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The impact of a training cycle on statistics and probability for future primary schoolteachers with a gender-focused approach within the framework of education for sustainable development

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Abstract

This study explores a training cycle in statistics and probability for future primary school teachers, aimed at fostering gender equality and education in sustainable development. By implementing methodologies such as lesson study and didactic-mathematical knowledge and competencies model, an intervention was conducted with two groups of future teachers: the first group comprised 16 participants, while the second had nine, with the latter receiving an enhanced version of the training cycle. The assessment was carried out using content analysis and tests before and after the cycle, in addition to focus groups with the second group. The findings indicate improvements in pedagogical skills, gender equality, and knowledge in statistics and probability, underscoring the effectiveness of the training cycle. It is concluded that, despite the lack of notable differences between the two versions of the training cycle, it is effective in its educational aim and in raising awareness on sustainability issues.

Keywords: stochastic literacy, future teachers, primary education, statistical project, education for sustainable development

INTRODUCTION

In the current context, with the abundance of information and data, it is essential to educate the population in statistics and probability. In this regard, stochastic literacy (statistical and probabilistic), from Gal's (2002, 2005) perspective, it implies the ability to structure, interpret, evaluate, and communicate information related to these concepts, as well as to address practical situations involving random or uncertain phenomena. This competence is not only crucial in individual decision-making but also plays a vital role in understanding complex sociocultural and environmental issues (English & Watson, 2016).

However, despite this evident need, current educational reforms exhibit shortcomings in the teaching of these areas due to the lack of consensus on the appropriate pedagogical approach (Danä & Taniåžli, 2018; English, 2014; Kaplan & Thorpe, 2010; Sharma, 2017; Shaughnessy, 2007). In response, there is an emphasis on adopting a multidimensional perspective in stochastic literacy, connecting it with contemporary sociocultural and environmental issues. Interdisciplinary approaches that integrate data and probability with natural and social sciences are promoted, along with methodologies such as statistics with projects (Batanero, 2013; Batanero & Díaz, 2011; Garfield & Ben-Zvi, 2008; Wild & Pfannkuch, 1999).

Furthermore, it is emphasized the significance of furnishing educators with a robust and context-based training in these domains (Cobb & Moore, 1997; Franklin et al., 2007; Batanero, 2019; Groth & Meletiou-Mavrotheris, 2018). Within this framework, education for sustainable development (ESD) emerges as a valuable ally in the instruction of statistics and probability (Su et al., 2023a; Vásquez & Alsina, 2022). ESD, tailored to address global concerns within environmental, social, and economic realms, aims to reconfigure unsustainable patterns through pedagogy (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2020).

ESD has made significant strides in recent decades, solidifying its role as a fundamental educational strategy for achieving the 17 sustainable development goals

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Contribution to the literature

- This research demonstrates that the combination of the DKMC Model, LS, and the Statistical Project, in order to implement a training program in the field of stochastic education within the context of SDG 5, can promote the comprehensive development of future Primary Education teachers specializing in Mathematics and in statistical, probabilistic, pedagogical, and sustainability culture.
- The synergy of these methodologies provides the opportunity to create a training program for teachers in stochastic education that aligns with the demands of the 21st century.

(SDGs). In primary education, ESD not only instills sustainable values from an early age but also fosters the development of essential analytical competencies in the face of future challenges (Su et al., 2022; Vásquez et al., 2022). This comprehensive vision of ESD, aligned with the 17 SDGs, is reflected in academic curricula, aiming to educate citizens committed to sustainability and the well-being of future generations (UNESCO, 2014, 2017, 2020).

In particular, SDG5 promotes gender equality and underscores the significance of integrating sustainable principles into the educational curriculum, reaffirming its commitment to equity and inclusion in education. This is where ESD naturally becomes an ally of statistical and probability education, as both share objectives related to sustainable development and gender equality (Su et al., 2023b).

Recognizing that the training of future teachers is pivotal in addressing these challenges, this study has the overarching aim to investigate the impact of a training cycle focused on teaching content related to statistics and probability, within the framework of SDG5 and ESD, targeting future primary education teachers with a specialization in mathematics. From this overarching goal, two specific objectives (SO) are derived:

SO1. Evaluate the impact of the training cycle on each cohort of future primary education teachers specializing in mathematics.

SO2. Compare the differences in the effect generated by the original version of the training cycle as compared to its enhanced version in both groups of future primary education teachers specializing in mathematics.

To achieve these objectives, two assessment instruments in the form of questionnaires were implemented: one at the outset and another upon completion of the training cycle, in order to gather pertinent information and analyze the effects of the training. The focus of this study is grounded in the integration of various pedagogical approaches, such as lesson study (LS) and the execution of statistical projects, aimed at equipping future educators with a strong foundation in statistics and probability, as well as pedagogical competencies related to SDG5 and ESD.

CONCEPTUAL FRAMEWORK

Since the 1960s, there has been a growing global concern regarding the need to address the challenges associated with unsustainable development. In response to this concern, the United Nations has emphasized the importance of achieving a balance between socioeconomic development and environmental conservation. Their objective is to promote actions that tackle these issues (UNESCO, 2005).

In this context, ESD is established as an essential educational approach. Its purpose is to empower individuals to make decisions that enhance the current quality of life without compromising that of future generations (UNESCO, 2014, 2020). ESD has gained prominence through significant global milestones and efforts.

The Brundtland Report (1987), which introduced the concept of sustainable development, underscored the imperative need to educate future generations about the importance of sustainability. Subsequently, during the Earth Summit in Rio de Janeiro in 1992, the relevance of education in the context of sustainable development was further solidified, leading to the presentation of Agenda 21 in the subsequent years. The latter emphasized education and training in sustainability as a cornerstone for addressing global challenges (UNESCO, 2017). This approach aims primarily to balance environmental and socio-economic concerns, promoting development that combines human well-being with the preservation of valuable natural resources (Atkinson et al., 2014).

Since 2002, as depicted in **Figure 1**, the United Nations member states have strengthened their commitment to educational sustainability through the ratification of multiple agreements. Decade of education for sustainable development, which took place from 2005 to 2014, highlighted the need to raise awareness about sustainable development by integrating ESD into curricula and teacher training at various educational levels (UNESCO, 2005, 2014, 2015a).

Sustainable development can be advanced through the attainment of the 17 SDGs. In 2015, the international community introduced these SDGs as part of the United Nation's 2030 agenda, addressing critical aspects across environmental, economic, and social dimensions. ESD, closely linked to SDG4, aims to ensure inclusive and quality education for all by aligning disciplinary

Figure 1. International commitments related to ESD (Su et al., 2023a, p. 2)

Table 1. Type of ESD domain to promote SDGs (UNESCO, 2017)

ESD domain	Description
Cognitive	Comprises the knowledge and cognitive tools necessary to better understand SDG and the challenges involved in its achievement.
Socioemotional	Encompasses social skills empowering students to collaborate, negotiate, & communicate to promote SDGs, as well as skills, values, attitudes, & self-reflective incentives enabling their personal development.
Behavioral	Describes action competencies.

learning with SDGs (UNESCO, 2017). This alignment plays a crucial role in promoting a more sustainable future and raising awareness of the importance of addressing global challenges through education.

Regarding the implementation of ESD, it is important to note that UNESCO (2017) recommends incorporating this approach into curricula, textbooks, and the training of both in-service and pre-service teachers. In this regard, it highlights the necessity for these teachers to understand how to link the learning of SDGs with the aspects of ESD, as indicated in **Table 1**.

On the international stage, SDG5 emerges as a fundamental response to persistent gender inequality. Its primary focus is on eliminating any form of discrimination against women and girls (UNESCO, 2015a, 2015b). The essence of this goal goes beyond words; it lies in a deep understanding that gender equality is pivotal for societal socio-economic and cultural progress (UNESCO, 2020).

Education, specifically mathematics education, is an area, where this challenge manifests significantly. Historical cultural stereotypes have historically relegated women and girls to secondary roles in this field (Aparici et al., 2018). These stereotypes and biases, ingrained in subtler aspects of the educational process, have a profound impact on the presentation and teaching of content. For instance, math problem statements and the structure of activities can unintentionally reinforce gender roles and stereotypes (Chisamya et al., 2012; Cvencek et al., 2011). The consistent exclusion of female role models in math problems or the continuous representation of female figures in traditional roles can strengthen outdated ideas about gender, potentially negatively affecting the values, attitudes, and academic performance of female students (Incikabi & Ulusoy, 2019).

Therefore, it is essential that the training of primary education teachers, specializing in mathematics, establishes a direct connection with SDG5. This entails not only seeking gender equality in the educational sphere but also ensuring that mathematics education is inclusive and representative for all students. Teachers must acquire the knowledge and capability needed to address these biases, creating a learning environment that promotes and supports the aspirations of all, regardless of their gender (Franklin et al., 2007; National Council of Teachers of Mathematics [NCTM], 2000; UNESCO, 2018, 2020). Consequently, teacher training must ensure that mathematics education is impartial and equitable (Su et al., 2023b).

Stochastic Literacy Linked to ESD

The integration of the 17 SDGs through ESD in educational systems is key to addressing current challenges (UNESCO, 2017, 2020). Simultaneously, the relevance of stochastic literacy is magnified in our information age. Following Murray and Gal (2002), the European Commission has recognized since 1996 the need to enhance the statistical competencies of the population. Therefore, it is essential that the educational curriculum aligns with the demands of the 21st century, ensuring that learners are equipped to navigate a constantly changing and sustainability-oriented world.

NCTM (2000), one of the most prestigious institutions in the field of mathematics education, has emphasized the necessity of developing a critical perspective on statistics in young people. This entails not only preparing them for professional and everyday challenges but also empowering them to argue and make data-based decisions (English & Watson, 2016; Franklin et al., 2007).

According to Batanero (2019), stochastic literacy encompasses both statistical and probabilistic literacy, and it is essential that they are developed in conjunction, as these two areas are closely intertwined. Statistical data often involve unpredictable events, and randomness is always present, even when describing information. Furthermore, calculating or updating the probability of events becomes complex in the absence of robust statistical data. In this context, promoting stochastic literacy is fundamental since it establishes a crucial connection between the data collection and estimation process and various probability approaches, enriching the understanding of random events and statistical data.

Stochastic literacy goes beyond mere data interpretation, as it also involves the ability to comprehend uncertainty and randomness in various contexts, as well as the capacity to construct robust data-based arguments, which are essential for informed decision-making (Callingham & Watson, 2017; Franklin et al., 2007). Despite efforts made in various countries, including Chile, to incorporate stochastic education into compulsory education curricula and teacher training, the results have not been satisfactory. This is because stochastic education has focused on procedures and abstract concepts, which have not effectively addressed the gap in statistical understanding (Batanero, 2019; Callingham & Watson, 2017; Sharma, 2017; Shaughnessy, 2007; Su et al., 2022; Vásquez & Alsina, 2017).

Therefore, the incorporation of statistical projects or investigative cycles could enhance the understanding of stochastic concepts (Batanero & Díaz, 2011; Wild & Pfannkuch, 1999). These projects not only develop analytical and critical skills in students but also strengthen the connection between statistical learning and SDGs (Su et al., 2023a). These projects engage students in a comprehensive statistical research process, from problem detection to report development. By addressing statistics and probability through projects in the context of SDGs and ESD, stochastic literacy is enhanced, and the capacity to formulate action plans to promote sustainable development is fostered (Batanero & Díaz, 2011; Wild & Pfannkuch, 1999). Since the integration of stochastic literacy with ESD has the potential to educate individuals in data interpretation and the application of advanced analysis in unsustainable situations, it enriches information comprehension and develops essential skills to advance in achieving SDGs (Su et al., 2022; Vásquez & Alsina, 2022).

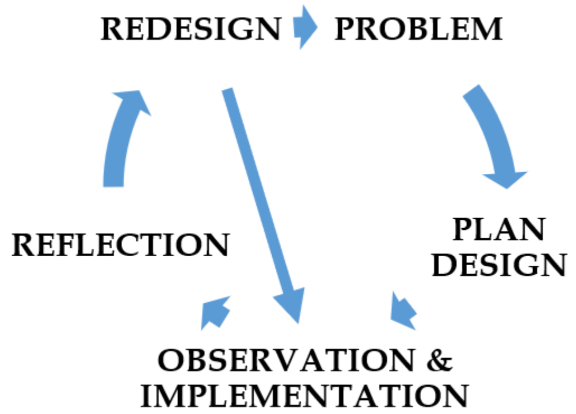

Figure 2. Phases of lesson study (Source: Authors' own elaboration)

Class Design with Lesson Study & Didactic-Mathematical Knowledge & Competencies Model

To align the teaching of statistics and probability with the training standards for future primary education teachers, it is essential to adopt an innovative pedagogical strategy, especially in the context of SDGs, particularly SDG5, which addresses gender equality and relates to statistical and probabilistic concepts (Su et al., 2023a).

Two pedagogical tools stand out as valuable in this approach: LS and didactic-mathematical knowledge and competencies (DMKC) model. These tools are essential for designing effective education.

LS has its roots in Japan and originated in the 1990s. Over time, numerous studies have highlighted its effectiveness in designing and improving educational proposals, especially in the field of mathematics education (Lewis, 2009). Japanese educators have widely adopted this methodology in the teaching of mathematics, which has allowed them to enhance their teaching practices in these areas (Lewis, 2016).

According to Soto-Gómez et al. (2015), LS methodology is based on an action research process consisting of the following five phases (**Figure 2**):

1. *Problem definition:* Linked to the long-term education goals, focusing on statistical and probabilistic concepts related to SDG5.
2. *Plan design:* The team of teachers and researchers collaborates to create curriculum and pedagogical content in the context of statistical projects related to SDG5.
3. *Implementation 6 observation:* A team member delivers the planned lesson while others observe and document the process.
4. *Reflection:* After implementation, the team gathers to analyze and evaluate what occurred during the lesson.

5. *Redesign:* Based on the previous reflections, the lesson is adjusted and taught to a different group of students with similar characteristics, followed by a final reflective session.

These phases highlight and enhance pedagogical proposals. The collaboration of at least three teachers allows for the development of a refined version of the lesson in question (Cheung & Wong, 2014; Fernández et al., 2003). Each of these phases is applied in all sessions of the training cycle with the aim of students acquiring competencies in statistics and probability in the context of SDGs (Su et al., 2023).

Didactic-Mathematical Knowledge & Competencies Model

DMKC model is fundamental in the training of mathematics education teachers, as it significantly contributes to promoting adequate knowledge of the discipline and improving the quality and sustainability of teaching (Su et al., 2023b). According to Godino et al. (2017), this model is based on the onto-semiotic approach (OSA) and consists of five dimensions that address different aspects of the teaching and learning of mathematics:

1. *System of practices:* Highlights problem-solving as a central element of mathematical learning, emphasizing the importance of understanding the contextual and global meanings of mathematical concepts.
2. *Didactic configuration:* Defines the roles and responsibilities of teachers and students, aligning them with multiple educational dimensions.
3. *Configuration of mathematical objects & processes*: Identifies and prioritizes the essential elements required for effectively solving mathematical problems.
4. *Normative dimension:* Establishes rules and regulations that guide the teaching and learning process of mathematics, providing an important regulatory framework.
5. *Didactic suitability:* Evaluates and ensures the relevance and effectiveness of pedagogical interventions, ensuring they are suitable for the educational context. This dimension, according to Godino et al. (2007), comprises six elements:
   a. *Epistemic suitability:* It assesses whether what is taught in schools aligns with what is considered standard knowledge in a specific area.
   b. *Cognitive suitability:* It focuses on whether what is taught aligns with what students can understand and learn at their current level of development.
   c. *Interactional suitability:* It examines the effectiveness of teaching strategies in resolving conflicts and challenges in the learning process.
   d. *Mediation suitability:* It evaluates whether the available resources and time are adequate to facilitate learning in the educational institution.
   e. *Affective suitability:* It related to students' interest, motivation, and engagement in learning, considering both institutional factors and students' personal backgrounds.
   f. *Ecological suitability:* It evaluates how the educational process adapts to the goals of the school and society, as well as the conditions of the environment in which it takes place.

These dimensions are explored in depth through OSA, enabling a comprehensive understanding of the educational process in mathematics. Furthermore, when designing and validating a training proposal in statistics and probability for future primary education teachers, we combine LS and DMKC models. This combination provides a pedagogical approach that promotes literacy in sustainability, statistics, and probability, enhancing the training of future teachers and the learning experience of students (Su et al., 2023a). Examples of its application can be found in Su et al. (2024a).

METHODOLOGY

In this research, we employed a mixed-methods approach, combining qualitative and quantitative aspects for a comprehensive analysis of the topics under investigation (Hernández-Sampieri et al., 2018) and quasi-experimental design. We conducted a pre- and post-assessment of a training cycle in statistics and probability. The data were analyzed and categorized using content analysis techniques, and scores were assigned to each response to measure the effectiveness of each version of the training cycle, applying the student's *t*-test. We also compared the differences in effectiveness between the two versions using this same statistical test. Additionally, we conducted a focus group with the participants to gather qualitative information about the improved version of the proposal.

Context & Participants

The research was conducted at a Chilean university with a strong reputation in the training of primary education teachers. Two groups of students participated: the first group (G1) consisted of 20 enrolled students, of whom 16 completed the pre and post-tests, and the second group (G2) had 16 enrolled students, with nine of them completing these assessments. Both groups share similar characteristics as they enrolled in courses with the purpose of enhancing their understanding of statistics and probability, as well as acquiring knowledge on how to teach these concepts, respectively.

However, the courses were conducted in different semesters and at university campuses located in different cities. In this regard, these two groups are independent since no student belonged to both groups at the same time.

To access these courses, it was necessary to have passed previous courses related to statistics and probability, in addition to possessing pedagogical skills. However, during the development of the training cycle in collaboration with the training professors responsible for each course in both campuses, who were part of LS team, it was ensured that the content delivered was in line with the curriculum of this course.

It is important to note that the selection of participant groups was non-random and was carried out with the authorization of the dean of the faculty of education, the school director, and the professor in charge of the course. Furthermore, all future teachers expressed their interest in participating in the research and provided their consent by signing an informative document.

Training Cycle

In this study, the training cycle refers to a set of planned classes aimed at achieving competencies and learning outcomes in a subject (Seckel & Font, 2020). This cycle was designed and validated following the guidelines of LS model with the support of DMKC model to include the statistical project, and its results have been reported in Su et al. (2024). The combination of these approaches allows for the development of a pedagogy that trains teachers committed to teaching statistics and probability while promoting an understanding of gender equity, in line with SDGs (Su et al., 2023a).

During this process, three teacher trainers specializing in subjects focused on deepening stochastic concepts and teaching statistics and probability collaborated, with two of them being responsible for the course. Additionally, two experts in elementary math education joined, forming these five professionals as LS team. The formation of this team was essential to carry out continuous iteration throughout the entire training process in line with the curriculum, which included planning, implementation, and reflection on the session content aimed at its application with the first group.

The training cycle follows the process illustrated in **Figure 2**. Initially, the original design was applied to G1, and subsequently, a revised version was implemented with G2 based on the results obtained in the first implementation. Regarding the structure of the design, originally, four sessions were planned, each lasting three hours, addressing concepts of statistics and probability in accordance with national education standards and curriculum, specifically within the context of SDGs, particularly SDG5. In the results section, we will provide a detailed explanation of the expansion of sessions applied to G2, based on the results obtained in the initial implementation. Below is a summary of the topics covered in each session of the original version. It is worth noting that complete details of the training cycle in both versions are available in study of Su et al. (2024).

In the first session, the focus was on statistics and its relevance in everyday life, especially in relation to gender equity. Key concepts such as population, sample, parameter, and variables were introduced, and ways to organize and represent data were explored. Practical activities were conducted to analyze gender inequalities using descriptive statistical measures, and information from the National Institute of Statistics of Chile (INE, 2015) was used to identify potential gender inequalities. The second session centered on the basic concepts of probability and its application in the context of SDG5. Teamwork was encouraged, and the results were analyzed in light of cultural values and traditions that affect women, particularly regarding domestic and caregiving responsibilities. Solutions to gender issues were explored. In the third session, the concepts of statistics and probability were further explored, once again focusing on their application in the context of SDG5, and the results were continued to be analyzed from the perspective of cultural and traditional values influencing gender responsibilities. Future teachers were asked to prepare a report with the project's results. Finally, in the fourth session, the results of the projects carried out by each group were presented, and viable solutions to address gender inequalities from the role of a primary education teacher were selected. Data and statistical measures provided by each group were discussed, and the task of designing project-based stochastic education activities to promote understanding of the concept of gender equity among primary education students, with the support of the teaching staff, was proposed.

Content & Focus of Training Cycle

With the aim of developing a training cycle aligned with our objectives, LS team conducted a comprehensive review. This included an analysis of the curriculum of the academic institution, where the study was conducted, as well as the teaching standards for basic general education in Chile (MINEDUC, 2022) and elements related to statistics and probability in the national curriculum for primary education (MINEDUC, 2018). We also conducted a review of the academic literature to identify possible sustainability-related topics that could be incorporated into primary education courses (Su et al., 2022), in addition to conducting a systematic review of studies published in indexed journals in recognized databases such as WoS, Scopus, and SciELO, addressing similar research findings (Su et al., 2023). This allowed us to identify key disciplinary and pedagogical elements for the effective

Table 2. Distribution of items by culture type, DMKC facet, & key sustainability competencies

Item	Literacy/culture	DMKC facet	Sustainability competency
1a	Statistics	Epistemic	Systematic thinking competency
1b	Statistics	Epistemic	Systematic thinking competency
1c	Statistics	Epistemic	Systematic thinking competency
1d	Statistics	Epistemic	Systematic thinking competency
1e	Pedagogical	Ecological	Systematic thinking competency
1f	Pedagogical	Interactional	Systematic thinking competency
2a	Probabilistic	Epistemic	Systematic thinking competency
2b	Probabilistic	Epistemic	Systematic thinking competency
3	Sustainability	Epistemic & ecological	Critical thinking competency
4	Sustainability	Epistemic, ecological, & mediational	Self-awareness, normative, & strategic competency
5	Pedagogical	Cognitive	Strategic competency
6	Pedagogical	Cognitive	Anticipation competency

implementation of SDG5 approach from the perspective of ESD.

Based on these findings, we identified several critical needs. Firstly, it is essential to organize the educational program content in accordance with the principles of statistical literacy, probability, pedagogy, and sustainability, as well as the competencies related to these concepts. This aligns fully with the institutional and national curriculum guidelines in the context of primary education. Secondly, it is necessary to select a pedagogical model that guides both the disciplinary and pedagogical development of this implementation. In this regard, we have opted for DMKC model, based on EOS, due to its widespread recognition as a highly suitable pedagogical approach for the teaching of mathematics, statistics, and probability. It is worth noting that our LS team includes two highly qualified experts with extensive experience in the application of this model.

Instrument for Data Collection

In this research, we employed expert-judged validated instruments to assess the content taught during the training cycle, which includes questions in the context of SDG5 that enable the connection of key concepts such as statistical literacy, probability, pedagogy, and sustainability. Two tests were administered to the two groups, one at the beginning and another at the end of the implementation (pre and post-test), each consisting of six questions addressing the aforementioned key concepts, as shown in **Table 2**.

In relation to the key concepts addressed in this research, four fundamental areas can be distinguished:

1. *Statistical literacy:* This refers to the ability to interpret and critically evaluate statistical information and arguments supported by data. It also includes the ability to communicate opinions on statistical information when relevant (Batanero, 2002; Gal, 2002).
2. *Probability literacy:* This area focuses on the basic knowledge of probabilities that people use in their daily lives (Batanero, 2005, 2006; Gal, 2005; Sánchez, 2009).
3. *Sustainability literacy:* This involves incorporating values related to sustainable development into teaching and learning processes (Martínez-Huerta, 2009).
4. *Pedagogical culture:* It refers to the interactions between different dimensions that influence teaching styles, including aspects such as academic discourse theory, legal regulation, and teaching practice (López-Martín, 2019).

Regarding the key competencies related to sustainability, as defined by UNESCO (2017), these encompass:

1. *Systems thinking:* The ability to analyze complex relationships and manage uncertainty.
2. *Anticipation:* Assessing various future scenarios and dealing with risks.
3. *Normative competence:* Understanding and negotiating values in conflict contexts.
4. *Strategic competence:* Implementing innovative actions collaboratively.
5. *Collaboration:* Promoting empathy and conflict resolution.
6. *Critical thinking:* Questioning norms and adopting informed positions.
7. *Self-awareness:* Evaluating one's own role in the community and society.
8. *Integrated problem-solving:* Applying multiple approaches to address complex sustainability problems, integrating all these competencies in a holistic manner.

These competencies are fundamental in the context of SDGs and ESD, as they promote an understanding of statistics, probability, and sustainability, facilitating the training of teachers committed to these goals. However, it is important to emphasize that, due to the individual nature of instrument application and the inherent uncertainty associated with real-world issues in the context of SDG5 in ESD as proposed in the

Table 3. Results of instrument evaluation by experts

Item	Pre-test			Post-test		
	Clarity	Pertinency	Relevance	Clarity	Pertinency	Relevance
1a	4.0	4.6	4.4	4	4.6	4.4
1b	4.8	4.4	4.4	4.8	4.4	4.4
1c	4.4	4.4	4.8	4.4	4.4	4.8
1d	4.8	4.8	5.0	4.8	4.8	5.0
1e	4.2	4.2	4.4	4.2	4.2	4.4
1f	3.8	4.2	4.4	3.8	4.2	4.4
2a	4.6	4.8	5.0	4.6	4.8	5.0
2b	4.2	4.8	4.8	4.2	4.8	4.8
3	3.6	4.4	4.4	3.6	4.4	4.4
4	3.8	4.4	4.4	3.8	4.4	4.4
5	4.8	4.6	4.8	4.8	4.6	4.8
6	4.0	4.4	4.4	4.0	4.4	4.4

questionnaires, not all of these competencies were addressed in the same manner, and some may not have been considered in the questionnaires.

Instrument Validity

To ensure the quality of the instruments used in this study, a validation process was conducted, which included a pilot test and evaluation by five experts with experience in statistics, probability, and sustainability. These experts analyzed the items in terms of clarity, relevance, and significance, using a rating scale from one (minimum) to five (maximum). The expert judgment validation process involves gathering informed opinions from individuals with expertise in the field, widely acknowledged as qualified specialists in the subject matter, and capable of providing relevant insights, evidence, judgments, and assessments (Escobar-Pérez & Cuervo-Martínez, 2008). **Table 3** presents the results of the item evaluation (1a, 1b, 1c, 1d, 1e, 1f, 2a, 2b, 3, 4, 5, and 6) that were part of a pre and post-test questionnaire. Additionally, experts were asked to provide suggestions to improve the wording of the items.

According to the data in **Table 3**, it is evident that the items received high ratings in terms of clarity, both in the pre-test and post-test. Most of them exceeded the threshold of four on the rating scale, indicating that the experts found the items to be comprehensible. Furthermore, regarding the pertinence and relevance of the items, positive ratings were also observed. This suggests that the items evaluated in both instruments are consistent. It is relevant to note that the ratings in the post-test were identical to those in the pre-test, which could indicate that the items were uniformly perceived in terms of clarity, pertinence, and relevance. No significant discrepancies were observed between the ratings of the two questionnaires.

It is essential to highlight that, in response to the observations and suggestions of the experts, adjustments were made, including modifications to the wording of the items and changes in the typographic format and description in the statistical graphics. Despite these adaptations, the improved version of the questionnaires was subjected to a pilot phase.

In the pilot test, four future teachers who were in their final year of the program participated, which implied that they had successfully completed subjects related to pedagogy, statistics, and probability, and had acquired the corresponding knowledge. The results of the pilot test yielded a Cronbach's alpha coefficient of 0.79, indicating adequate internal consistency of the questionnaire items.

Data Analysis

In this study, we analyzed the data in accordance with our SOs. For SO1, we employed a content analysis approach (Piñuel, 2002), which involves interpreting communicative products and using both quantitative and qualitative techniques to analyze the responses from the pre and post-test questionnaires in each cycle. We categorized the responses in both cycles and then complemented this analysis with the Student's *t*-test for related samples.

On the other hand, for SO2, we analyzed the post-test results of both groups using the Student's *t*-test for independent samples. Furthermore, we enriched our analysis by conducting focus groups with the second group.

RESULTS

In this section, we present the results in accordance with SOs. For SO1, we categorized the responses of the future teachers from both questionnaires into three levels, as detailed in **Table 4**. This rubric designed by LS team assist us in assessing their understanding of statistics, probability, and teaching in the context of SDG5.

Then, we assessed the pre and post-test responses of both groups using this rubric, assigning ratings from one to three. The results of these evaluations are summarized in **Table 5**.

Table 4. Rubrics of categories

Category	NR	Description
Insufficient	1	Inadequate responses or significantly deviating from the requirements. Lack of understanding and application of statistical and probability concepts in the gender context.
Acceptable	2	Responses containing relevant information but may be incomplete or have minor errors. Basic understanding of concepts but in need of improvement.
Satisfactory	3	Complete and accurate responses, meeting the evaluation criteria. Solid command of statistical and probabilistic literacy, effectively applied to SDG5.

Note. NR: Numerical rating

Table 5. Mean & standard deviation ratings of future teachers from both groups in pre- & post-tests

	Pre-test	Post-test
Group 1		
FP1G1	2.1	2.4
FP2G1	0.9	1.8
FP3G1	1.5	2.3
FP4G1	0.8	1.9
FP5G1	1.1	2.4
FP6G1	2.4	2.6
FP7G1	2.2	2.3
FP8G1	1.9	2.5
FP9G1	2.1	2.4
FP10G1	2.2	2.6
FP11G1	2.3	2.7
FP12G1	0.3	2.3
FP13G1	2.0	2.4
FP14G1	1.7	2.7
FP15G1	1.1	2.8
FP16G1	2.1	2.8
Mean	1.7	2.4
Standard deviation	0.64	0.28
Group 2		
FP1G2	2.0	2.4
FP2G2	1.9	2.4
FP3G2	2.3	2.3
FP4G2	1.6	2.4
FP5G2	2.6	2.7
FP6G2	2.4	2.7
FP7G2	1.2	2.8
FP8G2	1.7	2.8
FP9G2	2.0	2.8
Mean	2.0	2.6
Standard deviation	0.45	0.17

The results from **Table 5** indicate improvements in both groups after receiving the intervention in statistics and probability in the context of SDG5. In group 1, an average improvement of 0.7 points was observed, while in group 2, it was 0.6 points. Furthermore, a decrease in the standard deviation is observed in both groups (from 0.64 to 0.28 in group 1 and from 0.45 to 0.17 in group 2), implying greater consistency in participants' responses following the intervention. These results suggest that the training cycle of both versions was effective in enhancing the understanding of concepts related to statistics, probability, and SDG5 from a cognitive perspective in the context of ESD in both groups.

Furthermore, when comparing the scores on the pre-test and post-test exams between the two groups, it is noticeable that G2 initially had slightly higher scores on the pre-test, due to administrative considerations. This was because of the prior instruction they received before taking the pre-test, which provided knowledge of the topics considered in the training cycle. Regarding the post-test, it is also apparent that G2 achieved slightly higher scores, possibly as a result of the implementation of an improved version of the training cycle.

It is important to note that, despite the positive results obtained by the participants in the first cycle, LS team proposed to extend the duration of the training cycle in the new version to seven sessions. However, due to administrative constraints, a total of only five sessions could be conducted. The content of the original version was maintained, except that one full session was dedicated to the topic of the statistical project. This modification led to the second version of the training cycle, which was applied to the future teachers in the second group.

On the other hand, to assess the significance of the data in our study, we employed Student's t-tests, maintaining a 95% confidence level. This statistical test was chosen based on the following criteria: independence of observations, normality and homoscedasticity of data, and the quantitative nature of the utilized measurement scale. Among these prerequisites, it's noted that the data from G1 and G2 are quantitative and adhere to the independence assumption.

In relation to normality, Kolmogorov-Smirnov and Shapiro-Wilk tests were conducted. In the pre-test of cycle 1, the significance values, with 0.200 in the Kolmogorov-Smirnov test and 0.333 in Shapiro-Wilk test, exceeded the 0.05 threshold, thus indicating a normal distribution. Similarly, in the post-test of cycle 1, significance values of 0.157 and 0.086 were obtained, respectively, reaffirming normality. The data from the pre-test of cycle 2 also clearly exhibited a normal distribution, with significance values of 0.200 and 0.971. Finally, the post-test of cycle 2 yielded values of 0.200 and 0.094 in the same tests, likewise suggesting a normal distribution. These results consistently above the 0.05 threshold confirm normality in all data sets, both in the pre-tests and post-tests of cycle 1 and cycle 2.

Table 6. Result of paired-sample t-test

Student's t-test for related samples		Mean	Standard deviation	95% confidence interval for difference		t-value	df	Sig.
				Inferior	Superior			
Cycle 1	Post-testcycle 1-pre-testcycle 1	.76172	.54449	.47158	1.05186	5.596	15	.000
Cycle 2	Post-testcycle 2-pre-testcycle 2	.60417	.45393	.25524	.95309	3.993	8	.004

Table 7. Result of independent samples t-test

Independent samples t-test		Levene's test		t-test for equality of means						
		F	Sig.	t	Fd	Sig. (bilateral)	MD	SED	95% CI of difference	
									Inferior	Superior
Between cycle 1 & cycle 2	Equal variances assume	1.660	.210	-1.349	23.000	.190	-.13759	.10197	-.34853	.07336
	Equal variances not assume			-1.577	22.999	.128	-.13759	.08723	-.31803	.04286

Note. MD: Mean difference; SED: Standard error difference; & CI: Confidence interval

Regarding homoscedasticity, we applied Levene's test to the cycles in G1 and G2. A significance value of 0.210 was obtained, exceeding the 0.05 threshold, confirming homoscedasticity. This implies that the post-test results of G1 and G2 exhibit similar variances. The verification of normality and homoscedasticity, combined with the independence of observations and the quantitative nature of the data, validates the use of student's t-test for data analysis.

Given the above, the study proceeds to address the research the SOs. SO1 focuses on evaluating the efficacy of the training cycle by analyzing the pre- and post-test results in each group, which are considered related samples. SO2 investigates the differences in the impact of the training cycle between groups G1 and G2, treating these groups as independent samples.

In the context of SO1, the null hypothesis (H_0) was formulated, as follows: the implementation of the training cycle would not have a significant effect on the outcomes (μpre-test-μpost-test=0); while the alternative hypothesis (H_1) suggested otherwise (μpre-test-μpost-test≠0).

Then, paired-samples t-tests were performed to compare the results of the pre- and post-test for each cycle, and the results are detailed in **Table 6**.

The results of the paired-sample t-test for each group, presented in **Table 6**, provide a detailed insight into the impact of two different versions of a training cycle on the development of statistical literacy in the context of SDG5 within the cognitive framework of ESD. In cycle 1, the mean of the differences is positive, indicating a change or improvement after the intervention with the original version. The standard deviation of 0.54449 shows moderate variability in the pre and post-intervention score differences. The extremely low significance (0.000) and the confidence interval that does not include zero point to a significant and relevant difference as a result of the intervention. On the other hand, cycle 2, which used an enhanced version of the training cycle, shows an average increase of 0.60417, with an equally significant difference ($p<0.05$). In cycle 2, the mean of the differences is also positive, indicating a change or improvement after the intervention with the improved version. The standard deviation of 0.45393 is slightly lower than in cycle 1, implying slightly less variability in responses to the intervention. A significance value of 0.004 and a confidence interval that does not include zero support the existence of a significant difference due to the intervention. These findings suggest that both versions of the intervention were effective, although with variations in the magnitude and consistency of the effects.

Subsequently, to address SO2, which involves evaluating the impact of an improved version of the training cycle compared to the original edition and focuses on the post-test results, the following hypotheses were formulated:

1. Null hypothesis (H_0): Improved version of the educational cycle does not have a significant effect on post-test results compared to original version, expressed mathematically as: μCycle2_ImprovedVersion-μCycle2_OriginalVersion=0.
2. Alternative hypothesis (H_1): Improved version of the educational cycle has a significant effect compared to the original version, expressed as: μCycle2_ImprovedVersion-μCycle1_OriginalVersion ≠ 0.

Then, independent samples t-tests were conducted to assess the effectiveness of the improved version of the training cycle in relation to the post-test results, and the results are detailed in **Table 7**.

According to the data in the independent samples t-test results in **Table 7**, comparing cycle 1 (original version) and cycle 2 (improved version), it shows that there is no statistically significant difference between these two cycles. Levene's test indicated with a significance value of 0.210 that the variances between both cycles are similar. As for the t-test, both in the version assuming equal variances and in the version not assuming equal variances, the two-tailed significance values (0.190 and 0.128, respectively) are above the conventional threshold of 0.05, suggesting that there is no significant difference in the means of both cycles.

Furthermore, the confidence intervals in both cases include zero, reinforcing the conclusion that there is no statistically significant difference between the original and improved versions. In summary, the data does not show a significant improvement of the improved version compared to the original in terms of the evaluated metrics.

Despite the predictable outcome between cycle 1 and cycle 2 anticipated by LS team, due to the administrative requirement to conduct only five out of seven recommended sessions and the modification of some session content to meet administrative obligations in cycle 2, we decided to conduct a focus group with participants from the second cycle who attended. The objective was to gather their opinions on the enhanced version of the educational cycle. During the focus group, participants were posed with the following question: How would you assess the implementation of the statistics project in terms of promoting gender equality, its impact on stochastic education, compliance with SDG5 in the cognitive realm of ESD, and the strengthening of sustainability competencies?

On this occasion, 10 future teachers attended the focus group, with the absence of future teacher eight (FT8) and the inclusion of two additional participants who had not completed the pre- and post-test evaluations, and they have been coded as FT10 and FT11. The participants' dialogues have been grouped into the following categories:

Category 1: Implementation of Training Cycle

In this category, participants' perceptions of the execution of the training cycle in relation to gender equality were evaluated. The responses reflected an overall positive assessment. For example, FT6 stated:

> "I rate the implementation as a seven, the highest possible score, and I am convinced that this project has been fundamental to my training as a future primary education teacher."

Additionally, FT2 expressed:

> "The implementation was good, as it allowed us to obtain results and conclusions about a topic, in this case, SDG5."

Category 2: Improvement Suggestions

In this category, comments related to the duration and extent of project sessions were gathered. Participants expressed the need for more time to explore topics in-depth. For example, FT9 commented,

> "One potential area for improvement that I highlight is the duration of the project. In my opinion, more sessions or additional time would be needed to address some topics more thoroughly and allow for a greater focus on the intersection between statistics and gender equality."

Similarly, FT1 suggested,

> "I believe there could be room for additional improvements, especially if the project's duration were extended. This would enable us to delve more deeply into these topics and enhance my understanding."

FT10 also noted,

> "I believe we should have utilized more of the class schedule for the project as a whole rather than relying heavily on self-directed time to address challenges and resolve doubts."

Category 3: Progress in Concepts & Pedagogy

In this category, participants' perceived progress in terms of understanding concepts and pedagogy related to gender equality was evaluated. Responses highlighted the project's relevance to their future careers. For example, one participant (FT11) shared,

> "This project is particularly relevant to me and my future career as a primary education teacher, making it even more valuable. It has enriched my understanding of gender equality in the educational context and significantly strengthened my skills in statistics and data analysis."

Additionally, FT3 added,

> "It's a working method that allows learning through projects, something that would greatly benefit students."

Category 4: Relevance of Topic

This category explored how participants perceived the relevance of the gender equality topic in primary education. Comments reflected the importance of addressing this issue in the educational context. For instance, FT5 emphasized,

> "I felt that issues related to statistics and gender were effectively addressed. I highlight that collaboration and communication in the project were strong, contributing to an enriching experience."

Furthermore, FT6 stated,

> "This project is highly relevant to my future career as a teacher. I believe that implementing statistics related to gender equality is essential for students to become aware of social issues in this area, and I

> am convinced that this project has been fundamental to my training as a future primary education teacher.”

Category 5: Importance of Content & Resource Usage

In this category, participants’ perceptions of the quality of content and provided resources were evaluated. Responses praised the clarity in presenting concepts and the usefulness of resources. For example, one participant (FT6) mentioned,

> “The clarity in presenting statistical concepts related to gender equality was outstanding, making it very easy to understand. Additionally, the provided resources were very helpful and significantly contributed to my learning.”

FT2 also highlighted,

> “The presentation of statistical concepts in the context of gender equality was clear and accessible, facilitating comprehension.”

According to the feedback from the participants, their perception of the implementation of the educational cycle becomes evident. In general terms, they evaluated the project positively, rating it as good and even excellent, and highlighted its relevance and contribution to their training as future primary education teachers. Furthermore, they emphasized its impact on learning, especially in the development of disciplinary and pedagogical skills and knowledge related to statistics and gender equality within the cognitive framework of ESD.

Participants underscored the importance of the gender equality theme in primary education, considering that the project provided them with essential tools to address it in the educational context. Regarding areas for improvement, the majority expressed the need for longer sessions to explore specific aspects in greater depth.

In summary, the results and opinions of the participants indicate that this project had a positive impact on their development as future primary education teachers. They believed that the experience significantly contributed to their teaching development and the design of activities within the context of gender equality from the perspective of ESD to promote stochastic literacy. Overall, the experience was positively evaluated and supports the recommendation to extend the second cycle to seven sessions.

CONCLUSIONS

In this research, we examined the impact of a teaching proposal designed to incorporate sustainability aspects into the preparation of future primary education teachers through statistical projects, with a specific focus on gender equality within the cognitive framework of ESD. Analyzing the results in relation to our SOs, we identified important findings, as follows.

Regarding our first objective, which focused on evaluating the impact of both the original and the reformed versions of the teacher training program specializing in mathematics for future primary education teachers, using content analysis techniques and student’s statistical *t*-tests. In this regard, it has been observed that both versions had a positive impact on the development of knowledge and skills in statistics, probability, and SDG5 in the context of ESD. This highlights the importance of not limiting mathematics teacher training to technical skills but empowering teachers with disciplinary and pedagogical skills to teach mathematics relevantly in real-world contexts addressing social and environmental dimensions (Azcárate & Cardeñoso, 2011). Furthermore, focusing on developing stochastic competence as a transformative tool to provide education in statistics and probability aligns with societal demands (Batanero, 2005, 2006, 2013; Gal, 2019).

On the other hand, our results underscore the importance of integrating DMKC model with statistical projects aimed at competency development (Batanero & Díaz, 2011; Font et al., 2010). The responses from participants in the fourth category of the focus group support this claim as they indicate that this combination provides opportunities to acquire practical skills and foster critical reflection on real situations, which are essential for the training of teachers committed to sustainability. They facilitate the integration of interdisciplinary approaches in addressing sustainability and gender-related issues in teacher education.

Regarding the second objective, initially, when comparing the original version of the training program with the reformed version, no significant differences were found between the two versions through the *t*-test analysis. In response to this result, a focus group was conducted with G2 participants, and the minor difference noted between both cycles for the two groups can be attributed to the reduced training cycle implemented with G2, as previously anticipated by LS team.

The results highlight the need for a more comprehensive approach to the training of primary education teachers, especially regarding the inclusion of ESD to address SDG5. This aligns with the recommendations of UNESCO (2017) and the findings of Su et al. (2022), emphasizing that ESD should not be limited to isolated sessions but should be continuously present in teacher education.

Furthermore, these findings also emphasize that the incorporation of SDG5 from the cognitive aspect of ESD into the training of primary education teachers goes beyond simply adding a single additional session to the training cycle. It is necessary to dismantle gender stereotypes and deeply-rooted biases in the field of mathematics education to effectively address the perspectives of SDG5 in the teaching of school students from the early stages of their educational development.

This study reveals the feasibility of integrating sustainability alongside the teaching of statistics and probability in the training of primary education teachers. To maximize the impact of the training cycle, the adoption of innovative pedagogical methodologies is essential. An outstanding example is the fusion of LS and DMKC models, used in this study to integrate a statistical project to address real-world situations in the context of SDG5. This integration of models in designing the teacher training cycle promotes an understanding of SDG5 from the perspective of ESD, encouraging interdisciplinary and practical methods that promote gender equality through stochastic education in primary education.

Despite the potential contributions of this research, it is crucial to acknowledge certain limitations. One is the need for a larger and more random sample to potentially enhance the study's representativeness. Another limitation is the influence of external factors, such as administrative obligations leading to modifications in the initial planning. Therefore, future research should address these issues to minimize potential biases and uncontrolled variables.

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REFERENCES

Alsina, Á., & Calabuig, M.T. (2019) Vinculando educación matemática y sostenibilidad: Implicaciones para la formación inicial de maestros como herramienta de transformación social [Linking mathematics education and sustainability: Implications for initial teacher training as a tool for social transformation]. *Revista de Educación Ambiental y Sostenibilidad* [*Magazine of Environmental Education and Sustainability*], *1*(1), 1203. https://doi.org/10.25267/Rev_educ_ambient_sostenibilidad.2019.v1.i1.1203

Aparici R., Escaño J. C., & García-Marín, D. (2018). *La otra educación. Pedagogías críticas para el siglo XXI* [*The other education. Critical pedagogies for the 21st century*]. Editorial UNED.

Atkinson, G., Dietz, S., Neumayer, E., & Agarwala, M. (2014). *Handbook of sustainable development*. Edward Elgar Publishing. https://doi.org/10.4337/9781782544708

Azcárate, P., & Cardeñoso, J. M. (2011). La enseñanza de la estadística a través de escenarios: Implicación en el desarrollo profesional [Teaching statistics through scenarios: Implication in professional development]. *Boletim de Educação Matemática* [*Mathematics Education Bulletin*], *24*(40), 789-810.

Batanero, C. (2002). Estadística y didáctica de la matemática: Relaciones, problemas y aportaciones mutuas [Statistics and didactics of mathematics: Relationships, problems and mutual contributions]. In C. Penalva, G. Torregrosa, & J. Valls (Eds.), *Aportaciones de la didáctica de la matemática a diferentes perfiles profesionales* [*Contributions of mathematics teaching to different professional profiles*] (pp. 95-120). Universidad de Alicante.

Batanero, C. (2005). Significados de la probabilidad en la educación secundaria [Meanings of probability in secondary education]. *Revista Latinoamericana de Investigación en Matemática Educativa* [*Latin American Journal of Research in Educational Mathematics*], *8*(3), 247-263.

Batanero, C. (2006). Razonamiento probabilístico en la vida cotidiana: Un desafío educativo [Probabilistic reasoning in everyday life: An educational challenge]. In P. Flores, & J. Lupiáñez (Eds.), *Investigación en el aula de matemáticas. Estadística y azar* [*Research in the mathematics classroom. Statistics and chance*] (pp. 1-17). Thales Mathematical Education Society.

Batanero, C. (2013). Del análisis de datos la inferencia: Reflexiones sobre la formación del razonamiento estadístico [Inference from data analysis: Reflections on the formation of statistical reasoning]. *Cuadernos de Investigación y Formación en Educación Matemática* [*Research and Training Notebooks in Mathematics Education*], *8*(11), 277-291.

Batanero, C. (2019). Treinta años de investigación en educación estocástica: Reflexiones y desafíos [Thirty years of research in stochastic education: Reflections and challenges]. In J. M. Contreras, M. M. Gea, M. M. López-Martín, & E. Molina-Portillo (Eds.), *Actas del Tercer Congreso Internacional Virtual de Educación Estadística* [*Proceedings of the 3rd Virtual International Congress on Statistics Education*] (pp. 1-12). FQM126.

Batanero, C., & Díaz, C. (2011). *Estadística con proyectos* [*Statistics with projects*]. Universidad de Granada.

Brundtland, G. (1987). *El desarrollo sostenible.* [*Sustainable development*]. Naciones Unidas

Callingham, R., & Watson, J. M. (2017). The development of statistical literacy at school. *Statistics Education Research Journal, 16*(1), 181-201. https://doi.org/10.52041/serj.v16i1.223

Cheung, W., & Wong, W. (2014). Does lesson study work? A systematic review on the effects of lesson study and learning study on teachers and students. *International Journal for Lesson and Learning Studies, 3*(2), 137-149. https://doi.org/10.1108/IJLLS-05-2013-0024

Chisamya, G., DeJaeghere, J., Kendall, N., & Khan, M. A. (2012). Gender and education for all: Progress and problems in achieving gender equity. *International Journal of Educational Development, 32*(6), 743-755. https://doi.org/10.1016/j.ijedudev.2011.10.004

Cobb, G., & Moore, D. (1997). Mathematics, statistics, and teaching. *American Mathematical Monthly, 104*(9), 801-823. https://doi.org/10.1080/00029890.1997.11990723

Cvencek, D., Meltzoff, A. N., & Greenwald, A. G. (2011). Math-gender stereotypes in elementary school children. *Child Development, 82*(3), 766-779. https://doi.org/10.1111/j.1467-8624.2010.01529.x

Danä, Å., & Taniăžli, D. (2018). Examination of mathematics teachers' pedagogical content knowledge of probability. *MOJES: Malaysian Online Journal of Educational Sciences, 5*(2), 16-34.

English, L. D. (2014). Promoting statistical literacy through data modelling in the early school years. In E. Chernoff, & B. Sriraman (Eds.), *Probabilistic thinking: Presenting plural perspectives advances in mathematics education* (pp.441-457). Springer. https://doi.org/10.1007/978-94-007-7155-0_23

English, L. D., & Watson, J. M. (2016). Development of probabilistic understanding in fourth grade. *Journal for Research in Mathematics Education, 47*(1), 28-62. https://doi.org/10.5951/jresematheduc.47.1.0028

Escobar-Pérez, J., & Cuervo-Martínez. A. (2008). Validez de contenido y juicio de expertos: Una aproximación a su utilización [Content validity and expert judgment: An approach to its use]. *Avances en Medición* [*Advances in Measurement*], *6*, 27-36

Fernandez, C., Cannon, J., & Chokshi, S. (2003). A US–Japan lesson study collaboration reveals critical lenses for examining practice. *Teaching and Teacher Education, 19*, 171-185. https://doi.org/10.1016/S0742-051X(02)00102-6

Font, V., Planas, N., & Godino, J. D. (2010). Modelo para el análisis didáctico en educación matemática [Model for didactic analysis in mathematics education]. *Infancia y Aprendizaje* [*Childhood and Learning*], *33*(1), 89-105. https://doi.org/10.1174/021037010790317243

Franklin, C., Kader, G., Mewborn, D., Moreno, J., Peck, R., Perry, M., & Scheaffer, R. (2007). *Guidelines and assessment for instruction in statistics education (GAISE) report: A pre-K-12 curriculum framework*. ASA.

Gal, I. (2002). Adults' statistical literacy: Meanings, components, responsibilities. *International Statistical Review, 70*(1), 1-25. https://doi.org/10.2307/1403713

Gal, I. (2005). Towards 'probability literacy' for all citizens. In G. Jones (Ed.), *Exploring probability in school: Challenges for teaching and learning* (pp. 43-71). Springer.https://doi.org/10.1007/0-387-24530-8_3

Garfield, J., & Ben-Zvi, D. (2008). Helping students develop statistical reasoning: Implementing a statistical reasoning learning environment. *Teaching Statistics, 31*(3), 72-77. https://doi.org/10.1111/j.1467-9639.2009.00363.x

Godino, J. D. Batanero, C., & Font, V. (2007). The onto-semiotic approach to research in mathematics education. *ZDM-The International Journal on Mathematics Education, 39*(1-2), 127-135. https://doi.org/10.1007/s11858-006-0004-1

Godino, J. D., Giacomone, B., Batanero, C., & Font, V. (2017). Enfoque ontosemiótico de los conocimientos y competencias del profesor de matemáticas [Onto-semiotic approach to the knowledge and skills of the mathematics teacher]. *Boletim de Educação Matemática* [*Mathematics Education Bulletin*], *31*(57), 90-113. https://doi.org/10.1590/1980-4415v31n57a05

Groth, R., & Meletiou-Mavrotheris, M. (2018). Research on statistics teachers' cognitive and affective characteristics. In D. Be-Zvi, K. Makar, & J. B. Garfield (Eds.), *International handbook of research in statistics education* (pp. 327-355). Springer. https://doi.org/10.1007/978-3-319-66195-7_10

Hernández-Sampieri, R. H., & Mendoza, C. (2018). *Metodología de la investigación: Las rutas cuantitativa, cualitativa y mixta* [*Research methodology: Quantitative, qualitative and mixed routes*]. McGraw Hill.

Incikabi L., & Ulusoy, F. (2019). Gender bias and stereotypes in Australian, Singaporean and Turkish mathematics textbooks. *Turkish Journal of Education, 8*(4), 298-317. https://doi.org/10.19128/turje.581802

INE. (2015). *Síntesis de resultados. La dimensión personal del tiempo* [*Summary of results. The personal dimension of time*]. Instituto Nacional de Estadística.

Kaplan, J. J., & Thorpe, J. (2010). *Post secondary and adult statistical literacy: Assessing beyond the classroom. Data and context in statistics education: Towards an* *evidence-based society. Proceedings of the 8th international conference on teaching statistics*. International Statistical Institute.

Lewis, C. (2009). What is the nature of knowledge development in lesson study? *Educational Action Research, 17*(1), 95-110. https://doi.org/10.1080/09650790802667477

Lewis, J. M. (2016). Learning to lead, leading to learn: How facilitators learn to lead lesson study. *ZDM, 48*(4), 527-540. https://doi.org/10.1007/s11858-015-0753-9

López-Martín, R. (2019). La figura del maestro y la cultura pedagógica en la España franquista. Reflejos desde la literature [The figure of the teacher and pedagogical culture in Franco's Spain. Reflections from literature]. *Utopia y Praxis Latinoamericana* [*Utopia and Latin American Praxis*], *24*(87), 97-112. https://doi.org/10.5281/zenodo.3464045

Martínez-Huerta, J. (2009). *Educación para la sostenibilidad* [*Education for sustainability*]. Centro de Educación e Investigación Didáctico Ambiental [Environmental Didactic Education and Research Center].

MINEDUC. (2018) *Bases curriculares primero a sexto básico* [*Curricular bases first to sixth grade*]. Unidad de Currículum y Evaluación [Curriculum and Assessment Unit].

MINEDUC. (2022) *Estándares pedagógicos y disciplinarios para carreras de pedagogía en educación general básica* [*Pedagogical and disciplinary standards for pedagogy careers in basic general education*]. Unidad de Currículum y Evaluación [Curriculum and Assessment Unit].

Muñiz-Rodríguez, L., Rodríguez-Muñiz, L. J., & Alsina, Á. (2020). Deficits in the statistical and probabilistic literacy of citizens: Effects in a world in crisis. *Mathematics, 8*(11), 1872. https://doi.org/10.3390/math8111872

Murray, S., & Gal, I. (2002). Preparing for diversity in statistics literacy: Institutional and educational implications. In B. Phillips (Ed.), *Proceedings of the 6th International Conference on Teaching of Statistics* (pp. 1-8). IASE.

Navarro, J. (2019). *Mujeres matemáticas* [*Mathematical women*]. RBA Libros.

NCTM. (2000). *Principles and standards for school mathematics*. National Council of Teachers of Mathematics.

NCTM. (2003). *Principios y estándares para la educación matemática* [*Principles and standards for mathematics education*]. Sociedad Andaluza de Educación Matemática Thales [Andalusian Society of Mathematical Education Thales].

Piñuel, J. L. (2002). Epistemología, metodología y técnicas del análisis de contenido [Epistemology, methodology and techniques of content analysis]. *Estudios de Sociolingüística* [*Sociolinguistics Studies*], *3*(1), 1-42. https://doi.org/10.1558/sols.v3i1.1

Sánchez, E. (2009). La probabilidad en el programa de estudio de matemáticas de la secundaria en México [Probability in the high school mathematics curriculum in Mexico]. *Educación Matemática* [*Mathematics Education*], *21*(2), 39-77.

Seckel, M., & Font, V. (2020). Competencia reflexiva en formadores del profesorado en matemáticas [Reflective competence in mathematics teacher trainers]. *Magis, 12*(25), 127-144. https://doi.org/10.11144/Javeriana.m12-25.crfp

Sharma, S. (2017). Definitions and models of statistical literacy: A literature review. *Open Review of Educational Research, 4*(1), 118-133. https://doi.org/10.1080/23265507.2017.1354313

Shaughnessy, J. M. (2007). Research on statistics learning and reasoning. In F. K. Lester Jr (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 957-1009). NCTM.

Soto-Gómez, E., Servan-Núñez, M. J., Pérez-Gómez, A. I., & Peña-Trapero, N. (2015). Lesson study and the development of teacher's competences: From practical knowledge to practical thinking. *International Journal for Lesson and Learning Studies, 4*(3), 209-223. https://doi.org/10.1108/IJLLS-09-2014-0034

Su, C. S., & Marchant, C. (2021). The statistical reasoning level of Chilean students of pedagogy in mathematics on statistical hypotheses tests. *Acta Scientiae* [*Journal of Science*], *23*(6), 209-236. https://doi.org/10.17648/acta.scientiae.5772

Su, C. S., Díaz-Levicoy, D., & Hsu, C. C. (2024). *Propuesta de un ciclo formativo para la enseñanza de la estocástica y el desarrollo sostenible en futuros profesores de educación primaria mediante el estudio de clases* [*Proposal for a training cycle for teaching stochastics and sustainable development in future primary education teachers through class study*]. Formación Universitaria [University Training].

Su, C. S., Díaz-Levicoy, D., Vásquez, C., & Hsu, C. C. (2023a). Sustainable development education for training and service teachers teaching mathematics: A systematic review. *Sustainability, 15*(10), 8435. https://doi.org/10.3390/su15108435

Su, C. S., Hsu, C. C., & Díaz-Levicoy, D. (2023b). Desarrollo de competencias y aspectos de género en las actividades sobre estadística y probabilidad en libros de texto de educación primaria [Development of competencies and gender aspects in activities on statistics and probability in primary education textbooks]. *Tangram-Revista de Educação Matemática* [*Tangram-Mathematics Education*

Magazine], *6*(2), 26-50. https://doi.org/10.30612/tangram.v6i2.17204

Su, C. S., Seckel, M. J., & Vásquez, C. (2022). What learning opportunities does the Chilean primary education curriculum offer to train in sustainability? *Mathematics Teaching Research Journal, 14*(3), 108-132.

UNESCO. (2005). *United Nations decade of education for sustainable development 2005-2014: UNESCO international implementation scheme*. UNESCO.

UNESCO. (2014). *UNESCO roadmap for implementing the global action program on education for sustainable development*. UNESCO.

UNESCO. (2015a). *ESD–Building a better, fairer world for the 21st century*. UNESCO.

UNESCO. (2015b). *Transforming our world: The 2030 agenda for sustainable development*. UNESCO.

UNESCO. (2017). *Education for the sustainable development goals: Learning objectives.* UNESCO.

UNESCO. (2018). *La UNESCO avanza la agenda 2030 para el desarrollo sostenible* [*UNESCO advances the 2030 agenda for sustainable development*]. UNESCO.

UNESCO. (2020). *Education for sustainable development: A roadmap*. UNESCO.

Vásquez, C., & Alsina, A. (2017). Lenguaje probabilístico: un camino para el desarrollo de la alfabetización probabilística. Un estudio de caso en el aula de educación primaria [Probabilistic language: a path to the development of probabilistic literacy. A case study in the primary education classroom]. *Boletim de Educação Matemática* [*Mathematics Education Bulletin*], *31*(57), 454-478. https://doi.org/10.1590/1980-4415v31n57a22

Vásquez, C., & Alsina, À. (2022). Retos contemporáneos en la formación del profesorado: Desarrollando competencias de sostenibilidad desde la educación estadística [Contemporary challenges in teacher training: Developing sustainability competencies from statistics education]. *Revista Científica ECOCIENCIA* [*ECOCIENCIA Scientific Magazine*], *9*(4), 111-132. https://doi.org/10.21855/ecociencia.93.704

Watson, J. M. (2006). *Statistical literacy at school: Growth and goals*. Lawrence Erlbaum.

Wild, C. J., & Pfannkuch, M. (1999). Statistical thinking in empirical enquiry. *International Statistical Review, 67*, 223-265. https://doi.org/10.2307/1403699