Culture and Technology: Reconfiguring the Attitudes of Pre-Service Science Teachers

Oscar Jardey Suárez[1], María Lorcy Rosero Mora[2]

[1]Universidad de Nariño, Facultad de Educación, Colombia.
ORCID: https://orcid.org/0000-0001-8780-595X. ojsuarez@uddenar.edu.co
[2]Universidad de Nariño, Facultad de Educación, Colombia.
ORCID: https://orcid.org/0009-0002-8534-3557. mlorcym@udenar.edu.co

ABSTRACT
Pre-service science teacher education faces the challenge of integrating technology in culturally diverse settings, where attitudes toward it shape its educational appropriation. This study analyzes changes in attitudes toward technology among pre-service science teachers at a public university in southwestern Colombia, before and after a teaching sequence oriented toward computational thinking. Using a quantitative approach and a one-group quasi-experimental pre-test/post-test design, the Pupils Attitude Towards Technology (PATT) instrument was administered to twenty-five pre-service teachers enrolled in a Natural Sciences and Environmental Education program. Results show statistically significant differences between both observations, a low overall Hake gain alongside a substantial shift in attitudes toward technology-related careers, and a reconfiguration of the underlying attitudes identified through exploratory factor analysis. The discussion reads these changes through a semiotic understanding of culture, arguing that the reported attitudes encode locally meaningful associations between technology and cultural practices such as the Black and White Carnival, agriculture, and the arts. The study concludes that the teaching sequence had a positive, culturally situated effect on pre-service teachers' attitudes toward technology.

Keywords: Technology attitudes, computational thinking, cultural diversity, pre-service teacher education, science education, PATT instrument

1. INTRODUCTION

The incorporation of technology into the teaching and learning of the natural sciences constitutes a growing field, particularly in pre-service teacher education. Computational environments and educational robotics favor the achievement of learning outcomes and the development of computational thinking, understood as a set of abstraction, decomposition, and problem-solving processes that transcends the strictly computer science field (Caballero-González and García-Valcárcel 2020; López et al. 2014: 133-48; Ministerio de Educación Nacional 2004; Rodríguez-Abitia et al. 2021: 153-64). In the Colombian context, this development is strategic for education graduates in general and particularly for those in science, who must mediate, in their professional practice, the relationship between technological advances and the sociocultural realities of their students.

Technology and culture mutually shape each other based on specific intentions, forms of knowledge, and social contexts. The appropriation of technological tools transforms the mental functions and the ways of thinking and acting of the subjects who use them

(Rodríguez-Arocho 2018: 1-21), while technology itself operates as a cultural artifact of knowledge and power, unevenly distributed among social groups (Ledesma Soto 2011). This dual condition, cognitive mediator and situated cultural artifact, requires that the cultural context of its teaching be taken into account (Molina 2010: 86-104), along with its effects on the ways of reading, learning, and relating to knowledge (Salmerón and Delgado 2019: 465-80). In southwestern Colombia, where mestizo, Indigenous, and Afro-descendant populations with their own traditions coexist, this consideration is especially relevant for science teacher education.

There are, however, few studies that systematically document the attitudinal change of pre-service science teachers toward technology when they are exposed to an educational sequence designed to develop computational thinking in a culturally diverse context. This work addresses that gap through the following question: What changes occur in the attitudes toward technology of pre-service science teachers at a public university in southwestern Colombia before and after an educational sequence within the framework of their teacher education? To answer it, an internationally validated instrument, the PATT, is combined with a close reading of the cultural particularities of the population studied.

2. THEORETICAL FRAMEWORK

The concept of attitude lacks a single, unequivocal definition. It is assumed here, following Molina-Beltrán et al. (2023: 44-56), as the relatively stable predisposition that leads a person to value and act in a certain way toward an object, in this case, technology. This general definition is articulated with the proposal put forward by Allen-Bame et al. (1993: 40-48) in the Pupils Attitude Towards Technology (PATT-USA) instrument, which understands attitude toward technology as a multidimensional disposition with cognitive, affective, and behavioral components regarding its social consequences, its accessibility, its creative potential, and the career prospects it raises. Later work confirms this multicomponent nature and its relationship with variables such as gender, academic motivation, and the educational use of technology (Çinar and Alci 2022: 1-18; Guillén-Gámez and Rodríguez-Fernández 2022; Novikova and Bychkova 2022; Svenningsson et al. 2022: 1531-51).

Computational thinking is understood as a transversal cognitive process that integrates abstraction, problem decomposition, pattern recognition, and algorithm design; it is not restricted to computer programming and is transferable to different disciplinary fields, including the teaching of the natural sciences (Kert et al. 2022: 625-51; Li et al. 2017; Rodríguez-Abitia et al. 2021: 153-64). Its development in pre-service science teacher education provides conceptual and methodological elements for designing, evaluating, and mediating classroom experiences that integrate technology in a critical and creative way, beyond its merely instrumental use.

The cultural dimension constitutes the third conceptual axis of this work. For Geertz (2003), culture is a web of historically transmitted meanings, embodied in symbols and practices, through which subjects communicate, perpetuate, and develop their knowledge of and attitudes toward the world; his approach, semiotic in its roots, invites us to understand attitudes toward technology as signs that point to systems of meaning shared by a community. This perspective is consistent with Molina et al. (2014), who argue, from the standpoint of science teaching, that attention to students' cultural diversity must be recognized as a central variable in the design of educational proposals. In a department such as Nariño, where mestizo, Indigenous, and Afro-descendant populations converge with traditions recognized worldwide, such as the Black and White Carnival, this semiotic

reading of culture is relevant both for interpreting pre-service teachers' initial attitudes toward technology and for the changes that their training may produce in them.

3. METHODOLOGY

The methodological approach is quantitative: numerical data suitable for statistical treatment are collected to test hypotheses about the change in attitudes toward technology, in accordance with the criteria of objectivity, measurement, and analysis proper to this approach (Hernández-Sampieri et al. 2014).

The design corresponds to a one-group quasi-experiment with a before-and-after measurement (Creswell 2015), represented by the notation O1 -> X1 -> O2: an initial observation (O1) of the attitudes of pre-service teachers using the Pupils Attitude Towards Technology (PATT) instrument, the intervention X1, an educational sequence developed over the course of a fourteen-week course, and a final observation (O2) using the same initial instrument, at the end of the course.

The instrument used is the PATT, proposed by Raat and de Vries (1986) and adapted in various contexts, including the United States, by Allen-Bame et al. (1993: 40-48). It organizes its statements into seven attitudinal categories (consequences of technology, gender-related differences, interest in technology, technology in the curriculum, difficulty of technology accessibility, creativity in technology, and careers or professions in technology), whose distribution is presented in Table 1. Each statement is rated on a scale from one to seven, where one represents total disagreement and seven total agreement.

Table 1. Attitudinal categories of the PATT instrument.

ATTITUDE	DESCRIPTION	NUMBER	STATEMENTS
Consequences of technology	The relationship of technology to different social contexts.	10	1,2,3,4,5,6,7,8,9,10
Gender-related differences	Comparison and perception of technology use between men and women.	7	11,12,13,14,15,16, R17
Interest in technology	Students' interest in independently exploring technological topics.	8	18,19,20,21,22,23,24,25
Technology in the curriculum	Incorporation of technology-related topics into education.	9	26,27,28,29,30,31,32,33,34
Difficulty of technology accessibility	Perceived ease or difficulty in learning about and with technology.	7	35,36,37,38,39,40,41
Creativity in technology	The relationship between creativity and the use of technology.	4	42,43,44,45

ATTITUDE	DESCRIPTION	NUMBER	STATEMENTS
Careers or professions in technology	Future projection into careers related to technological fields.	9	46,47,48,49,50,51,52,53,54

The sequence of activities that constitutes the intervention (X1) was distributed across four stages over the fourteen weeks of the course, presented in Figure 1 and described below.

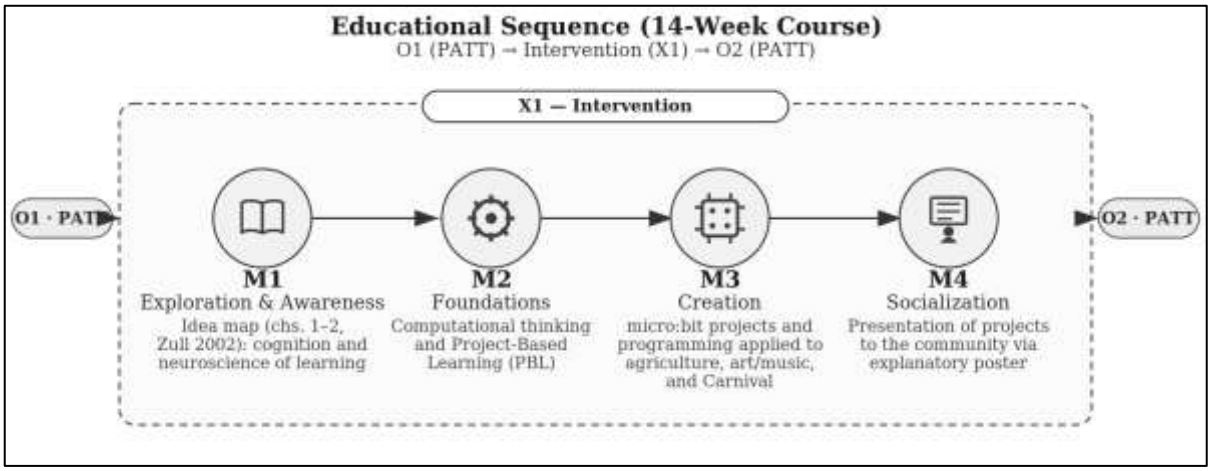


Figure 1. Flowchart of the educational sequence, Intervention (X1), developed during the 14-week course.

In stage M1, exploration and awareness-raising, students created an idea map based on chapters one and two of Zull (2002), setting out the foundations of cognition and learning from the standpoint of neuroscience. In stage M2, grounding, and computational thinking and its characteristics were studied, drawing on Caballero-González and García-Valcárcel (2020), Ministerio de Educación Nacional (2004), and Rodríguez-Abitia et al. (2021: 153-64), complemented by the Project-Based Learning methodology (Galeana 2006; Sánchez Martínez and Ruvalcaba Ledezma 2023). In stage M3, creation, students with no prior programming experience learned to program while developing a project that incorporated technological solutions using micro:bit boards; the projects, proposed by the students themselves, fall into three thematic strands: agriculture, music and art, and expressions related to the Black and White Carnival. In stage M4, dissemination, students presented their projects to the educational community by means of an explanatory poster together with the functional artifact.

The student sample was selected through convenience, non-probabilistic sampling, from among students enrolled in the Bachelor's Degree program in Natural Sciences and Environmental Education at a public university in southwestern Colombia, who were taking an elective course within the curriculum. The course initially comprised 43 adult students; twenty-five completed the full process and were considered valid informants, seventeen men and eight women.

The research was conducted at a public university in the department of Nariño, Colombia; the territory, with an area of nearly 34,000 kilometers, comprises sixty-four municipalities whose population is mostly rural. Afro-descendant, Indigenous, and mestizo populations converge there ethnically; the city of Pasto, located in the Andean mountain range, is home

mainly to a mestizo and Indigenous population. The region is a weaver of cultural syncretism that manifests itself in expressions of intangible heritage recognized worldwide, such as the Black and White Carnival, as well as in a rich variety of cuisines, myths, and forms of peaceful resistance to the sociopolitical tensions of the territory. This cultural diversity is reflected in the composition of the program's student body, which makes the cultural factor a key to interpreting the attitudes documented in the following section.

4. RESULTS AND DISCUSSION

The instrument applied at the initial observation (O1) obtained an overall Cronbach's alpha of 0.694 (standardized 0.751), with category values ranging between 0.674 and 0.723. At the final observation (O2), the overall alpha was 0.688 (standardized 0.755), with a range between 0.667 and 0.709. These values, stable across both observations, support the comparability of the O1 and O2 results.

Table 2 presents the means and standard deviations of the seven a priori attitudinal categories in both observations, together with their difference and the Hake gain ($\langle g \rangle = (O2-O1)/(7-O1)$), which estimates the magnitude of change independent of the starting point: values below 0.30 are considered low, between 0.30 and 0.70 medium, and above 0.70 high. For the interpretation of the means, 3.5 represents a neutral attitude; below 2.5 the attitude is highly unfavorable, between 2.5 and 3.5 slightly unfavorable, between 3.5 and 4.5 moderately favorable, between 4.5 and 5.5 very favorable, and above 5.5 fully favorable.

Table 2. A priori attitudes in the initial (O1) and final (O2) observations, difference, and Hake gain.

ATTITUDE	INITIAL OBSERVATION O1		FINAL OBSERVATION O2		DIFFERENCE (O2-O1)	HAKE GAIN <G>
	MEAN	SD	MEAN	SD		
Consequences of technology	4.82	0.43	4.78	0.41	-0.04	-0.02
Gender-related differences	3.64	0.71	3.80	0.67	+0.16	0.05
Interest in technology	4.74	0.70	4.84	0.75	+0.10	0.04
Technology in the curriculum	5.42	0.56	5.40	0.61	-0.02	-0.01
Difficulty of technology accessibility	2.68	0.83	2.82	0.70	+0.14	0.03
Creativity in technology	6.23	0.96	6.14	1.11	-0.09	-0.12

ATTITUDE	INITIAL OBSERVATION O1		FINAL OBSERVATION O2		DIFFERENCE (O2-O1)	HAKE GAIN <G>
	MEAN	SD	MEAN	SD		
Careers or professions in technology	3.38	0.58	4.66	0.54	+1.28	0.35

Student's t-test, applied after verifying the assumption of normality, showed statistically significant differences across all categories. The mean Hake gain was low ($\langle g \rangle \approx 0.05$) but significant, indicating a positive, moderate effect of the course activities on attitudes toward technology. This average, however, masks differentiated patterns: the creativity-in-technology category already started from high values in both observations (6.23 and 6.14, within the fully favorable band), so its slight decrease and negative gain reflect a ceiling effect rather than an attitudinal setback. The careers-or-professions-in-technology category, by contrast, registered the most important change in the study: it moved from a slightly unfavorable attitude (3.38) to a very favorable attitude (4.66), with a medium Hake gain (0.35).

Following Geertz (2003), who understands culture as a web of meanings that subjects draw on to interpret their world, the shift toward a favorable appraisal of technology-related careers points to a resignification; direct, hands-on engagement with programming and technological creation, mediated by projects with their own cultural grounding, appears to have transformed the meaning of technology, bringing it closer to the identity-related practices of the territory. Along these lines, Rodríguez-Arocho (2018: 1-21) argues that cultural tools transform the mental functions of those who use them; the attitudinal change observed suggests that the cultural mediation of the project, supported by hands-on work with the micro:bit board and other elements, was what made it possible to reconfigure the relationship between future teachers and technology.

Underlying Factors or Attitudes of the Study Population

Before the Intervention (O1)

The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy obtained a value of 0.564, mediocre but sufficient to proceed with the factor analysis; Bartlett's test of sphericity was significant (approximate chi-square = 266.289; df = 136; p = .000), confirming sufficient correlations among the statements for factor extraction via principal components.

Principal component analysis, with Varimax rotation and Kaiser normalization, identified five underlying attitudes (hereafter UA) that together explain 77.587% of the total variance before the intervention. The first UA, technology's creative and imaginative potential, explains 24.527% of the variance; the second, need for training and curricular inclusion of technology, contributes an additional 16.547% (cumulative 41.074%); the third, apprehension, disinterest, and perceived complexity toward technology, contributes 15.534% (cumulative 56.608%); the fourth, equity, accessibility, and inclusive openness toward technology, adds 12.487% (cumulative 69.095%); and the fifth, technological risk and institutional presence of technology, contributes the remaining 8.492%, up to the cumulative 77.587%.

Table 3. Grouping of statements by underlying attitude — Initial observation (O1).

UNDERLYING ATTITUDE (UA)	STATEMENT	EXTRACTION FACTOR
Creative and imaginative potential of technology	43. In technology you have many opportunities to use your imagination.	0.931
	45. Technology makes people more creative.	0.911
	44. Technology and creativity go hand in hand.	0.909
	42. Working in technology is very creative.	0.815
	1. Technology is very important in life.	0.744
Need for training and curricular inclusion of technology	31. There should be more education about technology.	0.903
	30. I should be able to take technology as a school subject.	0.874
	19. For students my age, technology is interesting.	0.730
Apprehension, disinterest, and perceived complexity toward technology	18. When something new is discovered, I want to know more about it right away.	-0.849
	37. You have to be very smart to be able to study technology.	0.811
	53. Most jobs in technology are boring.	0.787
	7. Technology scares me.	0.676
Equity, accessibility, and inclusive openness toward technology	39. Technology is only for brilliant people.	-0.843
	R17. Girls should not become car mechanics.	0.811
	24. I am not interested in technology.	-0.454
Technological risk and institutional presence of technology	9. The results of technology are often dangerous.	0.839
	27. At school you hear a lot about technology.	0.717

Note: extraction method, principal component analysis; rotation method, Varimax with Kaiser normalization; rotation converged in six iterations. Negative extraction factors indicate that the corresponding statement should be interpreted in the reverse sense of its wording.

The UA the creative and imaginative potential of technology groups together the perception that technology stimulates the imagination, fosters creativity, and facilitates innovation in personal and professional life. It reveals a disposition to understand technology not merely as instrumental support, but as a means that promotes cognitive flexibility and creative problem-solving in future teaching scenarios.

The UA need for training and curricular inclusion of technology captures the conviction that more technological instruction needs to be incorporated and formally established in the curriculum. It reflects both an awareness of the relevance of academic spaces devoted to technology and an appreciation of its motivational value for learning.

The UA apprehension, disinterest, and perceived complexity toward technology encapsulates affective resistance to its integration: fear of using it, the belief that it demands an exclusive intellectual aptitude, an associated sense of occupational monotony, and a lack of spontaneous motivation in the face of new discoveries. A high score on this grouping reveals a profile marked by technophobia and disinterest, an obstacle that pre-service teacher education must address to support educational mediation.

The UA equity, accessibility, and inclusive openness toward technology addresses the tension between an egalitarian view of technological culture and the persistence of sociocultural stereotypes: it rejects the elitist exclusivity of technology (statement 39 interpreted in reverse) and disinterest in it (statement 24, also reversed), in contrast with traditional gender biases regarding specific technical roles such as auto mechanics (statement R17). In the cultural context of Nariño, where gender and ethnic origin cut across educational trajectories, this underlying attitude points to a key area for critical reflection in professional training.

The UA technological risk and institutional presence of technology combine caution regarding its negative or uncertain impacts with an appreciation of its visibility within formal education, reflecting a balanced judgment oriented toward reflective technological literacy.

After the Intervention (O2)

The KMO test at the final observation registers a value of 0.611, higher than that of the initial observation, and Bartlett's test of sphericity remains significant (approximate chi-square = 324.086; df = 136; p = .000). These results indicate a somewhat greater sampling adequacy and a sustained consistency in the correlations among the instrument's statements after the course.

The principal component analysis conducted after the intervention likewise yielded five UAs, which together explain 80.068% of the total variance, a higher percentage than that observed before the intervention. The first, creative potential and mandatory curricular integration of technology, accounts for 32.652% of the variance —a larger share than its counterpart in O1— indicating greater cohesion of this component after the course. It is followed by cognitive accessibility and autonomy in technological learning (17.815%; cumulative 50.467%), gender stereotypes in practical competencies and professional devaluation of technology (11.669%; cumulative 62.135%), popular-science interest and the link between household technology and the school curriculum (10.602%; cumulative 72.737%), and interest in extracurricular technology spaces along with appreciation of its global relevance (7.331%; cumulative 80.068%).

Table 4. Grouping of statements by underlying attitude - Final observation (O2).

UNDERLYING ATTITUDE (UA)	STATEMENT	EXTRACTION FACTOR
Creative potential and mandatory curricular integration of technology	43. In technology you have many opportunities to use your imagination.	0.935
	42. Working in technology is very creative.	0.913
	44. Technology and creativity go hand in hand.	0.877
	45. Technology makes people more creative.	0.870
	31. There should be more education about technology.	0.861
	32. Technology studies should be mandatory for all students.	0.803
Cognitive accessibility and autonomy in technological learning	30. I should be able to take technology as a school subject.	0.757
	36. To understand something about technology, it is necessary to take a difficult training course.	-0.892
	3. Technology gives people more free time.	0.831
	38. You can learn a lot about technology on your own.	0.777
	39. Technology is only for brilliant people.	-0.717
Gender stereotypes in practical competencies and professional devaluation of technology	13. Boys are better at doing practical things than girls.	0.895
	48. I don't understand why anyone would want a job in technology.	0.857
Popular-science interest and the link between household technology and the school curriculum	25. I like reading technology magazines.	0.885
	28. Household technology is something schools should teach about.	0.884
Interest in extracurricular technology spaces and appreciation of its global relevance	34. I would like to hear more about technology in a hobby club at school.	0.837
	8. The world would be a better place without technology.	0.599

Note: extraction method, principal component analysis; rotation method, Varimax with Kaiser normalization; rotation converged in five iterations. Statements are numbered without the "Pos-" prefix to facilitate comparison with Table 3.

The UA creative potential and mandatory curricular integration of technology bring together the recognition of technology as a stimulus for imagination and creativity with the conviction that it should have a mandatory place in the curriculum. It shows how, after the course, the conception of technological tools as catalysts for divergent thinking becomes linked with the need to formalize their teaching.

The UA cognitive accessibility and autonomy in technological learning groups together the perception that technology can be mastered without complex formal training (statement 36 reversed), its capacity to free up time, the encouragement of self-directed learning, and the rejection of viewing it as the exclusive domain of brilliant minds (statement 39 reversed). It points to an attitude of empowerment in which technology ceases to be perceived as elitist knowledge and comes to be seen as an accessible domain.

The UA gender stereotypes in practical competencies and professional devaluation of technology groups together the differential attribution of practical skills by gender (statement 13) and the rejection of, or lack of understanding about, entering the technology workforce (statement 48). It encapsulates the persistence of androcentric biases regarding operational abilities and a lack of appreciation for the professional viability of technology, an aspect that pre-service teacher education must continue to address explicitly.

The UA popular-science interest and the link between household technology and the school curriculum brings together an enjoyment of reading popular technology material (statement 25) and the conviction that everyday technological knowledge should be taught in school (statement 28), building bridges between daily life and science teaching.

The UA interest in extracurricular technology spaces and appreciation of its global relevance groups together the desire for extracurricular training spaces (statement 34) and an appreciation of the usefulness of technology for the contemporary world (statement 8), reflecting a favorable disposition toward playful experiences combined with recognition of the social indispensability of technology.

Comparative Analysis between the Underlying Attitudes of O1 and O2

The contrast between the two factor structures reveals both continuities and transformations. The creative-potential factor remains the most robust at both time points, but it increases its explanatory weight (from 24.527% to 32.652%) and, after the intervention, merges with the demand for mandatory curricular integration, suggesting that the educational sequence reinforced the association between technology and creativity and consolidated a favorable stance toward its curricular institutionalization. The apprehension, disinterest, and perceived-complexity factor present in O1 does not reappear as such in O2: the statements that previously signaled fear or difficulty (36 and 39) are now grouped together with statements of empowerment and self-efficacy, indicating a favorable reconfiguration of this attitude. The equity and inclusive-openness attitude from O1 becomes, in O2, a more specialized factor centered on gender stereotypes in practical competencies: gender tensions do not disappear, but they manifest in a more circumscribed way. Finally, the technological-risk and institutional-presence factor from O1 diversifies in O2 into two more specific factors —popular-science interest and the curricular link of household technology, and interest in extracurricular spaces— suggesting a finer differentiation of technological interests following the educational sequence.

Taken together, these transformations are consistent with the proposal of Molina et al. (2014), for whom science teaching cannot be separated from the cultural context that

frames it; the course, beyond the scores themselves, reorganized the system of meanings through which future teachers understand technology, shifting it away from apprehension and toward creativity, autonomy, and curricular relevance. Svenningsson et al. (2022: 1531-51) note that the affective, cognitive, and behavioral components of attitude do not change uniformly; the data from this study confirm this, since the affective component (apprehension) is transformed more clearly than the component related to gender stereotypes, which is more resistant to change. Taken together, and statistically supported by Student's t-test, these differences make it possible to argue that the educational sequence brought about a reconfiguration of the underlying attitudes toward technology, favoring its appreciation as a creative, curricularly relevant, and culturally situated tool, and tempering, without fully eliminating them, the apprehensive attitudes and gender biases that characterized the group before the intervention.

5. CONCLUSIONS

The educational sequence had a statistically significant effect on pre-service science teachers' attitudes toward technology, with a low overall magnitude of change according to the Hake gain, consistent with the gradual nature of attitudinal change in short-duration interventions.

The most significant change in magnitude corresponds to the attitude toward careers or professions in technology, which shifted from a slightly unfavorable to a very favorable appraisal, with a medium Hake gain. Direct, hands-on engagement with processes of technological creation, mediated by culturally grounded projects, appears to be a plausible strategy for transforming future teachers' attitudes regarding the viability of technology-related career paths.

The factor analysis revealed the dissolution of the apprehension-and-disinterest factor and its replacement by a factor of cognitive accessibility and autonomy, indicating a reduction in barriers toward technology. The persistence of a specific factor of gender stereotypes in practical competencies indicates, however, that gender tensions do not dissolve automatically with the educational intervention and require explicit, sustained attention in pre-service teacher education.

This study points to the need to incorporate the cultural dimension as a central interpretive category in research on attitudes toward technology. In a culturally diverse context such as Nariño, attitudes toward technology require considering the traditions and identity-related points of reference of the mestizo, Indigenous, and Afro-descendant communities that make up the student body. Future research could further explore the differential analysis of these attitudes according to participants' ethnic and territorial origin, pre-service teachers from various fields and levels, and cross-sectional or longitudinal designs, among many other approaches that could contribute to understanding the specific nature of education in teacher-training contexts marked by difference and cultural diversity.

ACKNOWLEDGMENTS

We thank the pre-service science teachers who voluntarily participated in the study, and the public university in southwestern Colombia that supported the development of this research.

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