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Integrating Gender Equity in Vocational Studies to Transform Agricultural Activities Towards Green and Inclusive Businesses

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Abstract
Productive sectors greatly contribute to environmental pollution in Colombia, especially in rural areas. Green businesses emerged as an alternative to reduce such environmental impacts, applying clean technologies that require STEM knowledge. However, the participation of women in environmental STEM careers is still low, particularly those vocationally oriented to eco-efficient agricultural activities. Thus, the research aimed to answer the question: How to integrate gender equity in vocational training processes to transform agricultural activities towards green and inclusive businesses? A vocational institute acted as the unit of analysis for the case study. Interviews, focus groups and surveys were used to collect data on women in two selected training programs. The gender transformative and sustainable production approaches guided the identification of gender barriers and the implementation of strategies to remove them. As a result, female models led trainings and the installation of environmental prototypes, which inspired and developed STEM skills in the female apprentices, and reduced pollution in rural units. Finally, innovative pedagogical processes and gender aspects were introduced in organizational guidelines, seeking the institutionalization of the gender perspective in STEM environmental vocational training programs and fields.

Keywords: gender equity, vocational education and STEM, green business, woman, agricultural activities, rurality and sustainable production, gender transformative

1. Introduction

In developing countries, environmentally unfriendly agroindustrial practices with marked inequities predominate, widening gender gaps (OECD, 2021) and degrading biodiversity and ecosystem services in rural areas (Prakash & Verma, 2022). This approach consolidates an agroindustrial scenario where high volumes of wastewater are generated without being treated or reused (Petrik et al., 2022), greenhouse effect emissions increase (UN ECLAC, FAO & IICA, 2021), the excessive use of chemical fertilizers becomes more frequent with the consequent polluting runoff (Feng, et al., 2022), and the barriers that hinder the advancement of women in this field are accentuated (OECD, 2021).
Green and inclusive rural businesses emerged as an alternative to reduce these socio-environmental impacts, transforming rural units towards Cleaner Production (CP), that is, towards more sustainable production and consumption patterns aimed at avoiding pollution in productive activities. Becoming a green industry implies a transition to cleaner production (CP), which necessarily requires the introduction of clean technologies. This means a process of technological change (Bass, 2007; Vickers & Cordey- Hayes, 1999)

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towards a more sustainable manufacturing, requiring green STEM knowledge and skills (Achuve & Mkenda, 2019) for the transition of businesses towards the so-called smart circular economy (ADB, 2021). To ensure a more just transition, stronger bonds need to be formed between women and environmental technologies, providing them with equal opportunities to develop relevant skills for employment in the new green economy (ADB, 2021). The term STEM refers to interdisciplinary work, which integrates Science, Technology, Engineering and Mathematics (Domènech Casal, 2019).

This has been restated as the path to follow for post-covid reactivation in several regions (UN & ECLAC). In Latin America, the Bridgetown Declaration affirms the commitment of countries towards an inclusive, resilient and low-carbon reactivation, highlighting the fundamental role of technology transfer and capacity building to achieve this goal (UNEP, 2021). Colombia aims at a clean and sustainable recovery of the agricultural sector with high participation of rural women (DNP, 2021), thus contributing to a more effective peace implementation process in areas affected by the conflict (Gallego, et al., 2019).

However, in Latin America, both women and Micro, Small and Medium Enterprises (MSMEs) seem not to be part of the agenda of the new green STEM industries, including agroecology. Although MSMEs provide more than 99.5% of enterprises, their contribution to environmental degradation has been historically underestimated (Bandeira, et al., 2021). Most of them do not embrace eco-friendly technological alternatives (Bandeira, et al., 2021) and do not comply with environmental regulations (Villegas, et al., 2021), showing a slow and uncoordinated change towards sustainability (Moreno-Lerma, et al., 2021), with little possibilitiesof becoming part of the new green economy.

In the same way, women's underrepresentation in professional and vocational STEM careers (UNESCO, 2019; Akor et al, 2017) limits their participation in solving complex problems such as food security (Fisher, et al., 2020) and climate change, accounting for only 28% of new green jobs in Latin America (ILO, 2020), and being a minority in the so-called eco-businesses (Kern, 2018). In Colombia, although the importance of vocational training to help break gender gaps in STEM is recognized, especially in remote rural areas, 80% of the most demanded and best paid vocational careers are dominated by men (Sepúlveda, 2017:43). Despite the increase of women in environmental STEM training programs, they are not necessarily employed in positions where they apply the STEM skills acquired, due to a strong sexual segregation of labor activities in productive sectors.

In Latin America, the increase of women in agricultural production has led to a "false feminization" of the sector, as they are mainly employed in unpaid family tasks such as gardening and land preparation, and in processing plants in temporary jobs considered unskilled (such as cutting and packaging). There are few women in positions of machinery management, operation and supervision of industrial and technological processes, which require specialized skills and knowledge that they find difficult to access (RIMISP, 2008; CGIAR, 2020). This is due to the fact that in agribusiness, formal training is offered to permanent workers and workers in decision-making positions, the majority of whom are men (RIMISP, 2008). This is reflected in lower wages, job insecurity and absence of leadership roles, which increases women's vulnerability at the social and economic level (CGIAR, 2020), and hinders their participation as a key actor to accelerate the transition to the new green economy. Thus, the research aimed to answer the question: How to integrate gender equity in vocational training processes to transform agricultural activities

towards green and inclusive businesses?
The Vocational Training Institute (VTI) acted as the unit of analysis for the case study. Qualitative and quantitative data was collected in two training programs with a STEM and environmental focus. The gender transformative and sustainable production approaches guided the identification of gender barriers and the implementation of strategies to remove them. The implementation of environmental technology prototypes in small rural productive units focused on the adoption of good environmental practices and the introduction of clean technologies aimed at reducing water consumption, and the treatment and use of solid and liquid waste. These were developed jointly between apprentices, female rural entrepreneurs, and women experts in STEM fields and sustainable production, proving to be an innovative and effective pedagogical strategy. Based on learning-by-doing and learning-by-interacting methodologies, the prototypes allowed the development of green STEM knowledge and skills in apprentices and female entrepreneurs, the visibility of female STEM role models in the agro-industrial sector, and the significant reduction of pollution generated in a small rural business with coffee and pork production.

2. Research Methodology

The selected research method, Case Study, is a method that is completely concentrated on the analysis of a selected case, seeking to learn from that single case and to optimize the understanding of it (Stake, 2005). It allows researchers to explore and analyze a complex real life phenomenon (the case) in depth, using a variety of data sources (Yin, 2009; Baxter & Jack, 2008). The Vocational Training Institute (VTI) acted as the unit of analysis for the case study.
Mixed methods with triangulation of qualitative and quantitative data (Creswell et al., 2003) were used to increase our understanding of aspects of gender inequality in STEM fields and green industries in two Vocational Training Institute (VTI) programs: a) Technician in Environmental Monitoring, b) Technology in Integrated Management of Quality, Environment, Safety and Occupational Health. Both quantitative and qualitative data were equally important to build a comprehensive understanding of the case (Yin, 1984; Stake, 1995). Following a mixed methods triangulation design, quantitative and qualitative data on the same phenomenon were collected separately and then the different results were complemented, compared or validated during interpretation (Creswell & Plano, 2006).
The research was conducted over two years in two phases. At the beginning of the Project, Phase 1 focused on: I) Review of grey and scientific literature, on factors that may act as barriers to the enrollment, permanence and advancement of women, in STEM careers in the field of green industries, with emphasis on developing countries; II) Elaboration of the gender baseline, aimed at identifying the situation of women apprentices and their perception of gender gaps in the educational context, and recognizing family, socio-economic and pedagogical aspects, which could affect their participation and advancement in STEM vocational careers in the field of Green Industries. Documentary review (databases), surveys and semi-structured interviews, and focus groups with female trainees and instructors at different stages of the training cycle, provided information for the elaboration of the gender baseline. Through the use of multi-stakeholder dialogues, and

from an appropriate context, the results of the gender baseline were compared with what had been found in the literature (De las Cuevas, et al., 2022), validating the barriers already identified or including new ones. From an initial large group of identified barriers, five were finally selected as main barriers. As a key strategy to try to remove them, the development of clean technology prototypes, with female leadership and participation, was selected.

Phase 2 focused on the design, implementation, monitoring and follow-up of environmental prototypes in a rural enterprise (coffee and pork production), supported by women from sustainable production STEM fields, rural women, and Vocational Training Institute (VTI) female apprentices. The design stage included the elaboration of an environmental diagnosis of the rural business and an action plan with alternatives for environmental improvement. Initially, theoretical-practical workshops as an educational research tool, helped to identify knowledge gaps in sustainable production in rural women and female apprentices, and to share empirical and technical knowledge specialized in relevant environmental and production aspects, enabling them to participate more actively in the subsequent multi-stakeholder dialogue processes carried out to identify the critical points of pollution, and to agree on environmental improvement actions on which the prototypes would focus.

Subsequently, in the implementation, monitoring and follow-up phases, to evaluate the correct performance of the new technological prototypes, and the development of green knowledge and skills in women, two methods were used: i) Systematic direct observation supported by forms to collect accurate information on predetermined aspects (Marroun & Young, 2018), ii) Workshops that started with a theoretical part followed by a practical activity, allowing women to apply the theoretical knowledge acquired and researchers to evaluate their level of acquisition (Ahmed & Asraf, 2018). Both methods allowed to know aspects such as: the women's ability to correctly describe the new concepts and cleaner processes, and operate the new environmental technologies; their skills to manipulate devices and fill out forms necessary for the operation and control of the new green processes.

3. Development and Results

In its two phases, the study followed the principles for the transfer of cleaner production (CP) and transformative gender. Both approaches agree on the need to identify the root causes of a problem, of corporate environmental pollution or gender inequality, as a first step before attempting to solve it (UNICEF, 2019; Prieto-Sandoval, 2021); in other words, they propose to start with the identification of main barriers to promote gender equality and more responsible environmental behavior, upon which actions will be defined and implemented to remove them. These interventions seek to challenge and transform structures, stereotypes, beliefs, behaviors, habits and norms that accentuate inequalities (UNICEF, 2021; Stewart, et al., 2021), and unsustainable production patterns (Dieleman, 2007; Van Hoof, 2014), at the individual, organizational and community levels (MacArthur, et al., 2021).

From a Learning-by-doing approach, it is possible to achieve a participatory transformation process where changes respond to the real needs of different stakeholders,

and thus are more easily adopted and sustained over time. Collective learning processes are key to the transition towards green industries, by recognizing the different sources of technical, business and community knowledge in the development of initiatives such as renewable energy projects (Trischler, 2020; Günzel-Jensen & Rask, 2021).
Such transition towards the integration of new clean technologies in production processes implies a process of practical and real-time learning within organizations; it is a process of Learning-by-Doing (Wenxi, et, al., 2018) that cannot be done behind a desk (Dieleman, 2007), and in which women as agents of environmental change must have an active participation.
Accordingly, Phase I of the research analyzed the main barriers that women face in vocational STEM careers oriented to green industries, and in Phase II developed participatory environmental prototypes with female leadership in a rural enterprise, as a strategy to try to remove them.

3.1 Phase 1 – Gender Barriers

The identification of barriers faced by women in vocational STEM programs in the field of green industries was based on a literature review and the elaboration of a gender baseline in two Vocational Training Institute (VTI) programs. The review was divided into two thematic blocks concentrating on the identification of barriers faced by "women in green industries", and "women in vocational STEM programs"; this taking into account that there are minimal studies that attempt to approach in an integrated manner the three axes of interest of the research; in other words, that attempt to understand the barriers faced by women in "Vocational Fields - STEM in Green Industries".

3.1.1 Literature Review

Although women are recognized as key players in the transition to the green economy (Kwauk & Braga, 2017), multiple barriers limit their leadership and effective participation in the greening of economic sectors, being only one third in new eco-businesses (Pallares-Blanch, et al., 2015). Such underrepresentation has led researchers to ask: Why women are not integrating into the green economy at the same rate as men (Kern, 2018)?. It is argued that this new economy has brought with it social, cultural and organizational patterns, among others, that have generated situations of gender inequality in the labor field throughout history. Thus, patriarchal patterns are reproduced that favor the creation of green jobs in technological macro-projects and male-dominated sectors (e.g., sophisticated solar energy farms), with few investments in small-scale eco-initiatives where women could have a greater participation (Kern, 2018).
Such patterns are accentuated by the difficulty of women, particularly rural women, to access technical training processes in specialized environmental fields (Emmons, et, al., 2019), forcing them to remain at the bottom of the eco-business chain, performing activities such as planting seeds and drying grains (Babugura, 2020). It is necessary to train and empower women to develop STEM and environmental leadership skills (Kwauk & Braga, 2017), and to have greater influence and decision-making power over the productive processes and their business in general (IFPRS, 2012). For rural women over 40 years old, age also poses an obstacle to their education, as they may feel insecure in the face of academic challenges, and must face family and time pressures due to their multiple

responsibilities.
Although vocational technical education with a STEM focus is fundamental for women to acquire technical knowledge, practical experience, and competencies for green jobs, there are multiple psychological, family, cultural, organizational and social barriers that women must face from the time they join the training program until they become part of the labor force (Evans, 1995). Societies with persistent cultural patterns that encapsulate genders in inflexible roles, and gender stereotypes in certain economic sectors and occupations, seem to influence the decision on the type of training programs that women and men prefer to enroll in. This results in low levels of women entering technical and technological programs such as construction, mechanics, and electricity, which in turn leads to low participation in STEM occupations. The lack of successful female role models in STEM careers discourages new generations of women from enrolling in STEM careers. On the other hand, when an instructor in a training activity limits the participation of female trainees in physical tasks considered difficult, heavy or exhausting for them, and prefers to assign them roles such as report writing, it hinders their learning process and the development of STEM skills by taking them away from activities proper to their specialty and turning them into passive observers (Fernandez-Darras, et al, 2020; Sevilla, et al, 2019). This trend is also observed in firms; this is the case of female trainees in Industrial and Automotive Mechanics programs, who were expected to sweep, tidy and keep the workshop area clean instead of being assigned maintenance activities (Fernandez-Darras, et al, 2020).
Poor governmental and organizational policies can also accentuate gender disparities in the new green economy. Some green policies exclude women by considering them as a natural supporter of green initiatives, considering that they do not need to be specifically included as they naturally integrate into environmental guidelines (Kern, 2018). Also, more work is required with industrial sectors to ensure that both environmental and gender equity principles are incorporated into their organizational values and guidelines, in order to prevent labor segregation in green businesses (Kwauk & Braga, 2017).

3.1.2 Gender Baseline

The application of a variety of methodologies during the development of the baseline allowed for the identification of gender barriers in vocational STEM fields in the green industry. Initially, a database with information from two Vocational Training Institute (VTI) programs over a five-year window was reviewed, focusing on aspects such as: number of female and male apprentices, stage of training of female apprentices (enrolment, permanence, internship, and advancement), and program duration.
From this review, a universe of 219 potential female apprentices to be surveyed was found, on which a sample size of 21 individuals was determined in order to have a high degree of representativeness with respect to the population. The type of sampling was stratified probabilistic, applied in a simple random manner and proportionally distributed, with a significance of 5%, 95% confidence and a margin of error of 10%. Three types of semi-structured questionnaires were prepared according to the apprentice's stage of training: Type I - apprentice in the entry stage, Type II - apprentice in the permanence stage, Type III - apprentice in the business practice stage. The purpose of these questions was to identify gaps in environmental knowledge, socioeconomic aspects and the trainees'

perception of gender gaps in their training process, which could act as barriers to their progress in STEM careers in the field of green industries. Questions were asked such as: Do you know female STEM referents? Do you think that having female instructors in your training program affects your permanence in it?, In which environmental topics did you feel better trained and in which would you like to deepen your knowledge?, Do you think that some organizations prefer to select men rather than women? and In your practical business stage are you in charge of " leading" or "supporting" environmental initiatives?.
Thirty-eight surveys were applied via Google Forms, identifying trends such as: 59% of female apprentices know female STEM referents; 84% feel motivated to continue in STEM careers by having female instructors; 62.5% are interested in key topics for green industries, including environmental regulations and impacts, waste, and water resource management; 56.5% support environmental initiatives in businesses, while only 13% are in leadership positions; 61% consider that some organizations prefer to hire men more than women.
At the same time, two types of semi-structured questionnaires were prepared for interviews, which sought to know the perception of the instructors through their experience, on issues associated with gender gaps and the level of knowledge of the female apprentices in their training process. Questions were asked such as: Have you identified situations of vulnerability among rural female apprentices? and What is your opinion on the distribution of roles for holding positions in the enterprises? Individual interviews through Google Meet were conducted with 100% of the instructors with more than one year's seniority, corresponding to seven people (men and women). The interviewees expressed that female apprentices from rural environments have difficulties adapting to the educational institution and to the urban environment. Also, "Within the firms, the male gender is perceived as the one with greater authority and commanding voice to exercise leadership roles; therefore, men tend to be linked to coordination positions and women to lower-ranking administrative issues".
Focus groups were led by women with expertise in areas such as gender, sustainable production and STEM, around guiding questions. The aim was to know the level of environmental knowledge, leadership, aptitude, attitude, and perception of the female apprentices on situations of gender inequality. Reflection was supported by questions such as: In which environmental issues do you feel better trained and in which would you have liked to deepen your knowledge?; and ethnographic drawings that recreate possible sexist situations or behaviors in the educational context based on subjective perceptions; both helped to motivate and guide the participation of the female apprentices in the processes of reflection on gender inequalities. In particular, the drawings allowed to break the ice and generate a safe space where the trainees felt calm and safe to share their experiences. One of the drawings depicted a young woman's insecurity about the use of technological equipment and devices (i.e., scales, construction equipment, boilers), asking questions such as: Are these items for men or for women, and now, which training program will I choose? Due to the Covid pandemic, eight focus groups were conducted virtually through Google Meet, with an average capacity of 15 trainees to ensure that the floor was rotated, for a total of 97 female participants. The results showed the trainees' interest in deepening their knowledge on topics such as: environmental regulations and impacts, waste and water resource management, and green businesses. At the same time, perceptions such as: "It is

difficult for us women to choose careers in science and technology because these are for men" and "Families influence the decisions of daughters, limiting their study options", were also revealed.

Regarding the analysis of the data collected through the different tools, this was processed in Excel format and analyzed through the constant comparative method, identifying themes and repeated patterns that were then classified into categories. The analysis revolved around three axes: gender, sustainable production and vocational STEM education.

From a triangulation approach, the results of surveys, interviews, and focus groups were compared, validated, and complemented each other. From this analysis, five barriers were selected as the main ones affecting the advancement of women in STEM vocational careers in the field of green industries, these being: I. Low visibility of female leadership in highly masculinized environmental STEM fields, discouraging other women to continue with their vocational training and progress in their field of work; II. Sexist and gender stereotypes that establish the skills, roles, and careers suitable for women and men, limiting their participation in the academic and working world; III. Bosses, instructors or the apprentices themselves may limit women's participation in practical activities considered masculine, specific to the career or job position; IV. Lack of training for women in topics associated with green industries, limiting their advancement to positions of greater leadership in their field of work; V. Organizational guidelines with a weak inclusion of a gender perspective in vocational programs with an environmental STEM focus.

3.2 Phase 2 – Environmental Prototypes

As a strategy to remove root causes of inequality that prevent greater participation of apprentices and rural women in green industries, simple and low-cost environmental technological prototypes were developed, led by women experts in STEM fields, in a small rural productive unit with pig and coffee production. Both are very important agro-industrial activities in the Colombian economy, which also generate high negative impacts on the environment. The firm, led by an adult woman (over 40 years old), was carrying out a traditional process with a high potential for technological reconversion, and its location facilitated the arrival and entry of apprentices to the area.

Eighteen women, including one rural woman, apprentices, instructors and experts in STEM fields, supported the development of two prototypes: green coffee production system and mixed anaerobic biodigester for the managment of coffee and pig farming waste. These women had an active participation in the different stages of the prototype development, from its design to its implementation, monitoring and follow-up; thus, the visibility of female leadership in technological reconversion processes, usually dominated by men, in rural productive activities was promoted.

The design stage began with three theoretical and practical workshops, supported by recreational activities, using scale models of the coffee processing process, which encouraged the learning process. In these workshops, female STEM referents helped to transfer concepts and tools, increasing the knowledge and skills of rural women and apprentices to identify critical environmental points and promote alternatives for improvement. At the same time, female experts in sustainable production provided guidance on the use of environmental checklists and flow charts through practical

exercises. This helped to break down sexist stereotypes that underestimate the role of rural women and women in vocational careers in environmental business transformation.
I found the activity very productive, as this knowledge helps me to grow as a person and as a woman and not to remain as the "woman at home" - Vocational Training Institute (VTI) *apprentice.*
Afterwards, the prototype implementation stage was undertaken in the production unit, which focused on: the adoption of good washing practices and the installation of a dry pulping system to reduce water consumption, the installation of a fermentation tank with rounded corners and adequate drainage to avoid excessive washouts, the installation of composting pits for the use of coffee pulp waste through dehydration of coffee pulp and leachate recirculation, the construction of a box to divert wastewater from coffee washing for subsequent reuse, and the construction of a system for the treatment and reuse of wastewater from coffee and pig farming production (biodigester).

Photo 1 and 2. green coffee production system and mixed anaerobic biodigester for the managment of coffee and pig farming waste.

Female apprentices verified progress during the implementation cycle of the prototypes with the guidance of women experts through informal dialogues; thus, through the recognition of environmental technological transformations in a real context and time, the women clarified technical concepts, and strengthened knowledge and skills acquired in previous stages. This involved applying a Learning-by-Doing approach, related to STEM activities, where the apprentices carried out activities such as: taking water quality parameters (pH, Cl), measuring flow rates, and visual inspection of waste management. This active participation strategy constituted a change in the passive learning approach, expanding the participants' analytical capacity and their ability to recognize and integrate new knowledge.
It is important to replicate this type of practical activities on site, because it reinforces concepts and skills that help the learning process, but that are not yet addressed in classroom training - Vocational Training Institute (VTI) *Apprentice.*
The technological reconversion led to an improvement in the environmental performance of the production unit, as evidenced by: 82.6% savings in water consumption for coffee washing, recirculation of 100% of the leachates, use of 100% of the coffee pulp, treatment and use of 100% of the effluents from coffee and pig farming processes, production of organic fertilizer and natural gas by means of a biodigester. Production times were also

reduced by replacing obsolete manual equipment with semi-automated equipment. In addition, ergonomic conditions were improved, which had a positive impact on the woman entrepreneur's health.

The technological implementation in coffee pulping helped me to improve my health conditions, because I no longer have to make so much physical effort shaking the coffee.

Now we are saving water because we no longer wash the coffee so many times. In addition, we are using everything; the waste from the process is used to fertilize the coffee itself and we are thinking of implementing a vegetable garden, so that as time goes by the farm will become self-sustainable.

In this way, the strategy helped 100% of the participants to: deconstruct gender stereotypes related to their field of action, recognize important female leadership in the STEM and green industry fields, and weaken barriers related to women's low access to knowledge and clean technologies.

Finally, for the monitoring and follow-up stage of the implementations, the woman rural entrepreneur and 100% of the apprentices verified the start-up and operation of the prototypes with the help of female STEM experts, through a direct observation exercise in which they learned to apply follow-up and evaluation forms (checklists). This process made it possible to verify the correct functioning of the new technologies, supported by informal dialogues for constant feedback among the participating women. Through a collective learning process, the effective transfer of knowledge was evaluated on technical aspects such as: ideal conditions for proper operation of the prototypes, proper water and waste management, appropriate sizing of elements, level of saturation of the biodigester, application of good practices to avoid the entry of rainwater into the new cleaner process and the existence of leachate leaks. This on-site interaction allowed the researchers to detect in time gaps in the appropriation of knowledge and green skills, correcting them to modify individual, family and productive process practices. In this way, in a safe space, 100% of these women were able to freely express their concerns about new technologies, clarify concepts, and finally develop greater skills and abilities to compete in the green industry.

"I feel confident to ask you, engineer, the things I don't understand to make this machine work" - Rural business woman

In addition, these spaces helped to break down barriers that have been imposed on women when their participation in masculinized learning activities is limited, even more so when these are led by female STEM leaders who promote self-confidence and leadership in other women.

"Before I did not speak much, I preferred my husband to do the talking. Now I feel more confident to talk about the technological changes that were made on my coffee farm, thanks to the fact that you have made me share this with the apprentices and visitors that have come to learn about my experience" - Rural businesswoman.

On the other hand, the benefits of technological conversion motivate the woman entrepreneur to become involved and empowered on a larger scale in her production unit, increasing her leadership and recognition in her family environment (husband and son). This leadership is reflected in her decision to transform a linear production model with high environmental impacts into a circular production model based on the reduction and reuse of products and waste; thus, demonstrating a radical change in organizational values, principles and processes, that is, in the heart of the production unit.

This showed that 100% of the participating women developed skills to identify, implement and sustain sustainable production actions in specific productive sectors. Through the integration of new pedagogical strategies (prototypes), in the organizational guidelines and training activities of the educational institution (VTI), begins a process of institutionalization of an innovative educational model with female STEM referents who promote Learning-by-Doing and Learning-by-Interacting approaches in rural economic sectors of great relevance but little addressed.

4. Discussion and Conclusion

Following gender transformative and sustainable production approaches, the research was concerned about gender equity in vocational studies to transform agricultural activities towards green and inclusive businesses. Such transformation implies a knowledge and information transfer process in STEM areas relevant to the transition towards cleaner production (CP) based on environmental technologies; this process must also be conducted from a gender perspective that allows for a meaningful participation of women. Thus, the research begins with the identification of the barriers that hinder the participation of rural women and women in vocational STEM careers in environmental transition processes in polluting rural enterprises, and continues with the development of strategies to remove them. The implementation of clean technology prototypes on a farm with pig raising and coffee production, developed jointly between apprentices, female rural entrepreneurs, and women experts in STEM fields and sustainable production, proved to be an effective strategy for integrating women from diverse backgrounds into environmental transformation processes in agro-industrial contexts. Therefore, the research contributes to our understanding of more inclusive knowledge transfer processes in cleaner production (CP), in vocational STEM careers and small scale rural enterprises.

As stated by Bass (2007), Vickers & Cordey- Hayes (1999), and Van Hoof (2014), the researchers strongly argues that the transfer of new CP knowledge to the firms necessarily implies intense learning process; in turn, without a gender perspective, this process will not translate into more sustainable productive sectors (Alarcón & Cole, 2019; Kumar Pathania, 2017). Understanding the importance of external agents for the transfer of new knowledge into SMEs (Jones & Macpherson; 2006), in particular CP consultants and trainers for clean technologies dissemination (Mitchell, 2006), the research relied on women experts in STEM fields to transfer the principles and practices of sustainable production to small rural entrepreneurs and SENA apprentices, thus acting as external providers of new environmental knowledge. External knowledge has been considered by many as complementary knowledge that the firm can use in combination with its internal knowledge to develop new skills (Bell & Albu, 1999), enhance its capacities to build sustainability-oriented innovations (Ghassim & Bogers, 2019) leading to increased competitiveness (Ma et al., 2018).

Through constant interaction, women from different backgrounds shared specialized and empirical knowledge to guide coffee and pork production processes towards more resource-efficient activities. Women's networks are seen as safe spaces where women share their opinions and beliefs, facilitate knowledge transfer, increase collective action, and help build capacity on the issues around which women interact (Prillaman, 2021). Networks allow access to environmental know-how (Alayón et al., 2022). Studies of CP transfer initiatives have determined that "learning by interacting" is the mechanism of learning of most relevance in the context of CP (Mitchell, 2006). In our case, this interaction helped the absorption, transformation and effective application of new environmental knowledge in a rural enterprise, leading to the successful adoption of environmental technology prototypes (Qi et al., 2021) with female leadership. Thus, the research is aligned with the new concept of "open eco-innovation mode", which considers that openness to new sources of knowledge, among these environmentally responsible partners, is beneficial for the discovery of solutions to the internal environmental constraints of firms (Chistov et al., 2021).

Equally important is the fact that this interaction process allowed women with low environmental knowledge to interact intensively with female STEM role models in pollution prevention. Studies have shown that when women are exposed to STEM role models with whom they share similarities (such as gender), it helps them to break down deep-rooted negative beliefs about their participation in science and technology fields (Van Camp et al., 2019), thereby reducing the implicit cultural stereotype that science is masculine (Schmitt & Wilkesmann, 2020; Young et al., 2013). In our project, female models led trainings and the installation of environmental prototypes, which inspired and developed STEM skills in the female apprentices and farmer, and reduced pollution in rural units. Apprentices expressed their desire to become the next Colombian scientists and professionals to lead environmental initiatives. Thus, the clean technology prototypes with female leadership were able to address root causes of gender inequality, persistent in the field of green industries and particularly in agro-industrial activities that require STEM skills.

On the other hand, the prototypes allowed rural women and apprentices to learn about the implementation and operation of innovative environmental technologies to solve real environmental problems. Easy to apply prototypes, in addition to serving as a "learning-by-doing" tool, allowed to generate positive environmental changes from easy to apply clean technologies. The latter are recommended by multiple authors to initiate the transfer of CP to MSMEs, as they are low cost (Nulkar, 2017), require less effort, generate significant benefits in a short time (Torres-Guevara et al., 2021), and prioritize the application of good environmental practices in firms to increase efficiency in their production process (Vargas et al., 2019).

Thus, the new technologies and cleaner processes implemented led to environmental and productive benefits, resulting in the reduction of pollution in coffee and pig production, leading to compliance with environmental regulations, an increase in the quality of coffee and its sale price thanks to a new classification as a BE4 ecological mill, and a reduction in the purchase of chemical fertilizers and gas for household cooking, positively impacting the woman who owns the production unit and her family. Last but not least, by adapting the prototypes to the physical needs of the rural woman and her local context, it became possible for her to operate technologies that previously could only be handled by men, since they required a great degree of physical effort. Thus, clean technologies were placed within women's reach, breaking sexist stereotypes, by demonstrating to them and proving for themselves that their operation is simple and can be easily performed by a woman.

On the other hand, the benefits of technological conversion motivated the rural woman to become involved and empowered on a larger scale in her production unit, increasing her leadership and recognition in her family environment (husband and son). This leadership is reflected in her decision to transform a linear production model with high environmental impacts into a circular production model based on the reduction and reuse of products and waste; thus, demonstrating a radical change in organizational values, principles and processes, that is, in the heart of the production unit. Bass (2007) argued that "*the more in-depth the learning processes of CP new concepts are, the more radical the CP innovation process within the existing organizational context will be"*. Thus, the modification of core values, business models, goals and policies reflects major organizational changes. This indicates the transferred environmental principles have been effectively internalized and therefore will be retained in the firm (Thomson & Hoffman, 2000). It can be implied that the prototypes motivated the process of internalization of CP in the rural enterprise, which helps the sustainability of gender-based environmental initiatives.

Finally, the successful results of the implementation of environmental prototypes with female leadership demonstrate that small rural businesswomen are capable of developing circular economy actions, generally associated with large industries. This can be achieved with simple and low-cost technological changes.

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