, have been extensively studied in the context of science education (Bandura, 1997; Britner and Pajares, 2006). A growing body of research has specifically examined the role of science learning self-efficacy, which encompasses an individual's beliefs about their capabilities to learn and perform various science-related tasks and activities such as virtual reality and lab acitivities (Usher and Pajares, 2009; Glynn et al., 2011; Gungor et al., 2022).

Science learning self-efficacy has been conceptualized as a multidimensional construct, comprising distinct yet interrelated dimensions (Wang and Tsai, 2019; Tan et al., 2021). These dimensions include experimental science proficiency, which reflects an individual's confidence in conducting scientific experiments and interpreting data; practical science application, which involves the ability to apply scientific knowledge and skills to real-world situations; and science communication efficacy, which encompasses the belief in one's ability to effectively communicate scientific concepts and ideas (Lin and Tsai, 2013; Sezgintürk and Sungur, 2020).

Research has consistently demonstrated a positive relationship between science learning self-efficacy and academic achievement in science subjects (Britner and Pajares, 2006; Usher and Pajares, 2009; Alhadabi, 2021). Students with higher levels of science learning self-efficacy tend to exhibit greater persistence, resilience, and engagement in science-related tasks, leading to improved academic performance (Glynn et al., 2011; Zheng et al., 2018).

Moreover, science learning self-efficacy has been identified as a critical factor in shaping students' science identity, which refers to an individual's recognition of themselves as someone who understands, participates in, and values science (Trujillo and Tanner, 2014; Syed et al., 2019). Students with higher levels of science learning self-efficacy are more likely to develop a stronger science identity, as their confidence in their abilities to learn and perform science-related tasks reinforces their self-perceptions as capable and competent in the field (Hazari et al., 2010).

Studies have looked at how demographic factors, like gender and economic status, might affect confidence in science learning self-efficacy (Tan et al., 2023). However, the influence of gender on science self-efficacy is less clear, with some studies finding no difference between male and female students, while others suggest that male students may have higher levels of self-efficacy and better science learning outcomes (Trisnawati et al., 2020; Nurhasnah et al., 2022). Research has shown that men and women may have different levels of confidence in their science abilities (Zeldin et al., 2008; Robinson et al., 2022). However, other studies point out that these differences often depend on social and cultural backgrounds (Reuben et al., 2014; Robinson et al., 2022). Overall, these findings highlight the importance of considering demographic factors when examining confidence in science learning self-efficacy, as they can play a role in shaping students' beliefs and motivation in science education.

Understanding that self-efficacy in science learning is important, experts suggest specific ways to help students believe more in their science abilities (Usher and Pajares, 2009; Glynn et al., 2011). These methods include hands-on experience, observing others, positive encouragement, and learning to handle stress (Bandura, 1997; Usher and Pajares, 2009). The study of students' confidence in their science learning abilities is key in science education. Researchers are looking into how this confidence relates to academic success, science identity, and other influencing factors. Boosting this confidence is important for getting students involved, helping them to keep going, and making them successful in science fields. This work is vital for creating a skilled and varied group of STEM professionals.

Gender's effect on science identity and science learning self-efficacy

Educational research has been paying close attention to how gender, science identity, and confidence in science learning intersect. This review looks at how gender affects the development of science identity and learning confidence in science. It points out differences between genders, examines the reasons for these differences, and discusses ways to overcome them. Science identity is about whether a person sees themselves as someone linked to science. It is important for getting students interested in science and helping them stick with it (Carlone and Johnson, 2007). Studies show that boys are more likely to consider themselves connected to science from an early age (Alexander et al., 2012; Archer et al., 2014). This trend is due to cultural ideas and gender roles that suggest science is mainly for men (Robinson et al., 2019; Al-Balushi et al., 2022). Girls encounter stereotypes that imply science is not suitable for them. This can affect how they see themselves in relation to science (Reuben et al., 2014; Master and Meltzoff, 2020). However, positive support from teachers and family can help girls feel more connected to science (Hazari et al., 2017; Wang et al., 2020).

Believing in one's ability to succeed in science is crucial for motivation and staying with science studies (Bandura, 1997). There's a noticeable difference in this belief between genders. Girls often feel less capable in science, especially in areas like physics and engineering (Britner and Pajares, 2006). Studies suggest girls feel less capable in science because they get less encouragement and have fewer role models (Herrmann et al., 2016). But mentoring and hands-on learning can greatly boost girls' confidence in their science abilities (Zeldin et al., 2008; Jackson et al., 2016; Stets et al., 2017).

Having a strong science identity can increase a student's confidence in their science abilities (Gubbels and Vitiello, 2018). If students see themselves as "science people," they are more likely to believe they can achieve in science. Similarly, if they believe in their science abilities, they will likely develop a stronger science identity. Research shows that science identity and confidence support each other, leading to more interest and persistence in science for both boys and girls (Alexander et al., 2012). A positive classroom environment and inclusive teaching methods can help build both science identity and confidence, especially for students who are less represented in science (Trujillo and Tanner, 2014).

A recent study on science education in Russia has brought attention to many obstacles and inequalities associated with gender. Gender inequalities continue to exist in Russian science education, as women are not adequately represented in research output and scientific influence across different fields of study. Throughout history, women in Russia have had limited representation in science (Kataeva et al., 2023). Their research output and scientific influence in these domains have consistently been lower compared to men (Paul-Hus et al., 2015; Loyalka et al., 2021). The discrepancy is apparent from the early stages of education, as males are more commonly represented among the top 20% of high-achieving students in science at both the fourth and eighth-grade levels. This pattern has been documented in other nations, including Russia (Meinck and Brese, 2019). Notwithstanding these difficulties, girls in Russia are more inclined to take academic paths in secondary education in comparison to boys. This tendency is impacted by family money and parental education. However, no further impacts of gender on this transition have been discovered (Bessudnov and Malik, 2016). Nevertheless, the collective proficiency of Russian students, encompassing both males and females, falls behind that of nations such as China, highlighting the necessity for enhanced pretertiary education to adequately equip students for science and technology programs at the university level (Loyalka et al., 2021). These findings indicate that although there have been improvements in certain aspects, there are still notable differences between genders in Russian science education. This highlights the need for specific initiatives aimed at promoting gender equality and improving the overall quality of science education.

To reduce the gender gap in science identity and confidence, there are interventions like mentoring programs, fair teaching methods, and introducing students to a variety of science role models. Studies have found that female science role models can make a big difference for female students. They help build both science identity and confidence (Conner and Danielson, 2016). Mentorship from female scientists has been shown to boost female undergraduates' confidence and connection with science (Dennehy and Dasgupta, 2017). In conclusion, gender has a big influence on science identity and confidence in science learning. Although there are noticeable differences, targeted efforts and inclusive teaching can lessen these differences. They can make science education more equal. Future research should keep looking at how gender, identity, and confidence in science are related. It should focus on interventions that create a science learning environment that is welcoming and fair for everyone.

Science success's effect on science identity and science learning self-efficacy

Understanding the link between doing well in science, feeling connected to science, and believing in one's science abilities is very important in the study of science education. Knowing how success in science shapes the way people view themselves as science learners and doers is helpful. It can lead to more interest and lasting involvement in the science field. When people feel they are "science people" and are seen that way by others, we say they have a science identity. Doing well in science helps strengthen this identity. This includes getting good results, being acknowledged, and getting positive feedback. Important research by Avraamidou (2020) and Bryan et al. (2011) shows that success in science activities and recognition from others are crucial for developing a strong science identity.

Believing you can succeed in science is known as self-efficacy in science learning. Success in science boosts this belief by showing you can do well and are skilled in science. Studies by Britner and Pajares (2006) and Usher and Pajares (2009) highlight that achievements and overcoming challenging tasks are essential for building this self-confidence. The development of a science identity and the belief in your science abilities are interconnected. A strong science identity can drive you to attempt difficult science tasks, and succeeding in these can increase your confidence in your abilities. Trujillo and Tanner (2014) and Sandrone (2022) have found that educational strategies that improve science identity and self-efficacy lead to better academic performance in science.

Educational interventions aimed at enhancing success in science can have a positive effect on students' science identity and self-efficacy. These can include inquiry-based learning, feedback, and peer collaboration, as suggested by Sheffield et al. (2021) and Eagan et al. (2023), who argue that connecting science education to students' lives and self-regulated learning are beneficial. In conclusion, positive experiences and achievements in science education are vital. They encourage success and support teaching practices, recognition, and opportunities for mastering experiences. This strengthens students' identification with science and belief in their science capabilities. Future research should continue to explore these relationships and the effectiveness of interventions designed to enhance all three components in diverse educational contexts.

Methodology

General background

In this study, the effect of science learning self-efficacy on science identity was investigated, along with whether gender and science success play a moderating role in this relationship. A quantitative approach was employed, and a theoretical model, as depicted in Figure 1, was developed for the analysis. The Partial Least Squares Structural Equation Modeling (PLS-SEM) approach was utilized to test the model. The choice of PLS-SEM was strategic, due to the complexity of the model which includes multiple sub-dimensions of science learning self-efficacy. Additionally, the preference for PLS-SEM was reinforced by its suitability for data that do not necessarily follow a normal distribution.

> H1. The dimensions of science learning self-efficacy affect science identity.
>
> H2. Gender has a moderating role on the effect of science learning self-efficacy on science identity.

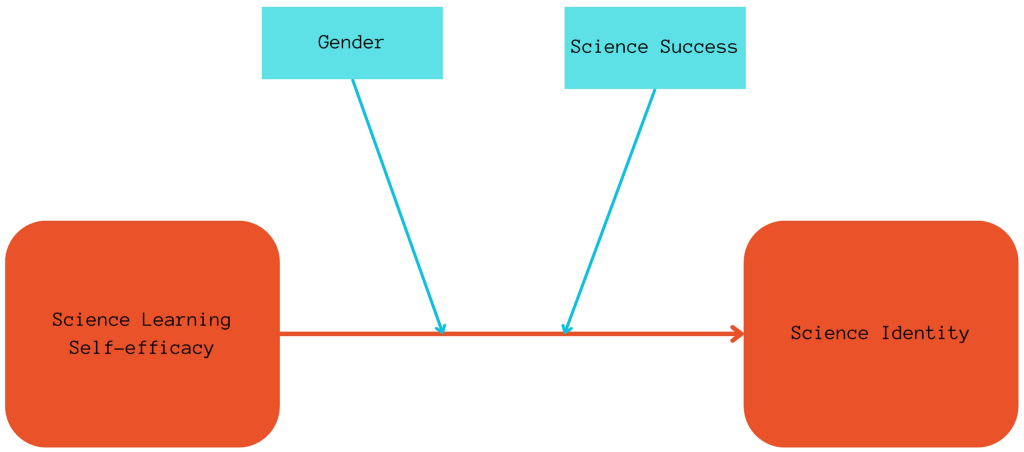

FIGURE 1
Theoretical model.

> H3. Science success have a moderating role on the effect of science learning self-efficacy on science identity.

Sample

The questionnaire in this study was mainly distributed to high schools in Russia. Six high schools (2 schools in each city) were in Moscow, Almetyevsk, Khabarovsk cities. All the participants were asked to read and approve the ethical consent form before participating in this study. The schools were randomly selected in consultation with local administrators to ensure a diverse sample. Before participating, all students were required to read and approve an ethical consent form. While specific age data was not collected, Russian high school students typically range from 14 to 18 years old. Initially, 600 questionnaires were distributed. After removing incomplete responses, the final sample consisted of 519 participants. The gender distribution was nearly equal, with 263 females and 256 males.

Data collection tools

In this research, the team collected data using two different questionnaires. We used the Science Identity Scale (Chen and Wei, 2022) and the Science Learning Self-Efficacy Scale (Lin and Tsai, 2013). Both scales (in appendix) were applied to the linguistic adaptation process. For linguistic adaptation, three experts were enlisted. The first expert was responsible for translating the scales from English into Russian. Subsequently, the second expert retranslated the Russian-translated scales back into English. The third expert then compared both translations along with the original scales, thereby validating the Russian version of the scales.

Chen and Wei (2022) confirmed that the Science Identity Scale is both valid and reliable. It was made for students in the later years of high school. The scale has 24 items. The Cronbach's alpha for the scale was 0.95. This means the questions are very consistent within the scale.

The Science Learning Self-Efficacy Scale, as assessed by Lin and Tsai (2013), is designed for students in their later years of high school. It consists of 25 items spread across five sub-dimensions. The scale has a Cronbach's alpha of 0.97, indicating it is a very reliable tool for measuring students' belief in their science abilities. A test of the model including the previously identified sub-dimensions was conducted. However, the HTMT value turned out to be very high, suggesting that there might be overlapping items. Therefore, an exploratory factor analysis was carried out on a randomly selected group of 260 people from the main sample. To determine the number of factors, a parallel analysis was used. A Varimax rotation was applied for factor loadings (Williams et al., 2010). As a result of the factor analysis, items that overlapped were removed (items 1, 2, 4, 7, 13, 17, 23). Bartlett's Test of Sphericity showed a chi-square value of 5,619, which is significant ($p < 0.001$), and the KMO was calculated to be 0.953. According to the results of the factor analysis, the scale items were divided into four different sub-dimensions. The first sub-dimension includes 8 items and has been named "Integrative Science Competence." The second sub-dimension contains 6 items and is called "Practical Science Application." The third has 5 items, named "Experimental Science Proficiency." The fourth sub-dimension includes 2 items and is termed "Science Communication Efficacy." Altogether, these dimensions account for 75% of the variance in the scale.

The gender of the participants was determined based on their self-reports. In the evaluation of science success, success in Physics, Chemistry and Biology courses was calculated based on grading between (1–5). The average success of 3 subjects was recalculated as Science success.

Data analysis

The researchers used a statistical method called Partial Least Squares Structural Equation Modeling (PLS-SEM) to analyze the data. This method is useful for testing theoretical models with multiple factors. First, the researchers checked that the survey questions used to measure each factor were reliable and valid. The factor loadings, Cronbach's alpha, and average variance extracted values all met the recommended thresholds, indicating good reliability and validity. Factor loadings above 0.70 were deemed acceptable. Internal reliability was established based on composite reliability above 0.70. Average variance extracted (AVE) above 0.50 confirmed convergent validity. Discriminant validity was verified using the Fornell-Larcker criterion and Heterotrait-Monotrait (HTMT) ratio, ensuring constructs differed from others (Henseler et al., 2017; Hair et al., 2019; Wong, 2019). Next, the researchers examined the direct effects of the dimensions of science learning self-efficacy on science identity using path analysis. Bootstrapping with 5,000 resamples was used to calculate the t-statistics and *p*-values for assessing the significance of path estimates. Finally, moderating roles for gender and science success were tested. All PLS-SEM analyses were performed using the SmartPLS v 4.0 (Ringle et al., 2022).

Research results

Model measurements

The model in which all the items were included was tested. The loading values of the 3rd and 5th items of science identity were removed because they were lower than 0.70. Then the model was tested again. Starting with factor loadings, which measure the strength of the relationship between each item and its supposed underlying construct, we observe that all listed items demonstrate loadings above the 0.70, signifying robust correlations.

Table 1 presents factor loading and reliability coefficients for dimensions related to Science Learning Self-Efficacy Scale and Science Identity Scale. Generally, factor loadings above 0.7 are considered good, indicating that the items are likely to be a good measure of the underlying construct they are intended to represent. Also, it displays the Cronbach's alpha, Composite reliability (rho a and rho c), and the Average Variance Extracted (AVE). Cronbach's alpha values are used to assess the internal consistency of the items within each latent variable. The values provided are high (all above 0.9), suggesting excellent internal consistency. The Composite Reliabilities (both rho_ and rho_c) are similarly high, which further supports the reliability of the constructs. The AVE values are all above 0.5, the commonly recommended threshold, indicating a satisfactory level of convergent validity. Table 1 indicates that the items used to measure each construct in the study are reliable and that the constructs are well-defined. The high-reliability coefficients suggest that the latent variables are likely to be stable and consistent across different samples of respondents.

Table 2 presents the Heterotrait-Monotrait (HTMT) ratio of correlations, which is an index used to assess the discriminant validity in constructs within a model. A value of HTMT less than 0.90 is often considered indicative of adequate discriminant validity. The values shown suggest that all constructs in the science learning self-efficacy pairs exhibit discriminant validity, as most HTMT values are below the 0.90 threshold. The value between science identity and Integrative Science Competence is higher than the determined threshold value 0.90. But since science identity and Integrative Science Competence are from different scales and Science identity is a dependent variable, it does not pose a problem.

Table 3 presents the Fornell-Larcker criteria matrix. The diagonal elements of the table (bolded) represent the square root of the Average Variance Extracted (AVE) for each construct. The AVE square root should be higher than the off-diagonal elements in its corresponding row and column, which represent the correlations between constructs. Based on the Fornell-Larcker criterion, for discriminant validity to be established, the square root of the AVE (diagonal elements) for each construct must be greater than the correlations between that construct and any other construct in the model (off-diagonal elements). It would indicate that each construct is distinct and captures phenomena that are not captured by the other constructs, fulfilling the Fornell-Larcker criterion for discriminant validity. This suggests that the constructs in the model are sufficiently different from each other, which is an important aspect of building a sound theoretical model (Figure 2).

Table 4 summarizes statistical findings on the relationship between various science educational factors and the construct of "identity." Each factor's influence is measured by the original sample's path coefficient, its sample mean, and standard deviation, followed by a calculation of t statistics to determine significance. The results for Experimental Science Proficiency show a path coefficient of 0.091, suggesting a slight positive effect on identity, with a standard deviation of 0.037. The t statistic of 2.460 and a *p* value of 0.007 indicate that this relationship is statistically significant, though the effect size is relatively small.

Integrative Science Competence has a notably stronger association with identity, evidenced by a path coefficient of 0.603. The consistency of this effect is underscored by an identical sample mean and a low standard deviation. The very high t statistic of 14.294 and a *p* value of practically zero strongly suggest that this is a robust and highly significant finding. The Practical Science Application factor shows a moderate positive influence on identity, with a path coefficient of 0.185. The t statistic of 4.807 and a negligible *p* value confirm the statistical significance of this relationship. Lastly, Science Communication Efficacy also has a small yet significant positive effect on identity, as indicated by a path coefficient of 0.089 and a t statistic of 3.470. Again, the *p* value of 0.000 affirms the statistical significance of this effect (Table 5).

For Experimental Science Proficiency, with an f^2 value of 0.013, the effect size of Experimental Science Proficiency on "identity" is very small. Cohen's f^2 values of 0.02, 0.15, and 0.35 are typically considered small, medium, and large effect sizes, respectively. Hence, Experimental Science Proficiency has a negligible influence on "identity." For Integrative Science Competence, the f^2 value of 0.455 indicates a large effect size, suggesting that Integrative Science Competence has a substantial impact on "identity." It is the most influential predictor among the ones listed. For Practical Science Application, the f^2 value of 0.059 suggests a small to medium effect size. This indicates that Practical Science Application has a moderate influence on "identity." For Science Communication Efficacy, with an f^2 value of 0.021, the effect of Science Communication Efficacy on "identity" is small, indicating it has some but limited influence (Table 5).

R-square value of 0.798 [0.772–0.824] for "identity" suggests that approximately 79.8% of the variance in "identity" can be explained by the independent variables included in the model. This is a high value, indicating a strong model that provides a good fit to the data. Adjusted R-square: The adjusted R-square value of 0.796 [0.770–0.823] is very close to the R-square value, which implies that the number of predictors in the model is appropriate, and the model is not overfitted with unnecessary variables (Figure 3).

TABLE 1 Factor loading and reliability coefficients for science learning self-efficacy and science identity.

Latent variables	Items	Loading values	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Science identity	SI_2	0.863	0.972	0.973	0.974	0.632
	SI_3	0.760				
	SI_4	0.734				
	SI_5	0.731				
	SI_6	0.761				
	SI_7	0.879				
	SI_8	0.841				
	SI_9	0.793				
	SI_10	0.805				
	SI_11	0.844				
	SI_12	0.844				
	SI_13	0.825				
	SI_14	0.725				
	SI_16	0.721				
	SI_17	0.776				
	SI_18	0.789				
	SI_19	0.785				
	SI_20	0.797				
	SI_21	0.811				
	SI_22	0.835				
	SI_23	0.820				
	SI_24	0.719				
Experimental science proficiency	SLSE_9	0.904	0.932	0.936	0.948	0786
	SLSE_10	0.906				
	SLSE_11	0.897				
	SLSE_12	0.854				
	SLSE_14	0.873				
Practical science application	SLSE_15	0.910	0.946	0.947	0.957	0.788
	SLSE_16	0.895				
	SLSE_19	0.866				
	SLSE_20	0.905				
	SLSE_21	0.831				
	SLSE_22	0.915				
Integrative science competence	SLSE_3	0.824	0.939	0.940	0.949	0.700
	SLSE_5	0.825				
	SLSE_6	0.841				
	SLSE_8	0.807				
	SLSE_18	0.813				
	SLSE_26	0.839				
	SLSE_27	0.889				
	SLSE_28	0.854				
Science communication efficacy	SLSE_24	0.964	0.930	0.933	0.966	0.935
	SLSE_25	0.969				

TABLE 2 Heterotrait-Monotrait ratio.

	Experimental science proficiency	Integrative science competence	Practical science application	Science communication efficacy	Science identity
Experimental science proficiency					
Integrative science competence	0.865				
Practical science application	0.753	0.822			
Science communication efficacy	0.618	0.684	0.696		
Science identity	0.794	0.914	0.802	0.678	

TABLE 3 Fornell-Larcker criteria.

	Experimental science proficiency	Integrative science competence	Practical science application	Science communication efficacy	S. identity
Experimental science proficiency	**0.887**				
Integrative science competence	0.810	**0.837**			
Practical science application	0.708	0.774	**0.888**		
Science communication efficacy	0.577	0.640	0.653	**0.967**	
Science identity	0.761	0.876	0.774	0.648	**0.795**

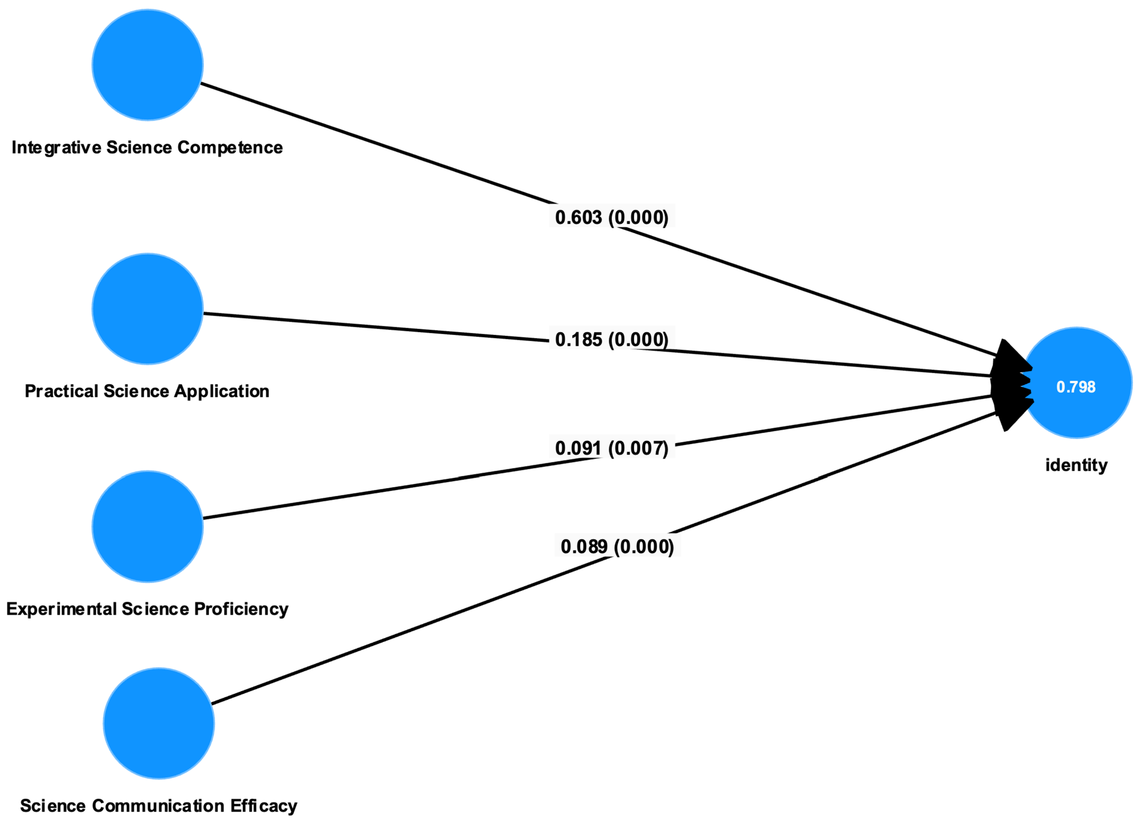

FIGURE 2
Path diagram for science learning self-efficacy and science identity.

Moderating effect

Table 6 presents original sample path coefficients, sample means, standard deviations, t statistics, and *p* values, all of which help assess the significance and strength of the relationships. Experimental Science Proficiency has a small positive effect on "identity" (path coefficient of 0.089) which is statistically significant ($p = 0.042$). Integrative Science Competence shows a strong positive effect on

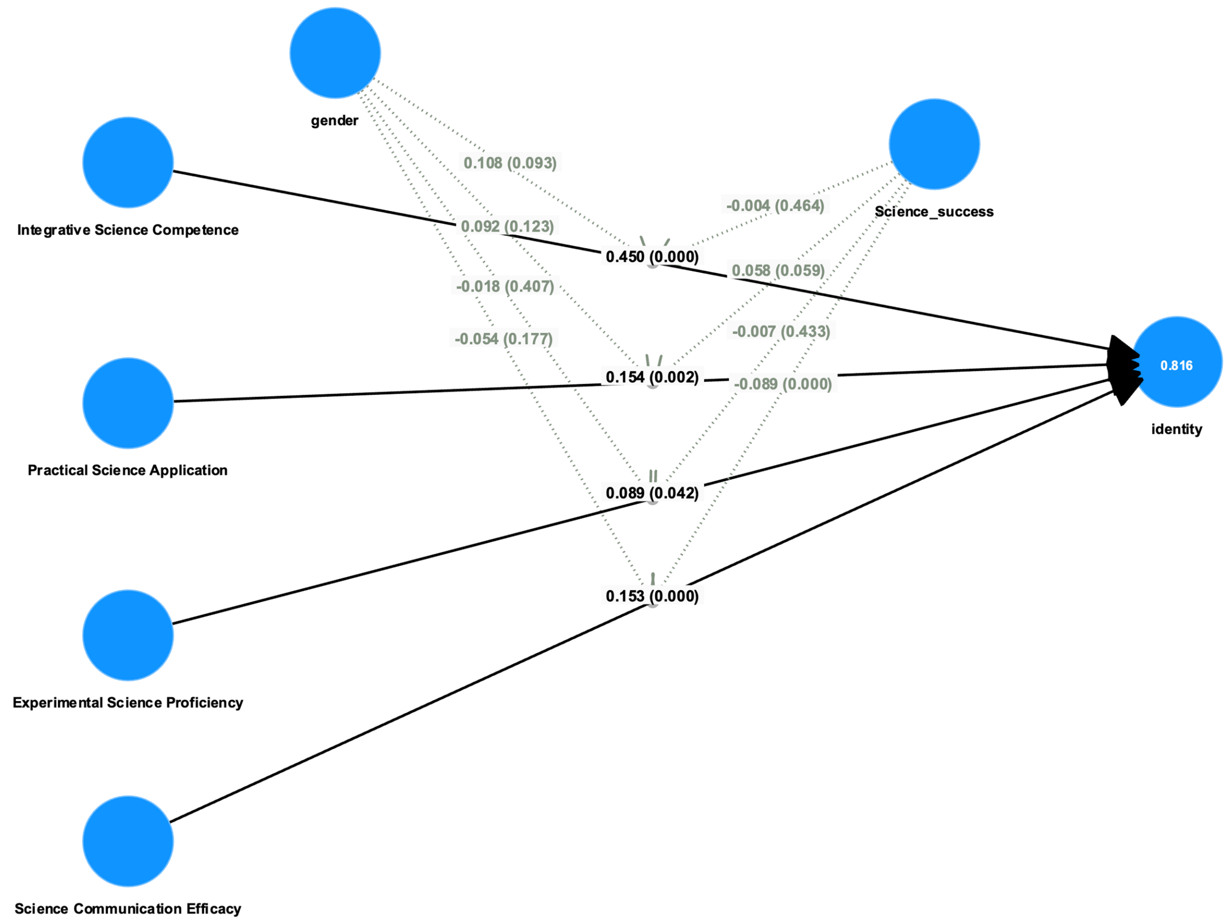

FIGURE 3
Path diagram for moderating effect.

TABLE 4 Path analysis for coefficient.

	Original	Mean	SD	*t*	*p*
Experimental science proficiency → identity	0.091	0.090	0.037	2.460	0.007
Integrative science competence → identity	0.603	0.603	0.042	14.294	0.000
Practical science application → identity	0.185	0.186	0.039	4.807	0.000
Science communication efficacy → identity	0.089	0.088	0.026	3.470	0.000

TABLE 5 Effect size values f^2.

	S. identity
Experimental science proficiency	0.013
Integrative science competence	0.455
Practical science application	0.059
Science communication efficacy	0.021

"identity" (path coefficient of 0.450), with high statistical significance ($p < 0.001$). Practical Science Application and Science Communication Efficacy both demonstrate moderate positive effects on "identity" (path coefficients of 0.154 and 0.153, respectively) and are statistically significant ($p = 0.002$ and $p < 0.001$, respectively). Science success also positively influences "identity" with a path coefficient of 0.148 and is statistically significant ($p < 0.001$).

In Interaction effects, the interaction of gender with Integrative Science Competence, Practical Science Application, and Science Communication Efficacy indicates a mix of small positive and negative influences on "identity." However, none of these interactions are statistically significant, given that their *p* values exceed the conventional threshold of 0.05 for significance. Notably, the interaction between science success and Science Communication Efficacy is negative (path coefficient of −0.089) and is statistically significant ($p < 0.001$). This suggests that the combined effect of science success and science communication efficacy on identity is different than when these factors are considered alone.

From the data, we can observe the direct effects of science learning self-efficacy (Experimental Science Proficiency, Integrative Science

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TABLE 6 Path analysis for coefficient.

Paths	Original	*M*	SD	*t*	*p* values
Experimental science proficiency → identity	0.089	0.090	0.052	1.728	0.042
Integrative science competence → identity	0.450	0.451	0.061	7.333	0.000
Practical science application → identity	0.154	0.155	0.052	2.967	0.002
Science communication efficacy → identity	0.153	0.152	0.036	4.252	0.000
Science_success → identity	0.148	0.148	0.026	5.806	0.000
Gender → identity	−0.061	−0.061	0.044	1.366	0.086
Gender × integrative science competence → identity	0.108	0.109	0.082	1.322	0.093
Gender × practical science application → identity	0.092	0.092	0.080	1.160	0.123
Gender × experimental science proficiency → identity	−0.018	−0.019	0.075	0.235	0.407
Gender × science communication efficacy → identity	−0.054	−0.055	0.059	0.928	0.177
Science_success × integrative science competence → identity	−0.004	−0.001	0.042	0.089	0.464
Science_success × practical science application → identity	0.058	0.056	0.037	1.560	0.059
Science_success × experimental science proficiency → identity	−0.007	−0.007	0.042	0.168	0.433
Science_success × science communication efficacy → identity	−0.089	−0.088	0.025	3.526	0.000

Competence, Practical Science Application, and Science Communication Efficacy) on science identity. Integrative Science Competence stands out with the strongest positive direct effect on science identity, followed by Practical Science Application and Science Communication Efficacy, which also show significant positive relationships. Experimental Science Proficiency presents a significant relationship as well, but with a smaller effect size. Science success also positively contributes to science identity, highlighting its direct role in shaping a person's identification with science.

When introducing gender as a potential moderating variable, the effects on science identity are nuanced. The interaction terms (gender with the different self-efficacy factors) do not show statistically significant effects on science identity, as their *p* values are not within the threshold for significance. This indicates that gender does not significantly alter the impact of science self-efficacy on science identity in the sample examined.

Similarly, science success as a moderator displays mostly non-significant interactions with the various components of learning science self-efficacy in relation to science identity. This suggests that the level of science success does not significantly change the way these self-efficacy components influence one's science identity, with one notable exception. The interaction between science success and Science Communication Efficacy shows a negative and significant effect on science identity. This implies that although Science Communication Efficacy positively affects science identity, when combined with science success, the effect becomes negative. This could indicate a complex dynamic where students who are successful in science but do not feel efficacious in communicating science may experience a conflict that negatively impacts their science identity.

In summary, while learning science self-efficacy components have a strong standalone impact on science identity, the moderating roles of gender and science success are not straightforward. Gender does not appear to influence the relationship significantly. In contrast, science success does seem to moderate the relationship between Science Communication Efficacy and science identity, albeit in a negative way, warranting further investigation to understand this interaction fully.

Figure 4 displays three lines, each representing the relationship between Science Communication Efficacy and science identity at different levels of science success: 1 standard deviation below the mean (red line), at the mean, and 1 standard deviation above the mean (green line).

The slope of the line for participants with science success at −1 SD (below average) is notably steeper and negative, suggesting that for these individuals, as Science Communication Efficacy increases, their science identity significantly decreases. This could indicate that lower levels of science success might amplify negative feelings or perceptions about science identity as the ability to communicate about science increases. For participants at the mean level of science success, the slope is flatter and appears to be more neutral or slightly positive, indicating that at average levels of science success, increases in Science Communication Efficacy have a less pronounced or slightly positive effect on science identity. Lastly, the line for participants with science success at +1 SD (above average) shows a positive relationship. This suggests that individuals with higher levels of science success experience an increase in their science identity as their Science Communication Efficacy improves.

In essence, this simple slopes analysis indicates that the effect of Science Communication Efficacy on science identity is contingent upon the level of science success. The moderating effect of science success is such that individuals with lower success in science may feel a decrease in science identity with better communication efficacy, whereas those with higher success may feel their identity bolstered by the same. This could reflect a potential discrepancy between perceived self-efficacy in communication and actual success in science activities, which could influence how one's science identity is formed or maintained.

Discussion

The results of this study provide important insights into the relationships between science learning self-efficacy, science identity, and the moderating roles of gender and science success. The findings

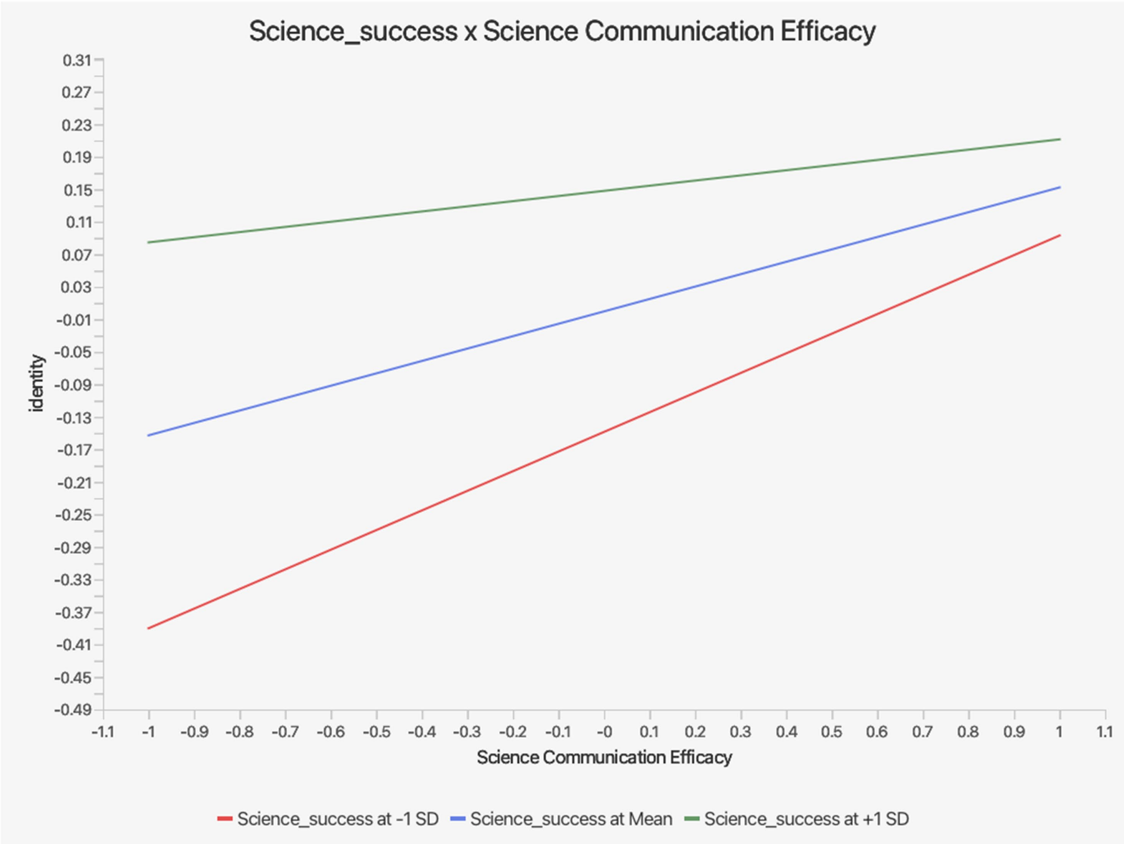

FIGURE 4
Moderating effect chart.

align with previous research highlighting the importance of self-efficacy beliefs in shaping one's identity and engagement within a domain like science (Trujillo and Tanner, 2014; Syed et al., 2019).

Among the dimensions of science learning self-efficacy, integrative science competence emerged as the strongest predictor of science identity. This supports prior work emphasizing the significance of feeling capable of integrating and applying scientific concepts (Britner and Pajares, 2006; Wang and Tsai, 2019). Students who believe in their ability to understand integrated science ideas are more likely to see themselves as "science people." Additionally, practical science application and science communication efficacy also positively influenced science identity, consistent with studies linking these self-efficacy components to science identity development (Lin and Tsai, 2013; Gungor et al., 2022; Hu et al., 2022).

The direct effect of science success on science identity aligns with existing literature indicating that academic achievements reinforce one's sense of competence and identification with a field (Hazari et al., 2017; Chen et al., 2021). Positive experiences of mastering science tasks can strengthen students' view of themselves as capable scientists.

The finding that gender does not significantly affect the link between science learning self-efficacy and science identity in Russia is important and deserves further discussion. This result is different from some earlier studies that found gender differences in science self-efficacy and identity (Desy et al., 2011; Wang and Yu, 2023). The absence of a significant gender effect in our study suggests that other factors in the Russian education system might be more influential in shaping students' science self-efficacy and identity. This finding is crucial for educators and policymakers in Russia, as it indicates that efforts to promote science engagement and identity should focus on factors beyond gender, such as creating inclusive learning environments, fostering positive student-teacher relationships, and offering diverse science role models. By understanding that gender alone does not determine science self-efficacy and identity in Russia, educators can develop strategies that support all students, regardless of gender, in building strong science self-efficacy and identity. However, it aligns with research suggesting that such differences may depend on sociocultural factors (Sachdev, 2018; Chan et al., 2019). The lack of a significant moderating effect could be due to the specific educational context or sample characteristics in this study.

The moderating role of science success presents a more nuanced picture. While science success did not significantly moderate most relationships between self-efficacy components and identity, its interaction with science communication efficacy yielded a negative effect. This unexpected finding contradicts the general positive association between communication efficacy and identity. It suggests that for students with higher success in science, improved communication efficacy may not necessarily translate into a stronger science identity. Conversely, those with lower science success experienced a decrease in science identity as their communication efficacy increased.

This interaction could potentially be explained by a mismatch between perceived communication abilities and actual science achievements. Students who excel in science but feel less capable of communicating science ideas may experience a conflict that undermines their science identity. Conversely, those struggling with science success may feel a disconnect if their communication abilities exceed their perceived competence in the domain. This discrepancy could lead to a weakened sense of science identity, as suggested by the negative interaction effect.

These findings align with research highlighting the complex interplay between various factors in shaping science identity (Avraamidou, 2020; Huffmyer et al., 2022). While self-efficacy beliefs and success experiences generally support a positive science identity, the disconnect between different competency areas (e.g., communication vs. practical application) can potentially create tensions that negatively impact identity formation.

Future research should further explore the conditions under which communication efficacy interacts with science success to influence identity. Qualitative studies could provide deeper insights into students' experiences and perceptions regarding this phenomenon. Additionally, investigating potential mediators or moderators, such as instructional practices, feedback mechanisms, or sociocultural factors, could shed light on how to mitigate the negative interaction and foster a stronger alignment between communication efficacy, success experiences, and science identity.

This study contributes to our understanding of the complex relationships between science learning self-efficacy dimensions, science identity, and the roles of gender and science success. While integrative competence, practical application, and communication efficacy positively shape science identity, the interplay with success experiences warrants further examination. Tailored interventions that align self-efficacy beliefs with mastery experiences across different competency areas could be crucial in nurturing a robust science identity among diverse student populations.

This study examined how gender influences science success and the relationship between self-efficacy in learning science and science identity. It's important to note that teachers, their methods, and their teaching styles significantly impact what and how students learn in science. Although these factors were not directly studied, the results have implications for science education in Russian schools. Integrative science competence, practical science application, and science communication efficacy all positively influence science identity. This highlights the importance of teaching methods that foster these skills and competencies. Teachers should use strategies that allow students to connect science concepts, apply their knowledge in real life, and clearly communicate their understanding. The complex relationship between science achievement and science communication in forming science identity further emphasizes the need for teachers to create supportive learning environments that build students' confidence and encourage scientific discussions. More research is needed on how different teaching methods and pedagogical techniques in Russian schools impact students' science learning self-efficacy, science identity, and the connections observed in this study.

Conclusion

The results show how important it is to improve students' ability to think about and use multiple areas of science, as well as their communication and collaboration skills, in order to build a strong science personality. Students who think they can understand how scientific ideas fit together, use what they have learned in the real world, and explain scientific terms clearly are more likely to see themselves as interested in and passionate about science. In this study, gender did not have a big effect on the link between self-efficacy and identity. However, science success did have an effect, especially when it came to how it affected communication effectiveness.

These results have big effects on how science is taught in Russia. Teachers should use teaching methods that connect different aspects of students' self-efficacy with success experiences across the science curriculum to help them develop a strong sense of who they are as scientists and boost their confidence in their ability to learn. This can be done by:

1. Making lessons that stress combining scientific ideas and showing how various science subjects are linked is the first step.
2. Giving students lots of chances to learn science by doing things like lab work, projects, and activities that require them to solve problems in the real world.
3. Helping students present their scientific ideas clearly through group talks, written tasks, and presentations, and giving them helpful feedback and support.
4. Recognizing and praising students' science accomplishments, including how well they do in school and how much they learn and understand about science.

By using these strategies, Russian science teachers can make a learning environment that boosts students' confidence in their ability to learn science, improves their mastery experiences, and eventually helps them build a strong and lasting science identity.

The results also show that science teachers should be aware of how the complex relationship between science success and communication effectiveness shapes science identity. As a teacher, you should try to make your classroom a welcoming place where all students, no matter how good they are at science right now, feel comfortable talking about and discussing science. Teachers can help students create a more positive science identity by giving students who may have trouble communicating about science specific help and advice.

To build on these results, more study should use qualitative methods to learn more about how students' experiences and thoughts about developing their science identity changed over time. Focus groups and in-depth conversations with students and teachers could help us understand the unique problems, drives, and experiences that shape how Russians form their science identities. On top of that, longitudinal studies could tell us a lot about how science identity changes over time and how educational measures can help it grow.

Although this study offers interesting insights, it is important to understand its various limitations. Initially, the sample size was restricted to high school pupils residing in particular Russian cities, perhaps constraining the applicability of the results to different cultural or educational settings. The data collection's cross-sectional nature precludes making causal inferences regarding the observed associations. In addition, the study utilized self-reported measures, which could potentially be influenced by social desirability bias or participants' poor self-awareness. In addition, the study failed to consider potential confounding factors such as socioeconomic position, previous science experiences, or teacher influences, which could affect the connections between self-efficacy, science achievement, and science identity. To overcome these constraints, future research should utilize longitudinal designs, encompass a more varied sample, and integrate additional variables to gain a more comprehensive picture of the development of science identity among students. Continued exploration of the factors shaping science identity will contribute to the development of effective strategies for widening participation and ensuring equitable opportunities in science education and careers.

In the end, this study shows how important it is to help Russian high school students feel confident in their ability to learn science and give them opportunities to master concepts in order to build a strong sense of their own science identity. It is very important for science teachers to come up with and use teaching methods that help students develop skills like integrating science, using science in real life, and communicating clearly. By making the classroom a safe and interesting place to learn, teachers can give students the tools they need to build a strong science identity, which will help them succeed and stay in science-related areas.

Data availability statement

The data used in the study are available from the corresponding author upon reasonable request.

Ethics statement

The studies involving humans were approved by Almetyevsk State Oil Institute. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

TB: Writing – review & editing, Writing – original draft. AI: Writing – review & editing, Writing – original draft. AR: Writing – review & editing, Writing – original draft. SZ: Writing – review & editing, Writing – original draft. ES: Writing – review & editing, Writing – original draft. DT: Writing – review & editing, Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2024.1409077/full#supplementary-material

References

Al-Balushi, S. M., Mansour, N., Almehrizi, R. S., Ambusaidi, A. K., and Al-Harthy, I. S. (2022). The association between the gender gap in science achievement and students' perceptions of their own attitudes and capabilities. *Eur. J. Math. Sci. Technol. Educ.* 18:em2184. doi: 10.29333/EJMSTE/12559

Alexander, J. M., Johnson, K. E., and Kelley, K. (2012). Longitudinal analysis of the relations between opportunities to learn about science and the development of interests related to science. *Sci. Educ.* 96, 763–786. doi: 10.1002/sce.21018

Alhadabi, A. (2021). Science interest, utility, self-efficacy, identity, and science achievement among high school students: an application of SEM tree. *Front. Psychol.* 12:634120. doi: 10.3389/fpsyg.2021.634120

Antoshchuk, I. A. (2021). Moving through the STEM pipeline: a systematic literature review of the gender inequality in Russian engineering. *Monit. Public Opin. Econ. Soc. Changes* 3, 57–87. doi: 10.14515/monitoring.2021.3.1912

Archer, L., Dewitt, J., and Willis, B. (2014). Adolescent boys' science aspirations: masculinity, capital, and power. *J. Res. Sci. Teach.* 51, 1–30. doi: 10.1002/tea.21122

Avraamidou, L. (2020). Science identity as a landscape of becoming: rethinking recognition and emotions through an intersectionality lens. *Cult. Stud. Sci. Educ.* 15, 323–345. doi: 10.1007/s11422-019-09954-7

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York, NY: W. H. Freeman.

Bessudnov, A., and Malik, V. (2016). Socio-economic and gender inequalities in educational trajectories upon completion of lower secondary education in Russia. *Voprosy Obrazovaniya/Educ. Stud. Moscow* 2016, 135–167. doi: 10.17323/1814-9545-2016-1-135-167

Britner, S. L., and Pajares, F. (2006). Sources of science self-efficacy beliefs of middle school students. *J. Res. Sci. Teach.* 43, 485–499. doi: 10.1002/tea.20131

Bryan, R. R., Glynn, S. M., and Kittleson, J. M. (2011). Motivation, achievement, and advanced placement intent of high school students learning science. *Sci. Educ.* 95, 1049–1065. doi: 10.1002/sce.20462

Carlone, H. B., and Johnson, A. (2007). Understanding the science experiences of successful women of color: science identity as an analytic lens. *J. Res. Sci. Teach.* 44, 1187–1218. doi: 10.1002/tea.20237

Chan, H. W., Pong, V., and Tam, K. P. (2019). Cross-National Variation of gender differences in environmental concern: testing the sociocultural hindrance hypothesis. *Environ. Behav.* 51, 81–108. doi: 10.1177/0013916517735149

Chen, S., Binning, K. R., Manke, K. J., Brady, S. T., McGreevy, E. M., Betancur, L., et al. (2021). Am I a science person? A strong science identity bolsters minority students' sense of belonging and performance in college. *Personal. Soc. Psychol. Bull.* 47, 593–606. doi: 10.1177/0146167220936480

Chen, S., and Wei, B. (2022). Development and validation of an instrument to measure high school students' science identity in science learning. *Res. Sci. Educ.* 52, 111–126. doi: 10.1007/s11165-020-09932-y

Conner, L. D. C., and Danielson, J. (2016). Scientist role models in the classroom: how important is gender matching? *Int. J. Sci. Educ.* 38, 2414–2430. doi: 10.1080/09500693.2016.1246780

Dennehy, T. C., and Dasgupta, N. (2017). Female peer mentors early in college increase women's positive academic experiences and retention in engineering. *Proc. Natl. Acad. Sci. USA* 114, 5964–5969. doi: 10.1073/pnas.1613117114

Desy, E. A., Peterson, S. A., and Brockman, V. (2011). Gender differences in science-related attitudes and interests among middle school and high school students. *Sci. Educ.* 20, 23–30.

Eagan, M. K., Romero, A. L., and Zhong, S. (2023). BUILDing an early advantage: an examination of the role of strategic interventions in developing first-year undergraduate students' science identity. *Res. High. Educ.* 65, 181–207. doi: 10.1007/s11162-023-09745-8

Fraser, J., Shane-Simpson, C., and Asbell-Clarke, J. (2014). Youth science identity, science learning, and gaming experiences. *Comput. Hum. Behav.* 41, 523–532. doi: 10.1016/j.chb.2014.09.048

Glebova, M. V. (2023). Methodological approaches to the formation of a natural-science picture of the world among students in the context of the implementation of the requirements of the Federal State Educational Standards of secondary general education. In: II all-Russian (national) scientific conference with international participation "Russian science, innovation, education", 431–440.

Glynn, S. M., Brickman, P., Armstrong, N., and Taasoobshirazi, G. (2011). Science motivation questionnaire II: Validation with science majors and nonscience majors. *J. Res. Sci. Teach.* 48, 1159–1176. doi: 10.1002/tea.20442

Gubbels, J. A. A., and Vitiello, S. P. (2018). Creating and teaching science lessons in K–12 schools increases undergraduate students' science identity. *J. Microbiol. Biol. Educ.* 19:19.3.96. doi: 10.1128/jmbe.v19i3.1594

Gungor, A., Kool, D., Lee, M., Avraamidou, L., Eisink, N., Albada, B., et al. (2022). The use of virtual reality in a chemistry lab and its impact on students' self efficacy, interest, self-concept and laboratory anxiety. *Eur. J. Math. Sci. Technol. Educ.* 18:em2090. doi: 10.29333/ejmste/11814

Hair, J. F., Risher, J. J., Sarstedt, M., and Ringle, C. M. (2019). When to use and how to report the results of PLS-SEM. *Eur. Bus. Rev.* 31, 2–24. doi: 10.1108/EBR-11-2018-0203

Hazari, Z., Brewe, E., Goertzen, R. M., and Hodapp, T. (2017). The importance of high school physics teachers for female students' physics identity and persistence. *Phys. Teach.* 55, 96–99. doi: 10.1119/1.4974122

Hazari, Z., Sonnert, G., Sadler, P. M., and Shanahan, M. C. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: a gender study. *J. Res. Sci. Teach.* 47, 978–1003. doi: 10.1002/tea.20363

Henseler, J., Hubona, G., and Ray, P. A. (2017). Partial least squares path modeling: Updated guidelines. In *Partial Least Squares Path Modeling 19–39*. Springer International Publishing. doi: 10.1007/978-3-319-64069-3_2

Herrmann, S. D., Adelman, R. M., Bodford, J. E., Graudejus, O., Okun, M. A., and Kwan, V. S. Y. (2016). The effects of a female role model on academic performance and persistence of women in STEM courses. *Basic Appl. Soc. Psychol.* 38, 258–268. doi: 10.1080/01973533.2016.1209757

Huffmyer, A. S., Oneill, T., and Lemus, J. D. (2022). Evidence for professional conceptualization in science as an important component of science identity. *CBE Life Sci. Educ.* 21:ar76. doi: 10.1187/cbe.20-12-0280

Hu, X., Jiang, Y., and Bi, H. (2022). Measuring science self-efficacy with a focus on the perceived competence dimension: using mixed methods to develop an instrument and explore changes through cross-sectional and longitudinal analyses in high school. *Int. J. STEM Educ.* 9, 1–24. doi: 10.1186/s40594-022-00363-x

Jackson, M. C., Galvez, G., Landa, I., Buonora, P., and Thoman, D. B. (2016). Science that matters: the importance of a cultural connection in underrepresented students' science pursuit. *CBE Life Sci. Educ.* 15:ar42. doi: 10.1187/cbe.16-01-0067

Kataeva, Z., Durrani, N., Izekenova, Z., and Rakhimzhanova, A. (2023). Evolution of gender research in the social sciences in post-soviet countries: a bibliometric analysis. *Scientometrics* 128, 1639–1666. doi: 10.1007/s11192-022-04619-9

Kim, M. (2018). Understanding children's science identity through classroom interactions. *Int. J. Sci. Educ.* 40, 24–45. doi: 10.1080/09500693.2017.1395925

Lebeck, K., Ruth, K., Kohno, T., and Roesner, F. (2018). Arya: operating system support for securely augmenting reality. *IEEE Secur. Priv.* 16, 44–53. doi: 10.1109/MSP.2018.1331020

Lin, T.-J., and Tsai, C.-C. (2013). A multi-dimensional instrument for evaluating taiwanese high school students' science learning self-efficacy in relation to their approaches to learning science. *Int. J. Sci. Math. Educ.* 11, 1275–1301. doi: 10.1007/s10763-012-9376-6

Lisichkin, G. V., and Leenson, I. A. (2013). Natural-sciences education in secondary school in the USSR and Russia: history, trends, and challenges of modernization. *Russ. J. Gen. Chem.* 83, 1185–1203. doi: 10.1134/S1070363213060388

Loyalka, P., Liu, O. L., Li, G., Kardanova, E., Chirikov, I., Hu, S., et al. (2021). Skill levels and gains in university STEM education in China, India, Russia and the United States. *Nat. Hum. Behav.* 5, 892–904. doi: 10.1038/s41562-021-01062-3

Mansfield, J., Park Rogers, M., and Berry, A. (2022). Understanding identity development as a science teacher educator through shifts in pedagogical equilibrium. *Front. Educ.* 7:908706. doi: 10.3389/feduc.2022.908706

Masalimova, A. R., Zheltukhina, M. R., Sergeeva, O. V., Kosarenko, N. N., Tsomartova, D. A., and Smirnova, L. M. (2024). Science teaching in BRICS: a systematic review of pedagogical approaches and challenges. *Eur. J. Math. Sci. Technol. Educ.* 20:em2432. doi: 10.29333/ejmste/14434

Master, A., and Meltzoff, A. N. (2020). Cultural stereotypes and sense of belonging contribute to gender gaps in STEM. *Int. J. Gender* 12, 152–198.

Meinck, S., and Brese, F. (2019). Trends in gender gaps: using 20 years of evidence from TIMSS. *Large-scale Assess. Educ.* 7:8. doi: 10.1186/s40536-019-0076-3

Meyer, X. S., and Crawford, B. A. (2015). Multicultural inquiry toward demystifying scientific culture and learning science. *Sci. Educ.* 99, 617–637. doi: 10.1002/sce.21162

Miles, J. A., and Naumann, S. E. (2021). Science self-efficacy in the relationship between gender & science identity. *Int. J. Sci. Educ.* 43, 2769–2790. doi: 10.1080/09500693.2021.1986647

Moiseev, V. V., and Chernyh, S. A. (2019). *Actual problems of education and science in Russia*. Business and Management Research: Advances in Economics, 96.

Nurhasnah, N., Lufri, L., Andromed, A., and Mufit, F. (2022). Analysis of students' self efficacy in science learning. *Unnes Sci. Educ. J.* 11, 109–114. doi: 10.15294/usej.v11i2.58458

Paul-Hus, A., Bouvier, R. L., Ni, C., Sugimoto, C. R., Pislyakov, V., and Larivière, V. (2015). Forty years of gender disparities in Russian science: a historical bibliometric analysis. *Scientometrics* 102, 1541–1553. doi: 10.1007/s11192-014-1386-4

Pentin, A., Kovaleva, G., Davidova, E., and Smirnova, E. (2018). Science education in Russia according to the results of the TIMSS and PISA international studies. *Voprosy Obrazovaniya/Educ. Stud. Moscow* 2018, 79–109. doi: 10.17323/1814-9545-2018-1-79-109

Reuben, E., Sapienza, P., and Zingales, L. (2014). How stereotypes impair women's careers in science. *Proc. Natl. Acad. Sci. USA* 111, 4403–4408. doi: 10.1073/pnas.1314788111

Robinson, K. A., Perez, T., Carmel, J. H., and Linnenbrink-Garcia, L. (2019). Science identity development trajectories in a gateway college chemistry course: predictors and relations to achievement and STEM pursuit. *Contemp. Educ. Psychol.* 56, 180–192. doi: 10.1016/j.cedpsych.2019.01.004

Robinson, K. A., Perez, T., White-Levatich, A., and Linnenbrink-Garcia, L. (2022). Gender differences and roles of two science self-efficacy beliefs in predicting post-college outcomes. *J. Exp. Educ.* 90, 344–363. doi: 10.1080/00220973.2020.1808944

Robnett, R. D., Chemers, M. M., and Zurbriggen, E. L. (2015). Longitudinal associations among undergraduates' research experience, self-efficacy, and identity. *J. Res. Sci. Teach.* 52, 847–867. doi: 10.1002/tea.21221

Rushton, E. A. C., and Reiss, M. J. (2021). Middle and high school science teacher identity considered through the lens of the social identity approach: a systematic review of the literature. *Stud. Sci. Educ.* 57, 141–203. doi: 10.1080/03057267.2020.1799621

Sachdev, A. R. (2018). Gender disparity in STEM across cultures. *Ind. Organ. Psychol.* 11, 309–313. doi: 10.1017/iop.2018.20

Sandrone, S. (2022). Science identity and its "identity crisis": on science identity and strategies to Foster self-efficacy and sense of belonging in STEM. *Front. Educ.* 7:871869. doi: 10.3389/feduc.2022.871869

Sezgintürk, M., and Sungur, S. (2020). A multidimensional investigation of students' science self-efficacy: the role of gender. *Element. Educ. Online* 19, 208–218. doi: 10.17051/ilkonline.2020.653660

Shanahan, M. C. (2009). Identity in science learning: exploring the attention given to agency and structure in studies of identity. *Stud. Sci. Educ.* 45, 43–64. doi: 10.1080/03057260802681847

Sheffield, S. L., Cook, M. L., Ricchezza, V. J., Rocabado, G. A., and Akiwumi, F. A. (2021). Perceptions of scientists held by US students can be broadened through inclusive classroom interventions. *Commun. Earth Environ.* 2:83. doi: 10.1038/s43247-021-00156-0

Stets, J. E., Brenner, P. S., Burke, P. J., and Serpe, R. T. (2017). The science identity and entering a science occupation. *Soc. Sci. Res.* 64, 1–14. doi: 10.1016/j.ssresearch.2016.10.016

Syed, M., Zurbriggen, E. L., Chemers, M. M., Goza, B. K., Bearman, S., Crosby, F. J., et al. (2019). The role of self-efficacy and identity in mediating the effects of STEM support experiences. *Anal. Soc. Issues Public Policy* 19, 7–49. doi: 10.1111/asap.12170

Tan, A. L., Liang, J. C., and Tsai, C. C. (2021). Relationship among high school students' science academic hardiness, conceptions of learning science and science learning self-efficacy in Singapore. *Int. J. Sci. Math. Educ.* 19, 313–332. doi: 10.1007/s10763-019-10040-1

Tan, C. Y., Gao, L., Hong, X., and Song, Q. (2023). Socioeconomic status and students' science self-efficacy. *Br. Educ. Res. J.* 49, 782–832. doi: 10.1002/berj.3869

Trisnawati, H. A., Winarni, R., and Yamtinah, S. (2020). "Self-efficacy in scientific literacy student ability based on gender" in *3rd international conference on learning innovation and quality education (ICLIQE 2019)*, 727–734.

Trujillo, G., and Tanner, K. D. (2014). Considering the role of affect in learning: monitoring students' self-efficacy, sense of belonging, and science identity. *CBE Life Sci. Educ.* 13, 6–15. doi: 10.1187/cbe.13-12-0241

Usher, E. L., and Pajares, F. (2009). Sources of self-efficacy in mathematics: a validation study. *Contemp. Educ. Psychol.* 34, 89–101. doi: 10.1016/j.cedpsych.2008.09.002

Vincent-Ruz, P., and Schunn, C. D. (2018). The nature of science identity and its role as the driver of student choices. *Int. J. STEM Educ.* 5:48. doi: 10.1186/s40594-018-0140-5

Wang, J., Yang, M., Lv, B., Zhang, F., Zheng, Y., and Sun, Y. (2020). Influencing factors of 10th grade students' science career expectations: a structural equation model. *J. Balt. Sci. Educ.* 19, 675–686. doi: 10.33225/jbse/20.19.675

Wang, L., and Yu, Z. (2023). Gender-moderated effects of academic self-concept on achievement, motivation, performance, and self-efficacy: a systematic review. *Front. Psychol.* 14:1136141. doi: 10.3389/fpsyg.2023.1136141

Wang, Y. L., and Tsai, C. C. (2019). Exploring the structure of science learning self-efficacy: the role of science learning hardiness and perceived responses to capitalization attempts among Taiwanese junior high school students. *Res. Sci. Technol. Educ.* 37, 54–70. doi: 10.1080/02635143.2018.1480476

Williams, B., Onsman, A., and Brown, T. (2010). Exploratory factor analysis: a five-step guide for novices. *J. Emerg. Prim. Health Care* 8, 1–13. doi: 10.33151/ajp.8.3.93

Wong, K. K.-K. (2019). Mastering Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS in 38 Hours. *IUniverse.*

Zeldin, A. L., Britner, S. L., and Pajares, F. (2008). A comparative study of the self-efficacy beliefs of successful men and women in mathematics, science, and technology careers. *J. Res. Sci. Teach.* 45, 1036–1058. doi: 10.1002/tea.20195

Zheng, L., Dong, Y., Huang, R., Chang, C. Y., and Bhagat, K. K. (2018). Investigating the interrelationships among conceptions of, approaches to, and self-efficacy in learning science. *Int. J. Sci. Educ.* 40, 139–158. doi: 10.1080/09500693.2017.1402142