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Teacher self-efficacy for science teaching in elementary education: Teachers' expectations and beliefs in Chile

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Abstract

Teacher self-efficacy is recognized as a key factor in science teaching, however, there is limited evidence from highly complex border contexts. This study examined science teaching self-efficacy beliefs among in-service elementary teachers in the northern border region of Chile, using the science teaching efficacy belief instrument A. With a total sample of $n = 332$, the internal consistency of the science teaching self-efficacy ($\alpha = .84$, $\omega = .82$) and outcome expectancy (OE) ($\alpha = .78$, $\omega = .79$) dimensions was examined, and a simple linear regression model was estimated to assess the relationship between science teaching self-efficacy and OE. The results reveal a positive and statistically significant relationship between self-efficacy and OE ($b = 0.265$, $R^2 = .102$, $p < .001$). These findings indicate that self-efficacy significantly predicts OE, conditioned by the institutional and territorial context.

Keywords: teacher self-efficacy, science teaching, elementary education, outcome expectancy

INTRODUCTION

The current debate surrounding climate change, the COVID-19 pandemic, and the growing reliance on science in national development has intensified interest in science education, recognizing its value in fostering scientific competencies essential for the exercise of citizenship (Brumann et al., 2022; Ministerio de Educación de Chile [MINEDUC], 2023; United Nations Educational, Scientific and Cultural Organization [UNESCO], 2022). This issue acquires particular relevance in the Latin American context, where educational systems face structural gaps associated with socio-economic inequality, school segmentation, and unequal access to learning opportunities in science. Various international reports have shown that, on average, countries in the region perform below the Organization for Economic Co-operation and Development (OECD, 2019) average in scientific literacy, thereby constraining the development of critical citizenship and informed participation in contemporary socio-scientific debates.

Within this regional landscape, Chile is no exception. Achieving minimum levels of scientific education constitutes a fundamental challenge, particularly considering the six levels of scientific proficiency defined by the program for international student assessment. Data from the 2018 assessment indicate that 35% of Chilean 15-year-old students do not reach level 2 in scientific proficiency. This implies difficulties in identifying and understanding scientific problems, which limits engagement in discussions of more complex socio-scientific issues that affect them, and an inability to apply scientific knowledge and methods learned in school to solve problems that would enable them to better understand the world and improve their quality of life (OECD, 2019).

As complementary evidence, the assessments conducted through the national system for the evaluation of learning outcomes [sistema de medición de la calidad de la educación en Chile] have consistently documented significant regional disparities in student achievement across Chile. In particular, the results of the 2017 and 2018 evaluations for 8th and 6th grade, respectively revealed persistent gaps associated with socio-economic and geographic factors, with schools

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Contribution to the literature

- This study provides the first psychometric evidence of the science teaching efficacy belief instrument A (STEBI-A) among in-service elementary teachers in a Chilean border region, a context that has been scarcely represented in science education research in Latin America.
- Unlike previous studies focused on pre-service teachers or metropolitan contexts, this research examines self-efficacy beliefs among in-service teachers working under conditions of high socio-educational complexity, cultural diversity, and structural vulnerability.
- The findings show that the relationship between self-efficacy and outcome expectancy (OE) is shaped by the institutional and territorial context, with direct implications for the design of policies for continuing professional development of science teachers in peripheral regions.

located in peripheral and border regions tending to obtain results below the national average (Agencia de Calidad de la Educación, 2018, 2019). This pattern underscores the importance of examining teacher-related variables, such as science teaching self-efficacy, in contexts characterized by structural educational inequities, as is the case of the Arica y Parinacota Region.

Indeed, advancing science education in Chile has proven to be a complex endeavor, as reflected in the broad consensus among researchers and experts who have highlighted the substantial gap between teacher education institutions and the school system. Specifically, tensions, limited articulation, and insufficient alignment between initial teacher education and the demands of professional teaching practice have been identified (Bastías-Bastías & Iturra-Herrera, 2022; Cabezas et al., 2019). This situation has underscored the need to move toward substantive improvements in science teaching nationwide (Marzabal Blancafort & Merino Rubilar, 2021).

Consequently, it has been argued that a fundamental measure for fostering a broad movement toward the transformation of science education lies in prioritizing both initial and continuing teacher education (Quintanilla & Adúriz-Bravo, 2022). Undoubtedly, prioritizing science teaching constitutes an unavoidable pathway if the country aims to address the population's essential needs in terms of scientific literacy. In particular, placing emphasis on science education at the primary level represents a strategic imperative (Osborne et al., 2022; Roy et al., 2025).

On the other hand, the need has also been reported to investigate the multiple factors that influence the quality of science teaching at all educational levels, particularly at the primary level, where teachers are required to undertake this task despite not being specialists in science. Within this line of inquiry, one dimension that has attracted increasing research attention, given its documented effects on student learning, is teachers' self-efficacy beliefs for science teaching (Akerson & Bartels, 2023), understood as teachers' beliefs about their own skills and capabilities to teach in this subject area (Mohammed & Luguterah, 2024). Existing research has focused on elucidating how teachers perceive their capacity to promote student learning and on understanding how these beliefs are related to the outcomes they achieve and to their instructional practices (Witter & Hattie, 2024). In this sense, self-efficacy has emerged as an increasingly significant variable (González-Mayorga & Esteban, 2023; Karlen et al., 2023), as will be discussed in greater depth below.

At this point, it is important to emphasize that research in science education seeks to understand the complexity of teaching and learning science, often beginning with highly selected and isolated cases through an approach that is attentive to local culture and responsive to the emergent nature of socio-cultural phenomena. This perspective entails recognizing contextual conditions and giving voice to perspectives that are frequently marginalized (Kelly, 2023).

This suggests that research processes in the field of science education are situated within specific temporal and geographical contexts (Freire-Contreras et al., 2021). In particular, the northern border of Chile is a tri-border area of considerable complexity that warrants special attention in terms of science education and research for three fundamental reasons. First, it encompasses schools characterized by high levels of diversity, multiethnicity, immigration, and socio-economic vulnerability (Alvarado Urbina & Zapata Sepúlveda, 2020; Gómez Chaparro & Sepúlveda, 2022; Sánchez Espinosa & Norambuena Carrasco, 2019), which generate numerous opportunities and challenges related to educational inclusion (Weiss et al., 2024). Second, the region is marked by serious environmental problems, including the high presence of poly-metals, particularly lead and arsenic, water scarcity, and soil degradation. Finally, there is a concerning shortage of teachers, particularly in science and mathematics, with Natural Sciences projected as one of the most critically affected subjects in the coming years (Consejo Nacional de Educación, 2021; Elige Educar, 2021).

In light of this context, the present study acknowledges that teaching science in a highly complex setting such as the northern border of Chile requires teacher education characterized by high levels of professionalism and social commitment. From this perspective, the present study contributes to reducing the knowledge gap concerning teachers' beliefs in border regions by providing situated empirical evidence on science teaching in northern Chile. Specifically, this study addresses the following research question: What is the relationship between personal science teaching efficacy (ST) and OE among in-service elementary teachers in the northern border region of Chile?

The decision to focus on in-service rather than pre-service teachers responds to a theoretically and empirically grounded rationale. Unlike pre-service teachers, whose efficacy beliefs are still forming within controlled practicum contexts, in-service teachers operate within real institutional and territorial conditions that actively shape their professional beliefs. In high-complexity border contexts such as the one examined here, examining the beliefs of practicing teachers provides a more ecologically valid account of how self-efficacy develops and operates under the structural constraints that characterize the region.

Science Education at the Primary Level in Chile

The task of science education begins at the earliest stages of schooling by fostering in students the capacity to apply the knowledge and skills acquired in science classes to their daily lives. This includes asking questions about phenomena in the natural world, drawing conclusions, and making informed decisions based on evidence, an approach recognized in the Chilean curriculum as scientific literacy and identified as the central aim of science education (Bórquez-Sánchez, 2025; Guerrero & Torres-Olave, 2022; MINEDUC, 2012, 2023).

Although each region of the world establishes its own scientific standards, a shared principle is the expectation that content should not be taught in a decontextualized manner or through an encyclopedic and transmissive model (Reimers, 2021; Valladares, 2021). Research has shown that students who fail to reach adequate levels of scientific competence face multiple challenges in their personal and professional trajectories. Nevertheless, evidence indicates that less instructional time and institutional support are devoted to natural sciences than to other subjects, such as language and mathematics (Diliberti et al., 2023). Furthermore, it has been noted that most primary teachers who teach science do not go beyond content transmission (Nicolás-Castellano et al., 2023).

In Chilean primary education, specific content standards, learning objectives, and progress maps have been established for the development of scientific competencies (Sepúlveda-Obreque et al., 2024). This represents a significant curricular commitment compared to the heterogeneous treatment that science education receives across Latin American countries, where its depth and explicit articulation vary considerably (Zompero et al., 2022). In addition, science teaching in Chile is guided by pedagogical and disciplinary standards, as well as by the framework for good teaching [marco para la buena enseñanza] (MINEDUC, 2021). The framework, structured around four domains, provides guidance for

(a) the preparation of instruction,

(b) the creation of an environment conducive to learning,

(c) teaching for the learning of all students, and

(d) professional responsibilities.

Each domain delineates a set of knowledge, skills, and dispositions regarding teaching and learning that should inform professional practice and be interpreted within specific contexts (MINEDUC, 2021). Despite these advances, it is important to emphasize that science education in Chile is currently undergoing a process of transformation in response to contemporary demands (MINEDUC, 2023; Quintanilla & Adúriz-Bravo, 2022).

In this regard, recent empirical research has shown that Chilean government policies seek to grant students a more central role in the science learning process (Bravo & Reiss, 2023). However, the reality remains distant from these policy intentions insofar as teaching practices continue to assign learners a merely passive role (Marolla-Gajardo, 2019) and to disconnect scientific content from everyday reality (Massip Sabater et al., 2020). Moreover, several authors conclude that the Chilean primary natural sciences curriculum reflects the coexistence of two approaches (Guerrero & Torres-Olave, 2022; Quintanilla & Adúriz-Bravo, 2022). On the one hand, innovation is presented as a proposal for improvement that defines the purposes and aims of studying science. On the other hand, the persistence of a traditional model remains evident, characterized by an encyclopedic and decontextualized view of science (Marzabal Blancafort & Merino Rubilar, 2021; Pérez-Rodriguez et al., 2024).

It is important to underscore the three levels that influence science teaching in schools according to recent literature (Fischer & Neumann, 2023):

1. The level of individual teaching and learning processes in science, which includes knowledge, competencies, beliefs, motivation, and interest, as well as students' prior knowledge, cognitive skills, and cognitive development.
2. The level of the science classroom encompassing teacher and student activities and interactions and instructional quality as reflected in those activities and interactions associated with learning outcomes, such as teachers' pedagogical content knowledge, content knowledge, and general pedagogical knowledge.
3. The system level, which includes school system conditions and broader social units, such as school funding and governance structures (Honingh et al., 2020). Within this framework, teacher self-

efficacy for science teaching emerges as a central individual-level variable, with implications that extend to classroom and system levels.

Primary Teachers' Self-Efficacy for Science Teaching

Self-efficacy is conceptualized as a motivational construct grounded in teachers' perceptions of their own competencies and capabilities to carry out the task of teaching. This construct is supported by the judgments teachers make regarding their skills and capacities, from which beliefs emerge that influence the motivation, effort, and perseverance required to confront the challenges that typically arise in professional practice (Bandura, 1997). These beliefs are based on internal factors such as knowledge, confidence, and skills (Bandura, 1997; Gálvez-Nieto et al., 2023). At present, the predominant model of teacher self-efficacy remains that proposed by Tschannen-Moran et al. (1998), later refined by Tschannen-Moran and Hoy (2001). This model conceptualizes self-efficacy as a cyclical process of judgments that evolves from an individualistic perspective toward a more collective understanding of teaching activity (Lazarides et al., 2020).

Teacher self-efficacy is receiving increasing scholarly attention due to the positive effects that have been documented, as it has been shown to display similar positive correlations with teachers' instructional practices across various countries (Rodríguez-Hidalgo et al., 2024). The vast majority of prior research on teacher self-efficacy beliefs has concentrated on preservice and novice teachers, who have consistently been found to exhibit the lowest efficacy levels compared to their more experienced in-service counterparts (Lam et al., 2023). Despite the educational implications outlined above, there remain relatively few research reports examining self-efficacy beliefs among in-service teachers, and even fewer that specifically address science teachers. Among the studies identified, the work of von Knebel et al. (2023) is noteworthy, as their findings with a cross-sectional sample of science teachers indicate that teaching experience constitutes a significant positive predictor of self-efficacy beliefs, with in-service teachers consistently reporting the highest levels across all efficacy dimensions.

Current evidence converges on the idea that teachers' self-efficacy beliefs are not merely an individual disposition but a variable with cascading effects on classroom practice: it has been linked to instructional quality (Burić & Kim, 2020; Shwartz et al., 2021), student achievement (Li et al., 2024), and, in the affective domain, to burnout, job satisfaction (Vinokur et al., 2024), and professional commitment (Bastian & Widodo, 2024). Yet most of this evidence originates from stable, well-resourced educational systems, leaving open the question of whether the same associations are held in structurally marginalized or border contexts such as the one examined here.

Additionally, research consistently indicates that teachers' perceived competence in content delivery and classroom management functions as a protective factor against occupational stress and burnout while positively predicting professional satisfaction and commitment (Duan et al., 2024). Beyond individual-level factors, evidence from multi-country studies demonstrates that the predictors of teacher self-efficacy across its three core dimensions – student engagement, instructional strategies, and classroom management – vary substantially according to structural, environmental, and classroom-level conditions, underscoring the situated nature of efficacy beliefs (Fackler et al., 2021). In this regard, Lazarides et al. (2020) documented, through a longitudinal design, that teachers' self-efficacy for classroom management supports the development of perceived classroom structure and is shaped by job resources and demands across different career stages, thereby linking efficacy beliefs to both instructional quality and professional well-being. Taken together, these findings highlight that teacher self-efficacy is not a uniform or static construct. While Fackler et al. (2021) demonstrate that structural and environmental conditions modulate efficacy beliefs across systems, Lazarides et al. (2020) show that this relationship also operates longitudinally through job demands and resources across career stages. These perspectives are not fully reconcilable: the former emphasizes system-level constraints, whereas the latter foregrounds individual professional trajectories, suggesting that efficacy beliefs are shaped by the interaction of both, rather than by either factor alone.

Regarding science teaching, a growing body of research has examined the self-efficacy beliefs of in-service primary teachers, demonstrating that these beliefs operate as robust predictors of instructional behavior, science teaching frequency, and the adoption of inquiry-based pedagogical approaches (Mohammed & Luguterah, 2024). Specifically, teachers who report higher levels of ST are more likely to integrate science into their daily instruction, to engage students in hands-on and student-centered activities, and to persist in the face of the challenges inherent to primary science education. Measurement of these efficacy beliefs has relied predominantly on the STEBI-A (Riggs & Enochs, 1990), which assesses two interrelated dimensions: ST and science teaching OE. Despite its widespread adoption over more than three decades, subsequent psychometric work has identified limitations in the instrument's wording, dimensionality, and reliability, prompting ongoing efforts to revise and validate updated versions for contemporary research contexts (Unfried et al., 2022).

Conceptual models addressing the effects of teacher self-efficacy posit that efficacy beliefs are associated with important teacher outcomes, reporting direct positive relationships between teachers' ST beliefs and both teacher and student satisfaction, as well as indirect relationships mediated by instructional practices (Perera et al., 2022; Sokha, 2024). Indeed, self-efficacy has also been shown to influence teachers' confidence in delivering high quality science lessons (von Knebel et al., 2023).

Other studies have examined the influence of contextual, structural, and environmental factors on ST and have consistently identified school-level conditions, including collegial support, access to instructional resources, and the availability of time for lesson planning and delivery, as key predictors of teachers' efficacy beliefs across diverse educational systems (Fackler et al., 2021). In this regard, evidence indicates that primary school teachers frequently report low levels of confidence in teaching science, limited perceived preparation to do so effectively, and a tendency to hesitate or reduce the frequency of science instruction, patterns closely linked to deficits in pedagogical content knowledge and to low personal ST (Mohammed & Luguterah, 2024).

It is also noteworthy that teachers' conceptions of the nature of science, scientific inquiry, and science content have been found to be related to their self-efficacy beliefs (Akerson & Bartels, 2023). Consistent with evidence indicating that low levels of self-efficacy may reduce teachers' willingness to teach science and, ultimately, contribute to weaker educational provision at the elementary level. Hence, the aim of this study was to examine ST beliefs among in-service elementary teachers in the north of Chile, analyzing their psychometric properties and their relationship with OE.

MATERIALS AND METHODS

Design and Participants

A quantitative, non-experimental, cross-sectional study was conducted using descriptive and inferential analyses. The total sample used for the STEBI-A analysis consisted of n = 332 in-service primary education teachers who teach natural sciences in the Region of Arica and Parinacota, located in the northern border of Chile. A non-probability convenience sampling was employed, as participants were selected based on their accessibility and availability during in-service professional development activities (Creswell & Creswell, 2018). Participants were contacted through a special continuing professional development program implemented in northern Chile during in-service training courses and through the Regional Ministerial Secretariats of Education.

Data collection took place between 2024 and 2025 as part of FONDECYT project 11241075, entitled "Teaching natural sciences at the primary level in a border context: Relationships and tensions between professional practice, initial teacher training, and self-efficacy." To ensure broad participation across both urban and rural school settings, the instrument was administered through two complementary modalities: in person, during scheduled in-service professional development sessions, and remotely, via an online digital form. A total of 332 teachers from public and government-subsidized private schools in the Arica y Parinacota Region completed the questionnaire.

All participants signed an informed consent form indicating that participation was voluntary and anonymous, that the information collected would be treated with strict confidentiality, and that it would be used exclusively for academic purposes, in accordance with current ethical regulations. This study received ethical approval from the Ethics Committee of the Universidad de Tarapacá (approval number: C01-2024).

It is acknowledged that while the introduction frames self-efficacy as shaped by institutional and territorial conditions, the empirical model does not include such variables. This decision was deliberate: the present study focuses on the bivariate relationship between the two STEBI-A dimensions as a necessary first step in this context, given the absence of prior psychometric evidence. The contextual factors identified in the theoretical framework are therefore treated as interpretive elements and proposed as directions for future research incorporating more complex models.

Instrument

The STEBI-A for in-service teachers (Riggs & Enochs, 1990) was administered. Given that the original instrument was developed in English, a translation into Spanish was produced for the purposes of the present study. The translation was carried out by a specialist in academic and professional translation with expertise in educational and psychometric terminology. To verify semantic and conceptual equivalence with the source version, the translated items were reviewed by a panel of three bilingual experts in science education and psychometrics, who assessed the adequacy of each item and resolved discrepancies by consensus. Although a formal back-translation procedure was not conducted, the expert panel review followed established criteria for cross-cultural adaptation of psychometric instruments (Creswell & Creswell, 2018).

The STEBI-A comprises 25 items, presented on a 5 point Likert scale (1 = strongly disagree to 5 = strongly agree). Preliminary screening in the present sample identified four items with corrected item-total correlations that were negative or close to zero (ST21, ST25, OE10, and OE13). Because these items did not behave consistently with the remaining ones, they were removed prior to the analyses, yielding a 21-item version with 13 items for ST and 8 for OE. Possible scores range

Table 1. Scale and item reliability analysis for the ST dimension

Element	M	SD	Corrected item-total r	α if item deleted
Total scale	3.31	0.717	-	-
ST2	4.20	0.894	.151	.848
ST3 (Rev)	2.56	1.244	.452	.833
ST5	3.89	0.750	.150	.847
ST6 (Rev)	2.55	1.237	.484	.831
ST8 (Rev)	2.98	1.542	.736	.810
ST12	3.89	0.920	.331	.840
ST17 (Rev)	2.70	1.319	.685	.816
ST18	4.08	0.849	.223	.844
ST19 (Rev)	2.91	1.411	.328	.843
ST20 (Rev)	3.07	1.436	.778	.807
ST22 (Rev)	2.97	1.526	.752	.808
ST23	4.32	0.977	.245	.844
ST24 (Rev)	2.93	1.395	.812	.804

Note. n = 332; α = .841; ω = .82; Mean inter-item correlation = .26; Rev: Reverse-scored item; & Possible summed scores range from 13 to 65

Table 2. Scale and item reliability analysis for the OE dimension

Element	M	SD	Corrected item-total r	α if item deleted
Total scale	3.87	0.596	-	-
OE1	3.52	1.128	.413	.765
OE4	4.30	0.799	.482	.751
OE7	3.47	1.044	.307	.781
OE9	4.13	0.993	.308	.779
OE11	3.83	0.981	.490	.748
OE14	3.76	0.904	.585	.733
OE15	3.87	0.899	.705	.713
OE16	4.11	0.861	.622	.729

Note. n = 332; α = .775; ω = .79; Mean inter-item correlation = .32; & Possible summed scores range from 8 to 40

from 13 to 65 for the ST dimension and from 8 to 40 for the OE dimension. This decision is reported transparently as a sample-specific adaptation rather than as a property of the original instrument.

Sample items include "Even when I try very hard, I do not teach science as well as I teach most subjects" (ST, reverse coded), and "When a student's achievement in science improves, it is often because the teacher exerted extra effort" (OE). The STEBI-A is currently the most widely used international instrument for assessing in-service science teachers' self-efficacy and OE and has demonstrated satisfactory psychometric properties across diverse cultural contexts (Unfried et al., 2022).

Table 1 presents the item-level statistics for the ST dimension. These data make it possible to determine the individual contribution of each item to the internal consistency of the scale. The alpha coefficient if item deleted ranges from .804 to .848, suggesting that no individual item substantially compromises the overall reliability of the scale. Items ST3, ST6, ST8, ST24, ST22, ST19, ST20, and ST17 are reverse coded (indicated by the *Rev notation), consistent with the original design of the STEBI-A (Riggs & Enochs, 1990), which incorporated reverse-scored items to control for acquiescence bias. Item means (Ms) range from 2.55 (ST6) to 4.32 (ST23), reflecting an appropriate degree of variability in teachers' self-efficacy perceptions. Standard deviations (SDs) range from 0.750 (ST5) to 1.542 (ST8), indicating sufficient variability in responses and supporting the discriminative capacity of the instrument.

Table 2 presents the item-level statistics for the OE dimension. The alpha values if the item is discarded range from .713 (OE15) to .781 (OE7), suggesting that all items contribute in a relatively balanced manner to the overall reliability of the scale. Item OE1, with an M of 3.52 and the highest SD (1.128), exhibits the greatest variability in responses, which may indicate substantial differences in how teachers perceive this particular aspect of outcome expectations. In contrast, item OE4 presents the highest M (4.30) and lower variability (SD = 0.799), suggesting greater consensus regarding this component of expectations. Item OE7, whose deletion would produce the largest increase in alpha (from .775 to .781), warrants particular attention: although this increment is minimal and does not justify its elimination, it signals that this item captures a dimension of OE that is somewhat less internally aligned with the remaining items. Such heterogeneity across items is desirable from a psychometric perspective, as it allows for the capture of different facets of the OE construct.

It is acknowledged that the present study does not include exploratory or confirmatory factor analysis to verify the two-dimensional structure of the STEBI-A in this sample. The dimensional structure was assumed on the basis of the original instrument design (Riggs & Enochs, 1990) and its extensive use in the international literature. Future studies should examine factor structure and measurement invariance to consolidate the psychometric evidence of the instrument in Chilean border contexts.

Data Analysis

The internal consistency of both scales was estimated using Cronbach's alpha (α) and McDonald's omega (ω) coefficients. Both coefficients were reported because ω provides a more appropriate and general estimate of reliability than α; therefore, their combined use is recommended for Likert-type instruments (Hayes & Coutts, 2020). These analyses were conducted employing the psych package (Revelle, 2023) in R 4.4 (R Core Team, 2024) through the jamovi 2.6 software (The Jamovi Project, 2024).

Subsequently, a simple linear regression model was fitted with ST as the predictor and OE as the dependent variable. This specification follows the conceptual model proposed by Riggs and Enochs (1990), in which ST is theoretically antecedent to OE, consistent with Bandura's (1997) distinction between efficacy beliefs and outcome expectations as related but conceptually distinct constructs. The relationship is therefore interpreted not as a predictive relationship in the strict causal sense, but as an examination of the degree of association between these two dimensions of the instrument, with ST treated as the explanatory variable given its theoretically prior status.

Model assumptions were examined (normality of residuals through the Shapiro-Wilk test, as well as linearity and homoscedasticity). Formal statistical tests were complemented by graphical inspection using Q-Q plots and residual plots. It is acknowledged that with a sample size of $n = 332$, ordinary least squares estimates retain robustness even in the presence of minor deviations from normality. Regression analyses were conducted using the car package (Fox & Weisberg, 2023). The level of significance established for all analyses was $\alpha = .05$.

Although no a priori power analysis was conducted, a post hoc sensitivity analysis indicates that, with $n = 332$ and $\alpha = .05$, the study had 80% power to detect an R^2 as small as .023 in the regression model, well below the effect size observed ($R^2 = .102$). The sample size is therefore considered adequate for the analyses performed.

Measurement invariance across subgroups was not examined in the present study. Given the cultural and migratory diversity of the sample, this constitutes a recognized limitation. The absence of invariance testing is justified by the exploratory nature of the study and the limited sample size for subgroup comparisons; future research should address this through multigroup confirmatory factor analysis.

RESULTS

Reliability Analysis of the Science Teaching Self-Efficacy Scale

Before conducting inferential analyses, the internal consistency of the scales was examined using the full sample of participants ($n = 332$). The ST dimension yielded a Cronbach's alpha coefficient of $\alpha = .84$ and a McDonald's omega coefficient of $\omega = .82$, with an M of 3.31 (SD = 0.717). These values indicate an adequate level of internal consistency according to the criteria established by Nunnally and Bernstein (1994), who propose that coefficients above .70 are acceptable for research in the social sciences. The convergence between both estimators is noteworthy: whereas α assumes tau-equivalence among items, ω relies on a congeneric model and is therefore considered a more robust indicator when item factor loadings are not uniform. The close agreement between α and ω in the present sample suggests that the tau-equivalence assumption is approximately met, lending additional confidence to the reliability estimates obtained. These satisfactory reliability indices support the use of the total scores as valid indicators of teachers' self-efficacy in science teaching for subsequent analyses.

Of particular note is item ST8 (SD = 1.542), which yields the highest SD in the scale; this pattern is consistent with the negatively worded nature of the item and suggests that teachers' responses to reverse-coded items tend to be more heterogeneous, a finding commonly observed in self-efficacy instruments that incorporate mixed item directions. Inspection of the alpha-if-deleted values confirms that no single item, if removed, would substantially increase the overall coefficient, which supports the internal coherence of the scale as a whole.

Reliability Analysis of the Outcome Expectancy Scale

The OE dimension yielded a Cronbach's alpha coefficient of $\alpha = .78$ and a McDonald's omega coefficient of $\omega = .79$, with an M of 3.87 (SD = 0.596). These values fall within the acceptable range for psychometric instruments in educational contexts. Although these coefficients are slightly lower than those obtained for the ST dimension, they remain satisfactory. The modest divergence between α and ω ($\Delta = .01$) suggests a degree of heterogeneity in item factor loadings, which is consistent with the multifaceted nature of OE as a construct. The M of 3.87 indicates that, on average, teachers in the sample hold moderately high and positive expectations regarding the impact of science teaching on student learning.

Table 3. Descriptive statistics and intercorrelation of composite scales

	M	SD	1
1. ST	3.31	0.717	-
2. OE	3.87	0.596	.319**

Note. **p < .001

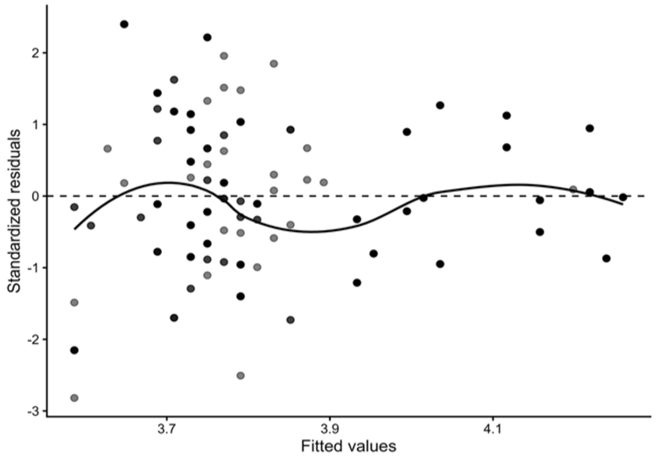

Figure 1. Residuals versus fitted values plot for the linear regression model (the authors' own elaboration using jamovi 2.6)

Linear Regression Analysis: Relationship between Self-Efficacy and Outcome Expectancy

Table 3 presents the descriptive statistics and intercorrelation for the two composite scales prior to the inferential analysis. The ST scale yielded an M of 3.31 (SD = 0.717) and the OE scale an M of 3.87 (SD = 0.596). The Pearson correlation between the composite scores was $r = .319$, $p < .001$, indicating a moderate positive association between ST and OE.

To examine the relationship between teachers' self-efficacy in science teaching and OE, a simple linear regression model was estimated using the total ST score as the predictor variable and the total OE score as the outcome variable. Prior to interpreting the model coefficients, the fundamental assumptions of linear regression were assessed, including linearity, independence of residuals, homoscedasticity, and normality of residuals. The assumption of linearity was evaluated through visual inspection of scatterplots, which indicated an approximately linear relationship between ST and OE. Independence of residuals was assumed based on the cross-sectional design of the study and the independence of observations. Homoscedasticity was examined graphically and by means of the Breusch-Pagan test, which was statistically significant, $\chi^2(1) = 34.88$, $p < .001$, indicating non-constant residual variance. The model was therefore re-estimated using HC3 heteroscedasticity-consistent standard errors (SEs) (Long & Ervin, 2000). The coefficient for ST remained essentially unchanged ($b = 0.265$, $SE = 0.042$, 95% confidence interval [CI] [0.183, 0.347], $t = 6.38$, $p < .001$), confirming that the inference is not affected by this violation (**Figure 1**).

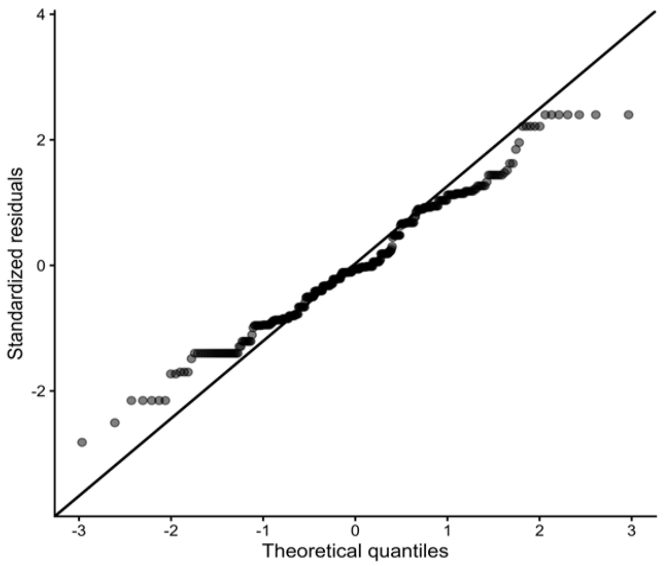

Figure 2. Normal Q-Q plot of standardized residuals (the authors' own elaboration using jamovi 2.6)

Normality of residuals was assessed using the Shapiro-Wilk test and the Q-Q plot, with results presented in **Figure 2**. Although the Shapiro-Wilk test was statistically significant ($W = .985$, $p = .001$), indicating a formal deviation from normality, inspection of the Q-Q plot suggests that this deviation is minor and primarily concentrated in the tails of the distribution. This pattern is characteristic of large samples, in which the Shapiro-Wilk test has high statistical power to detect trivially small departures from normality that carry no practical consequence for inferential validity. Given the robustness of ordinary least squares estimators to moderate deviations from normality when the sample size is adequate ($n = 332$), and in light of the central limit theorem, the model was interpreted without additional transformations of the variables (Field, 2018; Lumley et al., 2002).

The multiple correlation coefficient $R = .319$ indicates a moderate positive association between self-efficacy in science teaching and OE, and the coefficient of determination $R^2 = .102$ indicates that approximately 10.2% of the observed variance in OE can be linearly explained by self-efficacy beliefs.

The omnibus ANOVA test confirms that the regression model is statistically significant, $F(1, 330) = 37.3$, $p < .001$ (**Table 4**). This result indicates that the inclusion of self-efficacy as a predictor significantly improves the model's ability to explain variability in OE compared with a model that includes only the intercept. The regression sum of squares (12.0) represents the variability in OE explained by ST, whereas the residual sum of squares (105.6) corresponds to the variability not explained by the model. The relationship between these two sources of variability is reflected in the F statistic,

Table 4. Omnibus ANOVA test

	Sums of squares	df	Mean square	F	p
ST	12.0	1	11.951	37.3	< .001
Residuals	105.6	330	0.320		

Note. Type III sum of squares

Table 5. Model coefficients for OE

Predictor	Estimate	SE	95% CI lower bound	95% CI upper bound	t	p
Constant	2.995	0.1469	2.706	3.284	20.38	< .001
ST	0.265	0.0434	0.180	0.350	6.11	< .001

Note. Ordinary least squares estimates and HC3 heteroscedasticity-consistent estimates are reported in the text

whose magnitude and statistical significance support the validity of the proposed model.

The model coefficients are presented in **Table 5**. The intercept ($b_0 = 2.995$, SE = 0.147, $p < .001$) represents the expected value of OE when self-efficacy equals zero, although this value has limited substantive interpretation given that scores of zero on ST are not observed in practice with the STEBI-A. The regression coefficient for ST ($b_1 = 0.265$, SE = 0.043, $p < .001$) is the parameter of greatest theoretical interest. This coefficient indicates that for each one unit increase in the ST scale, an increase of 0.265 points is expected in the OE scale, holding all other conditions constant. The 95% CI for this coefficient [0.180, 0.350] does not include zero, confirming the statistical significance and positive direction of the relationship. The relatively narrow width of this interval (0.170 units) further attests to the precision of the estimate given the sample size. The t statistic of 6.11 and its associated p value (< .001) provide robust evidence that self-efficacy is a significant predictor of OE in this sample. **Appendix A** shows the empirical basis for item removal.

DISCUSSION

The positive association observed between ST and OE is consistent with a central proposition of social cognitive theory: efficacy beliefs organize the anticipation of consequences and professional persistence (Bandura, 1997). Interpreted in light of the study's context, this finding provides an opportunity to examine how teachers' beliefs about science teaching are configured when instruction takes place in territories historically shaped by inequality, cultural diversity, and structural marginality.

This finding is consistent with the results reported by Mohammed and Luguterah (2024) in a study of 308 secondary science teachers in Ghana. The authors found significant differences in both personal self-efficacy and OE according to school type and geographic location, demonstrating that institutional context substantially shapes the expression of teachers' beliefs. Similarly, von Knebel et al. (2023), in a study of 589 science teachers in Germany, confirmed that in-service teachers exhibited higher self-efficacy beliefs compared with pre-service teachers, a pattern consistent with the adequate levels observed in the present sample. However, unlike the German context, where specific disciplinary preparation in science and the number of science courses completed constituted key differentiating factors, the context of the north of Chile is characterized by generalist elementary teachers who lack specific disciplinary training in science. This may partially explain the more moderate profile of outcome expectations observed in this study.

From a theoretical perspective, the relationship between self-efficacy and OE should not be interpreted in reductionist terms. OE does not emerge as a simple linear projection of perceived competence; rather, it functions as a construct more permeable to accumulated experiences, organizational conditions, and contextual signals, such as the availability of resources, collegial support, or institutional stability. In this sense, self-efficacy operates as an enabling condition, but its translation into expectations about student learning appears to be shaped by the teaching context. This interpretation, advanced here as a plausible hypothesis rather than a demonstrated mechanism, is consistent with evidence documenting that structural and environmental school-level conditions, including collegial support, resource availability, and institutional stability, constitute significant predictors of teachers' efficacy beliefs across diverse educational systems (Fackler et al., 2021), and with the evidence reported by Mohammed and Luguterah (2024), who showed that self-efficacy alone is insufficient to produce successful inquiry-based practices when the school environment neither promotes nor sustains them. Moreover, the effect size observed in the present study, although moderate, falls within a range comparable to that documented in the psychoeducational literature on teachers' belief variables, where R^2 values around .10 are common and theoretically meaningful in contexts where multiple individual, interpersonal, and institutional factors interact simultaneously (Cohen, 1988; Hammack et al., 2024).

A distinctive contribution of the present study lies in shifting the discussion away from conventional samples, often centered on pre-service teachers or metropolitan contexts, toward a border region where science teaching takes place under specific structural tensions. Northern

Chile's border region, characterized by high cultural and migratory diversity, socio-economic vulnerability, socio-environmental pressures, and teacher shortages, constitutes a particularly suitable empirical setting for examining self-efficacy not as a decontextualized internal attribute, but rather as a professional belief negotiated within real constraints on teaching opportunities. Within this scenario, it is hypothesized that the considerable proportion of unexplained variance in OE may be associated with institutional determinants that shape how plausible teachers perceive their instruction will influence students' scientific learning, even when they feel competent to teach science. This interpretation is supported by the study conducted by Gálvez-Nieto et al. (2023) with 1,406 Chilean public-school teachers, who indicated that the structural socio-economic segregation of the Chilean school system constitutes a constraint on the enactment of teacher self-efficacy, insofar as school contextual conditions influence teachers' capacity to manage favorable learning environments.

A situated interpretation in Chile reinforces this perspective. Although the national curriculum explicitly recognizes scientific literacy and promotes orientations toward less transmissive practices, evidence has shown the persistence of traditional approaches in elementary education, particularly when teachers are not specialists in science and face pressures related to curriculum coverage and performance in other priority subject areas (Marzabal Blancafort & Merino Rubilar, 2021; Sepúlveda-Obreque et al., 2024). Under these tensions, it is hypothesized that teachers with adequate levels of self-efficacy may maintain more cautious outcome expectations when the school ecosystem does not enable visible trajectories of instructional effectiveness. This hypothesis warrants empirical examination through designs that incorporate institutional and contextual variables. This hypothesis is consistent with the findings reported by Kim (2024), who demonstrated that preservice teachers holding stronger traditional pedagogical beliefs exhibited significantly lower levels of both ST and OE, suggesting that the type of pedagogical orientation accumulated through professional experience, rather than merely its duration, plays a determining role in shaping teachers' beliefs. Hence, the moderate effect observed in the present study can be interpreted as empirical evidence of a structural phenomenon: teachers may believe they are capable of teaching science competently, yet not necessarily that the system guarantees the conditions for such teaching to produce consistent effects on student learning.

From a psychometric perspective, the internal consistency evidence obtained provides preliminary support for the applicability of the STEBI-A in northern Chile, offering a first step toward future comparisons with other regions and the development of longitudinal designs. This evidence is limited to internal consistency; claims about the instrument's broader descriptive adequacy should await confirmatory factor-analytic and invariance evidence. The slightly lower reliability of the OE dimension compared with the self-efficacy dimension, with coefficients of $\alpha = .78$ and $\omega = .79$ versus $\alpha = .84$ and $\omega = .82$, respectively, reproduces a pattern consistently documented in the international literature on the STEBI-A (Bleicher, 2004; Mohammed & Luguterah, 2024).

This pattern may be interpreted as reflecting the more heterogeneous and context-dependent nature of expectancies, which integrate attributions about learning, interpretations of the teacher's role, and beliefs about instructional control under real classroom conditions. As a result, they tend to be more responsive to contextual factors and to teachers' accumulated professional trajectories. In border territories, where working conditions may fluctuate and classrooms exhibit high levels of diversity, this responsiveness may be further amplified, suggesting the need for qualitative exploration of how teachers interpret the items associated with the OE dimension in culturally heterogeneous contexts.

The practical implications are clear. If self-efficacy is positively associated with OE, continuing professional development programs should be designed to strengthen not only pedagogical knowledge but also concrete experiences of professional mastery in science teaching that allow teachers to observe tangible impacts on student learning. Consistent with the findings reported by von Knebel et al. (2023), accumulated teaching experience in science and teachers' disposition toward teaching emerge as factors that professional development policies should systematically strengthen. However, the results also suggest that intervening solely at the individual level may produce limited effects if institutional conditions are not simultaneously transformed. Protected instructional time for science, access to contextually relevant resources, professional learning communities, and instructional leadership that legitimizes the discipline as a curricular priority are therefore required. In contexts of high diversity, situated feedback and collaborative support also emerge as relevant mechanisms for sustaining realistic and constructive expectations (Fackler et al., 2021; Hammack et al., 2024).

These findings also carry implications for initial teacher education. Given that generalist primary teachers in Chile are required to teach science without disciplinary specialization, pre-service programs should incorporate sustained and scaffolded experiences in science content and pedagogy. In northern Chile specifically, where teacher shortages in science are projected to worsen in coming years, initial training must prioritize the development of efficacy beliefs through authentic teaching practice, mentoring, and exposure to the contextual demands of border school environments.

In theoretical terms, this study provides evidence supporting the claim that, in contexts of high complexity, teacher self-efficacy specific to science teaching constitutes a significant predictor of OE. However, this relationship manifests with moderate strength and should be understood within a multilayered framework integrating individual, interpersonal, and institutional dimensions. This perspective opens a future research agenda oriented towards more complex models incorporating mediating and moderating variables, such as leadership support, school culture, resource availability, stability of the teaching staff, and opportunities for professional learning, as well as multilevel designs capable of capturing the differential influence of school and system-level factors on teachers' beliefs.

CONCLUSIONS

In-service elementary teachers working in the northern border region of Chile report moderate levels of self-efficacy for science teaching and relatively high OE, with a positive and statistically significant relationship observed between these two dimensions. This finding confirms, within a complex territorial context, the central assumptions of the social cognitive theory (Bandura, 1997) by showing that beliefs about one's capacity to teach science are associated with higher expectations regarding the impact of such teaching on student learning. Furthermore, the adequate internal consistency of the instrument provides preliminary evidence supporting its applicability in this regional context. Future studies incorporating factor analysis and measurement invariance testing are needed to consolidate the psychometric evidence of the STEBI-A in Chilean border contexts.

However, the moderate magnitude of the observed effect indicates that OE does not depend exclusively on individual self-efficacy but is shaped through interaction with contextual and institutional factors. In border territories characterized by high cultural diversity, socio-economic vulnerability, socio-environmental challenges, and structural limitations of the school system, teachers' beliefs are negotiated within real conditions that enable teaching. Therefore, self-efficacy should be understood as a situated professional belief, whose projection into optimistic expectations requires organizational environments that effectively support science teaching through sufficient curricular time, relevant resources, and sustained pedagogical support.

These results underscore the need to articulate both pre-service and continuing teacher education policies that strengthen pedagogical and disciplinary knowledge but also generate experiences of professional mastery capable of consolidating meaningful efficacy beliefs. In border contexts, promoting high-quality science education requires recognizing that strengthening teachers' confidence must be accompanied by structural transformations that make its impact on scientific literacy and civic education viable.

Among the main limitations of the study is the cross-sectional design based on self-report measures, which prevents the establishment of causal relationships and may be affected by perceptual biases. The use of non-probability sampling also limits the generalizability of the findings to other regions or contexts within the country. Furthermore, given that participants were recruited during continuing professional development activities, the sample may overrepresent teachers with higher levels of motivation and professional engagement, which constitutes a potential self-selection bias that should be considered when interpreting the findings. Overall, the use of a simple regression model underrepresents the structural complexity of the phenomenon, as multilevel analyses would allow for a more precise capture of the differential influence of school and system-level factors on teachers' beliefs.

Regarding directions for future research, it is essential to advance toward more complex explanatory models integrating mediating and moderating variables, such as leadership support, school culture, and opportunities for professional learning, as well as longitudinal designs that allow for a more in-depth understanding of the dynamics between self-efficacy, classroom practices, and learning outcomes over time. It is also important to explore the measurement invariance of the STEBI-A across subgroups of teachers and to qualitatively examine how teachers working in culturally heterogeneous contexts interpret the items associated with the OE dimension.

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Ethical statement: This study was approved by the Comité de Ética de la Universidad de Tarapacá on 27 March 2024 (approval number C01-2024). All participants provided informed consent prior to data collection; participation was voluntary, and participants could withdraw at any time without consequences. The questionnaire was anonymous and did not collect identifying personal data. Responses were stored in password-protected files accessible only to the research team and were used exclusively for academic purposes, in accordance with current ethical regulations.

AI statement: The authors declared that AI tools were used exclusively to review grammatical accuracy and linguistic fluency of the final manuscript. All intellectual content, including

conceptualization, data analysis, interpretation of results, and scholarly argumentation, was produced entirely by the authors.

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APPENDIX A

Table A1. Empirical basis for item removal

Item	Dimension	Corrected item-total r	Reason for removal
ST21	ST	-.438	Negatively worded; not reverse-coded in the source key
ST25	ST	-.245	Negatively worded
OE10	OE	-.331	Negative correlation after reverse coding
OE13	OE	.110	α rises from .715 to .775 when deleted

Note. Correlations computed on the complete 25-item solution & n = 332