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Identifying the role of Civil Society Organizations in shaping Indigenous Mexican women's health literacy, gender empowerment, and use of improved cookstoves

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Abstract

Background While large-scale interventions have addressed household air pollution through the implementation of improved cookstoves (ICSs), the impact of small-scale interventions led by Civil Society Organizations (CSOs), particularly when combined with participatory methods, remains underexplored. This study examines the intersection of gender, health, social structures, and empowerment to better understand the downstream effects of CSO-led initiatives.

Methods This three-phase participatory study (2019–2024) with Indigenous women in Mexico involved co-designing ICSs, conducting in-depth interviews with 14 participants, and analyzing secondary de-identified data. Interviews explored perceptions of CSO activities and ICS use across five thematic domains. Secondary data analysis consisted of iterative inductive and deductive coding.

Results Findings show that CSO engagement significantly influenced participants' perspectives. Participants described the barriers to access quality health care. They experienced an increased health literacy particularly regarding the respiratory risks of open-fire stoves. They also developed language and attitudes reflecting increased gendered equity and empowerment.

Conclusions This study demonstrates that promoting Indigenous women's rights to health and gender equity through CSO interventions empowered female participants to advocate for themselves, value their labor, understand women's rights, improve their health, and strengthen social and economic networks, fostering solidarity and reducing gender inequities. The collaborative methodology frames the process of stove design and usage as a conversation between local actors, practitioners, and scholars. Findings highlight the importance of integrating technology and local culture to address gender inequities and promote sustainable health improvements in marginalized communities.

Keywords Indigenous women, Gender empowerment, Health literacy, Improved cookstoves, Civil Society Organizations

1 Introduction

In Low- and Middle-Income Countries, approximately 2.4 billion people rely on solid fuels for cooking and heating [1], resulting in household air pollution that is closely linked to around 3.2 million deaths annually, including over 237,000 deaths of children under the age of five [1, 2]. Women are especially at risk, with biomass smoke exposure increasing the likelihood of chronic respiratory diseases like COPD [3]. Although interventions (installing chimneys in cookstoves, enhancing biomass fuel combustion stoves, transitioning to cleaner fuels) exist, their effectiveness varies, hampered by obstacles such as fuel affordability, cultural preferences, and inadequate infrastructure [4, 5].

It is widely recognized that women are primary actors in domestic household space, and, hence, are the predominant users of cookstoves worldwide. Thus, women comprise the largest proportion of people affected by household air pollution exposure, making this a highly gendered issue. A significant body of literature has examined the various factors that shape the gendered nature of household air pollution, e.g. women's worlds and domestic spaces, their experiences around stove usage, and large-scale interventions to reduce household air pollution [6–9]. Indeed, there are existing large-scale government initiatives that have distributed efficient wood-burning cookstoves [10, 11], showing reduced durations of respiratory infections compared to households relying on open fires [12, 13]. However, these large-scale interventions have had mixed results [5, 12, 14]. One factor that has been less examined is the role of small-scale interventions, such as those managed by Civil Society Organizations (CSOs), in (a) implementing the usage of improved cookstoves to reduce household air pollution and stove use time and (b) addressing the sociocultural, ecological, gendered, and economic elements around stove usage. Accounting for cultural factors is crucial to ensure the acceptance of interventions.

To help fill this gap in knowledge regarding culturally grounded, sustainable interventions in Indigenous communities, we analyze the long-standing work of a Civil Society Organization (CSO) in Hueyapan, Mexico. This CSO has collaborated with Indigenous women's cooperatives for over two decades, utilizing participatory methods to co-create development strategies that address local priorities. One such intervention focused on the introduction of improved cookstoves (ICS), which not only improved respiratory health outcomes but also promoted women's empowerment and health literacy. The intervention exemplifies best practices in participatory development, where small-scale innovations are co-designed with community members to ensure cultural relevance and sustainability. By integrating traditional practices into a socio-economic model, such as the use of natural pigments for dyeing textiles over an open fire, the CSO helped reframe this task as a source of empowerment rather than a burden. Drawing from in-depth qualitative data and an intersectional lens, we show how Indigenous women contextualize their experiences and articulate their agency through their engagement with the ICS intervention. Our research demonstrates the potential of CSOs to serve as key agents of transformation—leveraging participatory approaches to catalyze holistic, culturally respectful development rooted in gender equity, environmental sustainability, and Indigenous knowledge.

Participatory methods aim to include participants in the conversation and action of a particular project. They emphasize a "ground up" perspective drawn from the community members themselves with the aim of confronting power imbalances [15]. These

methodologies foster participants' problem-solving skills and give the tools (empowerment) to transform their situation. However, it is a large umbrella term for various approaches, not all of which actually include participants as agents [16, 17]. When methods are truly participatory and emancipatory, community members build political capabilities and critical consciousness, and are able to demand their rights as citizens [16]. These approaches have been connected to positive outcomes in participatory governance, where citizens can exercise their voice and vote [18, 19].

Our inquiry addresses the need for rigorous evaluation of community-based interventions and their outcomes (both un/anticipated and un/intended) that prioritize participatory approaches to enhance well-being. Our research illustrates how such methods, when led by CSOs and rooted in culturally relevant knowledge, can foster women's empowerment, enhance health literacy, and promote sustained adoption of technologies, like ICSs. By centering Indigenous women as active agents rather than passive recipients, the intervention enabled them to transform their living conditions while reinforcing their roles as cultural and economic contributors within their community.

1.1 Background: literature review

Cooking over traditional open-fire stoves is a significant source of household air pollution, with serious health consequences, particularly for women and children [10, 11]. In response, numerous interventions have targeted this issue, highlighting the need for effective solutions [1, 5, 6, 20]. Improved cookstoves (ICS) have emerged as a key technological response, designed to meet international standards for emissions, efficiency, and safety as outlined by the World Health Organization [21]. While various ICS models exist, evidence from a large randomized controlled trial in Mexico demonstrated that even with a 50% adoption rate of "Patsari stoves," users experienced improved lung function, reinforcing the potential health benefits of ICS when effectively adopted [22].

Research shows that uptake of ICS has not been seamless [8, 23, 24]. It has been shaped by sociocultural factors (e.g., significance of traditional cooking methods; perspectives about food tasting better when cooked on open-fire stoves; gender norms; affordability of wood) or technological ones (e.g., inadequate design of stoves for women's needs) [25, 26]. Indeed, a single one-size-fits-all design is impractical, given different populations' various needs, experiences, and desires [24]. Additional constraints on people's choices and continued adherence to open-fire stoves can include the tension between immediate needs (feeding one's family) versus less concrete future concerns (potential ill effects from smoke) [8]. Instead, scholars suggest that successful approaches must be interdisciplinary, incorporating hardware (new stoves) and addressing "software" (cultural attitudes to stoves) [8]. Significantly, larger structural factors that impact people's behaviors around stove use–such as scarcity, choice, or precarity–must be considered in any examination or intervention [7, 9].

The unequal distribution of household air pollution exposure makes this an intersectional issue [27], specifically around gender, age, class, ethnicity, and space. Like other scholars [26], we focus on how the intersection of these factors shapes behaviors and decisions, as well as increasing people's vulnerabilities and risks. Intersectionality was proposed as a heuristic to address the "vexed dynamics of difference and the solidarities of sameness," ([28], p.787) wherein approaches that only focused on individual factors limited understanding of the complexities of synergistic interactions. We argue that an

intersectional approach is clearly needed in examining women's use of ICS, as it's only possible to understand their behaviors and choices within the larger complex of their lives and the broader structures that give shape to their decisions. When women are disempowered and disenfranchised, their development (and that of broader economic structures) is affected [29, 30]. When women are considered fundamental to the process of development, and their productive (not just reproductive) contribution to a nation state is emphasized, their economic status increases [31]. Women who are actively involved in decision-making at the household level have been shown to positively impact their health [32]. While there has been much debate about what are actual indicators of gender-based (in)equality, we are drawn to Desai et al.'s argument [33] that one should sidestep seemingly objective measures of equality (e.g., educational attainment, health status) and instead focus on how women themselves define and explain their choices and, we would add, their lives.

Civil Society Organizations (CSOs) can promote inclusive government through transparency, participation, accountability, and greater equity for participants [34, 35]. Some of the empowerment-focused CSOs can serve as brokers between marginalized populations and broader networks, helping to address issues with patriarchy and gender equity [36]. However, some research shows that, while CSOs encourage engagement and participation, sometimes people's behaviors may take the form of compliance rather than true participation and empowerment [34] or where CSOs themselves are pressured by broader forces to use simplified narratives about gender empowerment [37]. In Mexico, civil society has persisted (albeit with mixed results) even within the complexity of state-level issues with violence, narcotraffic, and corruption [38].

1.2 Mexican health system context

The Mexican healthcare system has been described as fragmented (divisions between different systems regarding forms of care, organizational models, funding, etc.) and segmented (separation of populations based on their position within the labor market), which makes coverage problematic and unequally distributed [39, 40]. Mexico's health expenditure is 5.72% of its GDP; hence, its resources for providing health to its population are stretched thin [41]. Its healthcare system consists of public and private forms of care and attention, divided across various systems that operate in parallel. It is segmented into employment-based social insurance and publicly funded services for the uninsured, collectively covering over 90% of the population through federal and state support. A small minority relies on private insurance or pays out of pocket. This structural division reflects deep inequalities in access and quality of care[42].

Mexico's pursuit of universal healthcare has faced major setbacks due to inconsistent policy implementation and frequent structural reforms. These abrupt policy shifts over the past few decades have created instability, widened gaps in healthcare coverage, and deepened inequities in access to competent and effective care, particularly affecting rural and Indigenous populations [40]. This issue underscores the urgent need for sustainable, inclusive health strategies that prioritize continuity and protection for vulnerable populations.

In Mexico, 19.4% of the population identifies as Indigenous [43]. Most Indigenous communities live in structures where they are unable to autonomously determine their own health [44]. They face existing challenges in multiple dimensions: poverty and social

deprivation; limited access to education, healthcare services, social security, adequate housing, and essential services; lack of adequate water and sanitation; deforestation; climate change; and pollution [45, 46]. These may be understood as a social determination of health [47], including historical factors, political climate, and socioeconomic contexts. Inequities in social determinants are influenced by intermediate determinants: government programs and policies on healthcare, education, and justice; these are products of cultural wounds resulting from colonialism and modern-day structural violence. These wounds have far-reaching impacts beyond individuals, affecting entire communities and ways of life. Latin American critical epidemiology critiques conventional public health for its failure to address these systemic forces [47]. Such historical and modern-day contexts are recognized as crucial underlying factors contributing to the high rates of illness, disease, and mortality among Indigenous populations [48]. Indigenous women often experience discrimination, racialization, and structural violence to greater degrees than men, existing in a triple intersectional oppression: gendered (women in a patriarchal world), classist (impoverished, belonging to the exploited class), and ethnic (belonging to an ethnic minority) [49]. Despite these challenges, some Indigenous women are agentively addressing their circumstances and creating cooperatives to continue their empowerment [50, 51].

When health emergencies (e.g., the COVID-19 pandemic) arise, they amplify Indigenous people's risks due to existing structural issues [52, 53]. Government responses during the pandemic were reactive and inadequate, ultimately failing to address the socioeconomic context and inequities experienced by these communities [54, 55]. Research shows that CSOs played a vital part in alleviating some of the strain of the pandemic across several Low- and Middle-Income Countries [56]. Populations that rely on biomass stoves tend to have worse respiratory health, placing them at greater risk of severe complications if infected by a virus such as SARS-CoV-2 [55, 56]. This virus causes death by comorbidity and places greater pressure on inadequate health systems [57]. Thus, we argue that an intersectional approach that focuses on gendered exposure to smoke, on greater vulnerability because of economic or ethnic precarity, and on the effects of a strained and inadequate medical system can help to explain why Indigenous women might be at greater risk of morbidity or mortality from respiratory diseases.

1.3 Research questions

Our research questions for this research were: What are the perceived and observed health, economic, and cultural impacts of ICS use and adoption among women engaged in traditional cooking and dyeing practices? How do CSOs modulate the community's health needs based on social cohesion and female empowerment? To address these questions, we engaged in the following aims:

1. Understand how ICS interventions influence the economic, social, and cultural empowerment of Indigenous women in rural communities.
2. Identify and interpret the perceived barriers and facilitators to the adoption and sustained use of ICS, as experienced and articulated by women.
3. Understand the role of CSOs in mediating community health needs by fostering social cohesion and promoting gender-sensitive empowerment strategies, using thematic analysis of community narratives.

4. Generate contextualized, community-informed insights on how CSO-led initiatives contribute to health equity and the realization of women's right to health in structurally marginalized settings.

2 Methods

The involvement of CSOs in the Hueyapan community, such as Yoltli and Saber para la Vida A.C., enabled collaborative work in the design and implementation of participatory methodologies for women's empowerment and the development of social economy models. The project took place over three phases with different members of the team, described below.

2.1 Study location

The research took place in Hueyapan (population 13,080), located in the highlands of the state of Puebla, in central Mexico. About 79% of the population speaks an Indigenous language (primarily Nahuatl) [58]. Just over 52% are women [58] who, for generations, have engaged in embroidery and natural dyeing of wool textiles. The iconic shawls, *tomicotones* (ancestral coats), and other traditional clothing have characterized the broader region. The production and sale of handcrafts represent one of the artisans' principal activities and are an important component of their income.

2.2 Phase 1 (2019–2021): community-based implementation

This phase was carried out by the local CSO (Yoltli A.C.), in collaboration with the Iberoamerican University (UIA), under the leadership of Professor Morán (co-founder of Yoltli and UIA faculty member). Morán is an applied social anthropologist who has worked with these rural and Indigenous communities and performed participatory methods in fieldwork projects for at least two decades. She teaches participatory methodologies and collects qualitative data for UIA-Puebla's Social Service Program, which works closely with CSO Yoltli.

This phase focused on the co-development and implementation of improved cookstoves through five participatory workshops with 16 Indigenous women artisans affiliated with a local artisan´s organization (Matekit Hueyapan) to create awareness regarding health, economy, gender, and environment. Members have long engaged in a series of organizational/formative processes run by local, governmental, civil society, and transnational organizations (e.g., Oxfam) on topics such as gender equity, Indigenous rights, economic entrepreneurship, and, most recently, designing and building ICS, where women learned to perform traditionally male tasks (cement mixing or brick-laying) (Appendix 3). Workshops included participatory diagnosis, co-designing improved dyeing stoves, collective construction and adjustments of prototypes, finishes, tile placement, stove functioning, care, and maintenance (Table 1). Workshops occurred before, during, and after the ICS construction.

ICSs were constructed collaboratively to improve the production process of dyeing (3–6 h over fire) and reduce women's smoke exposure. Women designed the ICS to their own specifications and needs: location in their kitchen, height, number of openings for pots, and aesthetics (e.g., tiles, design). Although 16 ICS were implemented, two artisans were not interested in participating in interviews. Due to the COVID-19 pandemic, community activities were paused during parts of this period.

Table 1 Workshops imparted by the CSOs Yoltli A.C. and Saber Para La Vida, A.C

Workshop name	Objective	Results
Participatory diagnosis and design of improved natural dyes	Identify and establish the essential components necessary for the design and self-construction of an ICS specifically customized for natural dyes	Sixteen artisans attended and identified the health, economic, and gender problems of using traditional open-fire stoves for cooking and dyeing. Ideas, specific necessities, and drawings of the ideal ICS
Tests and adjustments of ICS for natural dyes	Evaluate the improved ICS prototype's performance in elaborating natural dyes, engaging in discussions to determine whether any modifications are needed for optimal functionality	After an intermediate session to revise the digital design made after their ideas, the prototype was built and tested with all the participants to determine the necessary adjustments
Construct the improved ICS for the elaboration of natural dyes	Co-develop and co-design ICS and develop construction skills	The initial two stoves were constructed with the active participation of family members, notably husbands, aimed at imparting skills in using construction tools and materials, empowering them to independently build their own stoves with or without assistance from a construction worker, resulting in a total of 16 stoves being built
Finishes and tile placement for the ICS	Enhance participants' skills in tile placement for the decorative elements and finishes of the ICS, ensuring both aesthetic appeal and ease of cleaning	Participants learned how to cut and place tiles in their new stoves. Participants designed and finished each of the 16 new ICSs to their own aesthetic preferences
Functioning, care, and maintenance of the ICS	Learn how to use, clean, care for, and maintain the ICS	Participants learned about their new ICS Tips were shared on how to light the stove faster and how often to clean the chimney

2.3 Phase 2 (2022–2023): data collection by CSO

The local CSO Yoltli wanted to understand how ICSs shape participants' everyday lives. To assess the impact of the intervention, a qualitative study was conducted through co-designed semi-structured interviews with 14 of the 16 female members of Matekit. Interviews explored women's experiences, perceptions of the cookstoves, and how the intervention influenced personal and family dynamics (Appendix 1). Data collection took place between July and August 2022. The 14 participants created a collaborative calendar listing their availability to meet for a semi-structured interview, selecting the type of activity they would engage in (demonstration of their work or their routine for collecting wood, water, or materials for natural dyes). Interviews were audio-recorded by Santa María and Morán; the women's kitchens and labor (domestic, handicrafts) were photographed; and rough sketches of kitchens, stove locations, and houses were drawn to understand participants' use of domestic space. Interviews addressed participants' experiences and perceptions of family interactions, ICS, kitchens, and other working spaces to understand their relationship with their social, built, and natural environment.

2.4 Phase 3 (2024): secondary data analysis

Secondary analysis was conducted between July and October 2024 at the University of Notre Dame (UND) using de-identified interview transcripts. The analysis team (led by García-Martínez and Smith-Oka) accessed the de-identified secondary data on July 10 2024. Descriptive statistics were performed by García-Martínez on the quantitative data. Smith-Oka, Horwitz, and Bucci analyzed the transcriptions for recurring themes through iterative inductive and deductive coding using standard methods in qualitative data analysis. We identified salient themes and quotes that carried meaning about

participants' perspectives [59]. Four primary deductive codes were generated from the interview guide (Environment, Gender, Health, and Stove Use); from these we generated sub-themes (e.g., wood provision/consumption, water usage; gender parity, identity, roles, empowerment, smoke inhalation, eye irritation, back and body pain; stove usage: cooking, dyeing). The main 17 codes generated were organized into a codebook. Each de-identified interview was copied into a shared document, and the analysis team members individually read the transcripts and coded for each code. We created a document for each code, copying the identified quotes. Through cutting and sorting [59], we identified core components for each code and identified which quotes best represented the code. Because of this collaborative process, there was significant agreement between the coders about the meaning of each code. All procedures complied with ethical standards and ensured participant confidentiality.

2.5 Ethics and consent process

During an assembly with the 16 members of Matekit, Morán presented the project. Fourteen women voluntarily agreed to participate, scheduling home visits for data collection. Verbal informed consent was obtained at that time, including permission for audio recordings and photographs to document the stoves. To ensure ethical rigor, verbal consent was reaffirmed during each home visit, respecting participants' autonomy and ensuring their continued voluntary participation in the research.

The study did not require further data collection or pose any inconvenience to participants. Ethical review and data protection protocols for this project adhered to UND's institutional guidelines. We submitted a protocol for secondary data analysis (Protocol ID: 24-06-8642) to UND's Institutional Review Board in July 2024. Because these were secondary, de-identified data, the IRB determined that the protocol did not meet the definition of research with human subjects. The analysis team could not identify individual participants during data analysis; thus, the project could proceed without further review from that office.

3 Results

3.1 Quantitative results

All participants were women; no men were included in the study. The 14 interview participants were not demographically homogeneous. The majority were in their 40 s, ranging from 28 to 67 years of age. Nine out of 14 reported being in a relationship (married or common law); 11 out of 14 completed secondary school; and just over half (8 women) received money from national social security and welfare programs (e.g., Becas Benito Juárez, which provide grants for education, or Pensión del Bienestar para Adultos Mayores, which provides money for elderly populations) (Appendix 4). What was interesting, given Mexico's high out-migration rate, is that only one of the participants received remittances from relatives in the United States. Half the participants reported respiratory diseases and 4 of them mentioned eye problems in themselves or at least one member of their families. They also reported using ICS and a combination of gas and open-fire (Table 2).

When the interviews occurred, the women had been using the ICS for only a few months. Nonetheless, participants were already noting the positive effects on their health and gendered labor. We tracked participants' uptake of the ICS stoves and how

Table 2 Descriptive characteristics of the 14 women interviewed

Variable name	N
Married/partnered status	
No	5
Yes	9
Educational level	
Primary	2
Secondary	9
High school	3
Received money from social security programs*	
No	6
Yes	8
Financial support from US migrants	
No	13
Yes	1
Experienced respiratory illness**	
No	7
Yes	7
Experienced eye illness**	
No	10
Yes	4
Participative role in the cooperative***	
No	3
Yes	11
Use of ICS	
No	2
Yes	12
Use of gas stoves	
No	4
Yes	10
Use of open-fire	
No	3
Yes	11
Wood purchase	
No	2
Yes	12

*Becas Benito Juárez and Adultos Mayores Programs were included

**Respiratory & eye illnesses were reported in at least one person in the family exposed to open firewood used

***Social, cultural, and economic participatory roles through the Cooperative Matekit and other institutions

Table 3 Combined use of ICS according to the type of stove

Types of stoves	Gas		Open-fire	
ICS	No (n = 4)	Yes (n = 10)	No (n = 3)	Yes (n = 11)
No (n = 2)	0	2	0	2
Yes (n = 12)	4	8	3	9

they might have continued to combine the use of these new stoves with other forms of fuel. Significantly, two months after the ICS implementation, all but two participants were using the ICSs for either cooking food and/or dyeing wool. However, the use of other forms of fuel continued, with 9 participants reporting the combined use of ICS and open-fire stoves, while 6 reported the simultaneous use of open-fire, gas, and ICS (Table 3).

The interview results showed several aspects that the participating women were concerned with: (1) an understanding of the structural and social determinants shaping their access to quality medical care, (2) an increased determination of their health literacy regarding the effect of open-fire stoves on their and their family's respiratory health, and (3) a development of language and attitudes around their sense of gendered equity and empowerment. We address these below.

3.2 Structural and social determinants of access to quality health care

Participants voiced concerns about accessing quality health care. Several stated that local clinics lacked doctors and that most providers were trainees. Medical school in Mexico expects its graduates to spend their last year working in an underserved region of the country. Thus, most small, rural clinics are staffed by medical students. One participant stated, "*There are doctors here, but the ones they send to [our clinic] are trainees, the ones who will almost get their license or are going to graduate*." However, the participant stated that, despite being trainees, "*they attend to us well*." Another participant said that they did not have enough doctors, "*Here there is one attending doctor, and the rest are trainees. So if […] one needs health [care], one needs greater attention, then you go to larger towns in the region*." Because these populations are rural, and they are not within the formal labor market, their healthcare is covered by the Ministry of Health.

This issue of lack of providers per capita is a concern nationwide, as many remote villages lack clinics or people to staff them [60], "*They're just starting to get [doctors at the clinic], as before we had no one*." One participant stated that if they went to the clinic for a consultation, "*you have to wait all day because there are not many doctors; there's only one or two doctors. So you have to wait there all day for a consultation*." Another participant added, "*Here the issue is that one has to go before the sun rises to line up to get a number. Because, well, I always go at quarter to eight to line up for my number. And I get numbers 20, 20, 24, 25, depending on how many people are there for a consultation*."

What most participants agreed upon was that they only received basic care at the local clinic. If "*it is serious or something*" they would go to larger towns about 40 min away or even further if the issue was more severe. If their care necessitated laboratory or other tests, they had to travel further. They also likely had to pay out of pocket, "*When I am seriously ill with something, and they ask me for tests, and I have to go to the laboratory. So that one we do have to pay for [in the larger town]*." However, even when they could travel to a larger hospital, because of the underfunded medical system, they were faced with overcrowded hospitals and a possible lack of care. One participant stated that doctors at the local clinic "*give us the referral, and we have to go to the hospital [in the larger towns]. But then they're also full, and there are no beds. We have family members who have had this happen*." Participants stated that they sometimes would go to a private doctor instead of public care as an alternative healthcare-seeking pathway, "*Sometimes when the situation is very, very difficult, well it's better to go to a private doctor; even if one's savings are finished […] I always have in mind that health is the primary thing*." Each of these options had different costs, with public care usually being less. Only one participant stated that they preferred private care because "*they charge really cheaply*."

Concerns with the cost of medical care were at the forefront of participants' narratives, "*Sometimes it's cheaper to buy a kilo of tortillas than a box of medications. The kilo*

of tortillas is about 20 pesos and that gives you food for the whole day. And the box of medicines is 500 or 600 pesos, and your pains continue."

3.3 Health literacy regarding the effect of stoves on respiratory health

Participants recognized the link between open-fire stoves and respiratory diseases, primarily experiencing immediate symptoms (coughing/eye irritation). However, only some participants connected the smoke with long-term respiratory conditions. It was only through further exploration during interviews that they began to reflect on the potential long-term health effects of the smoke (Fig. 1).

There was no doubt that participants experienced eye irritation. It was usually their first response when asked about the effect of the open-fire stoves on their health, "*My eyes would water because of the smoke.*" One participant described, "*Because we have seen how, when we go somewhere and they are using the fogón [open-fire stove] we used in the past, [...] it does sometimes hurt you. [...]. It can hurt your eyes, so then you are crying.*" Another immediate concern with smoke was how its smell impregnated clothes and how ICS were beneficial "*because, as we don't inhale the smoke as much as with the traditional [fogón], because all the smoke [would] get in your face or get all over your clothes.*"

Participants described how the design of the ICS reduced these issues, as "*the smoke goes out the chimney.*" A participant said that "*from the moment I light the fogón, I get covered in smoke.*" Another agreed, differentiating between both stoves, whereby with the open-fire stove, the smoke would "*spill everywhere, [and with the new stove] it goes straight up.*" Participants agreed that with the ICS, the smoke "*no longer affects us*" and "*one does not get as covered with [it]*" or "*inhale it as much.*"

Evidence suggests that because many Indigenous households utilized solid-fuel indoor stoves, these populations became more susceptible to contracting COVID-19 [54]. During the COVID-19 pandemic, each artisan received individual and collective health kits

Fig. 1 ICS and traditional open fire stove

to maintain international recommendations of hygiene and distance. Curiously, one participant made the argument that she was protected from COVID-19 precisely because she used the open-fire stove, "*I tell you that I thought [the smoke] prevented me from catching COVID. […]. I disinfected myself with the smoke. […]. I think the [smoke] must be a disinfectant because […] I always used firewood*."

While most participants focused on acute concerns with smoke—such as eye irritation or smoke-smelling clothes—when we probed deeper during interviews, some acknowledged that they also experienced coughs and other respiratory illnesses. One participant described it as nothing too serious, "*So much smoke can cause you to have a bit of a cough, but that's it*." Others delved into their or their female relative's respiratory issues, "*I always say that it must have been because of the smoke, right? My mother […] suffered for a time with a bit of cough; it was not a dry cough, and it lasted a while*." Another participant said that her mother "*was forbidden from cooking on this fogón because for years there she was [cooking], and it really damaged her. Not just her lungs but her eyes. Because of this, we decided to buy a gas grill so she could […] cook*."

The workshops impacted by the CSOs played an important part in giving the women the confidence to increase their health literacy. They helped them to feel more secure in medical settings. Thus, when doctors would tell the women about their health, the women were able to identify the connection between stoves and respiratory health, "T*he doctors have told us that […] it's actually very bad [to] inhale the smoke*." The increased health literacy was evident in how participants used biomedical terms (such as "asthma," "lungs," "bronchioles," and "x-rays") to describe their respiratory health. One woman said, clearly connecting the stoves to her bodily experiences "*[The smoke causes] long-term [cough], which is why you can see that I am coughing. There were more [respiratory problems] before because the stove was lower [on the ground]. So it hurt us a lot; our lungs got full of smoke*." One participant drew on language around medical technology to share that the doctors "*will one day ask me to get x-rays of my bronchial [tubes]*." Another described, using medical language, "*I've been for some time very, I call it asthmatic: my chest would be sore*." Interestingly, this same participant was unsure what the cause of the asthma was. She drew from ethnomedical terms to explain her illness, "*one doesn't really know; the [weather] here is very changeable; sometimes it is a bit hot, or it rains, [or] it's cold. So you don't know why you fall sick*."

3.4 Gender equity and female empowerment

Interventions involving ICS, coupled with community participation, serve to empower traditionally female domains by interconnecting CSOs with family and community outreach activities (Fig. 2). This shift allows for the integration of stove utilization into gendered labor (e.g., dyeing wool, creating traditional textiles for sale/export). It shifted the traditional female labor of embroidery/textiles from one that took place "*during my free time*" to one that contributed significantly to the family's income. This shift was described as, "*We were beneficiaries of the ICS, which, in some way, were focused for us to support each other for dyeing; also for things like preparing our food*." This approach operates within a socioeconomic model rooted in culture and fosters social and economic cohesion through the establishment of an Indigenous women's cooperative, which, as one participant stated, "*got us out of our comfort zone*."

Fig. 2 Woman using the ICS, note the tiled design and location of cookware

Participants mentioned several domains where they felt an increase in their empowerment, such as handling electronic technology ("*I never imagined that I will use a cellular, take a photo, communicate through WhatsApp, send a photo*."); tracking sales ("*they taught us to be producers, […] being like a company […] calculate statistics [of] how much you sold each month [and] identify which products sell more so you can make more*"); and performing more traditional male labor ("*we learned to make the [cement] mixture, […] how to cut the tiles, to handle the tools that are used to cut it*."). The use of gendered and empowered language gained from the workshops was evident, "*I think that one of the benefits we get is learning […] different things like where to search for markets … learning to sell our products, to calculate the cost of production, and in a way how to also diversify the products and materials*." This language was echoed by other participants who stated that because of the empowerment workshops, they could now calculate the value of their labor and sell their products accordingly, "*After just one workshop we were encouraged to think a lot [about] where money goes, where money comes in, and from where?*".

Empowerment also revolved around their Indigenous identity. One participant poignantly connected women's gendered labor and Indigenous identity to how buyers would question the price of their products whereby the buyers would undercut the value and labor the women put into their artisanal products, "*If you knew the background to these garments, all its process, its history, you would pay double, triple. Because I am giving you a little piece of a history […] of an Indigenous community*." She added that buyers may find a sweater in a department store, "*but mine has a history, the embroidery, and the dyeing protect the environment and, besides that, it can financially support a family*." However, one participant contrasted this empowerment with the reality of ethnic marginalization, reinforcing the fact that even though they were locally empowered, larger disenfranchising structures remained, "*It's still a rural zone, an Indigenous zone and such; but we try to keep learning […] new things*."

Evidence of successful CSO empowerment interventions showed that it is possible for men to engage in household tasks while still maintaining the belief that domestic labor ultimately falls under the woman's responsibility, "*My husband also helps out sometimes; when we've very busy he says, 'I will make the food.' If it's clothes washing, then we work on it together*." Another participant stated that "*we sometimes help each other. Sometimes he cleans, I wash the dishes, [and] he sweeps*." Another added, "*My husband [and I…] go down to where my mother [lives] and between all of us we help each other because we have to make skeins (of yarn), because we have to set (the dye)*." This suggests that behavior changes can occur within couples, even among the majority of couples in a community, without corresponding shifts in individual beliefs or broader societal norms regarding gender roles or male authority.

A significant outcome of this CSO intervention was the increased sense of solidarity among participants, which one participant defined as a "*fellowship*" that helped one another. This perception was echoed by other participants who used phrases such as "*we have coexisted among each other; we have learned from each other*" or "*we share among ourselves*." While all groups come with frictions, these were primarily seen as generative of greater understanding, such as one participant who likened the groups to a family: "*with some you get along well. […] There you learn what their attitudes are; […] one is grouchy, one is very strict, one is fickle, one is less precise. […] But there you start to come together as if you were a family*." This sense of a fellowship or family was articulated by some participants who discussed intergenerational support as a form of generalized reciprocity, where they could support older women, knowing that someday they might be recipients of similar support, "*We also support people who are older, of greater age; we sometimes think to ourselves that one day I will get to be that age*." One participant stated that they must work together, "*Because you can't as an individual*." She added that solidarity meant accommodating different forms of literacy, "*Even if many [women] can't write, they understand and know how to keep many things in their head. And that's the advantage: that while we are always united like this, [we move] forward*."

With the potential for individuals, regardless of gender, to challenge societal expectations and contribute to reducing gender inequalities, it becomes crucial to address dynamics between changes in beliefs, behaviors, and norms. This shift was captured by one participant who described how their empowerment was interpreted by others as a "*rebellious group of women who don't want to obey*."

4 Discussion

Our intersectional analysis of the engagement of Indigenous women in Hueyapan, Mexico participating in a community-based project has significant implications for scholarship addressing the role and impact of CSOs on women's use of improved cookstoves and the effects on their empowerment and health literacy, as well as significant downstream environmental effects.

Firstly, the role of community-based research methods meant that participants were not simply recipients of one-size-fits-all ICS, but were central to their individual design, implementation, and usage. This process empowered them. Through their participation in the workshops imparted by the CSOs they strengthened social and economic networks that allowed them to access different perspectives on gender, reduce inequities, and increase empowerment. We extend scholarship on the role of CSOs [36, 38] to argue

that these can function as mechanisms to increase solidarity, reciprocity, and social support. That is, the women's participation in the civil society organization created solidarity, unity, and helped them to feel they were not alone. Their participation as "rebellious women" and as partners as they designed and built their own stoves–and subsequently became experts on ICS construction–meant that they could speak comfortably and agentively about them, potentially teaching others in their community about these stoves and their benefits. Like scholars concerned with critical epidemiology [44], our work is rooted in community knowledge, participatory methods, and a commitment to equity, sustainability, and justice. Our work aligns with other cases worldwide to illustrate how centering community knowledge and agency (particularly of Indigenous women) both enhances the effectiveness and adoption of health technologies like ICS and fosters long-term social transformation. By bridging local empowerment with global development goals, these community-based, gender-sensitive interventions offer a viable pathway toward closing equity gaps and advancing sustainable, justice-driven solutions in rural communities [6, 27, 32, 33, 50, 51, 61].

Secondly, as other studies have noted [62, 63], not all people exposed to ICS necessarily use them. Our data provide a more comprehensive understanding of the intersecting factors of ecology, gender, empowerment, and health to provide avenues to address people's potential resistance to eliminating open-fire stoves as part of gendered labor. In particular, our participatory methodology frames the process of stove design and usage as a conversation between local actors, practitioners, and scholars, where local actors have the agency to determine whether they want the stove, how they will design it, and how they will use it. This participatory empowerment creates the space for dialogue and can address hesitations, limitations, and concerns before the stoves are even designed. It can thus be used as a model for other projects to improve the uptake and usage of ICS. Indeed, greater attention must be paid to people's critical right to health [64], through attending to ethical foundations of sustainability, sovereignty and liberation, solidarity, and security [44].

As is well known, there are unmitigatedly negative health impacts of smoke from open-fire stoves. It is important to take into account how these types of stoves have historically been used for culturally significant activities (e.g., food preparation, textile dyeing) and not dismiss them outright. Our work provides an integrated analysis of the connection between gender empowerment and health literacy. As the participants' words show, the use of improved cookstoves reduces their household air pollution; our work contributes to prior research that connects ICSs with the promotion of economic productivity and mitigation of environmental degradation [65] as well as those that reveal that ICS effectively reduced carbon emissions while improving women's and children's health outcomes by minimizing risks associated with biomass smoke [66]. Our intersectional approach pays attention to the wider forces shaping decisions as well as the downstream effects of changing behaviors. Transitioning to clean energy sources poses a challenge in rural and Indigenous areas due to issues with supply, demand, and unsustainable logging practices.

Thirdly, while our analysis in this article focused primarily on empowerment, there are important downstream effects of the impact of CSOs on participants' lives. For instance, some initiatives highlight women's active role in significantly reducing deforestation and greenhouse gas emissions [7, 12, 20]. In those initiatives, female participants were

involved in a variety of workshops (business management, tree nursery establishment, afforestation), which resulted in increasing their average household income tenfold [20, 66, 67]. We argue that one of the strengths of CSOs–such as Yoltli and Saber Para La Vida–is that they engage participants in a plethora of activities (i.e., gender equity, Indigenous rights, economic entrepreneurship, designing and building ICS), which have a positive effect on participants' lives, specifically through the process of accompaniment and broadening their social networks [68].

Finally, a synergistic positive externality is the increased health literacy among participants shaped by the emergent property of accompaniment. That is, though the CSO had the goal of empowering the women around economic literacy and stove design, it also seemed to have the effect of increasing their health literacy. Increased literacy, whether reading, digital, health, or other forms, helps local actors to become more confident and increase their capacity in various spheres [69]. Health literacy, specifically, is situational, multimodal, and co-produced in social relations; it is used across the globe to assess the effectiveness of interventions, especially for marginalized populations [70–73]. It is defined as the way that populations understand, respond to, and act upon health information [74]. As we showed in the results, most participants understood the link between the stoves and immediate health effects (eye irritation); however, only some participants made the connection between the stoves and their long-term effects on health, though they were starting to make that connection, aided by their increased confidence in themselves. As has been shown by other scholars working among Indigenous communities in Mexico, women in these communities tend to have lower health literacy, awareness of health problems, or empowerment to be advocates for their own and their family's interactions with healthcare structures [46]. Indeed, women's concerns and suffering are often silenced or ignored; that is, the women don't notice or pay much attention to their health concerns because these are caused by their gendered domestic labor (cooking, cleaning) [9]. The CSO workshops gave them the voice to talk about their health and their labor as interconnected. We argue that the CSO in this project acted as a community-based knowledge broker, improving the abilities of the women to advocate for themselves in markets but also to understand more about their own health, the connection between their stoves and their immediate respiratory health, and be able to be more agentive in their interactions with healthcare professionals the medical spaces.

4.1 Limitations and future scope of research

This study has some limitations. The sample consisted exclusively of women who were active participants in CSOs, who were selected through purposeful sampling. Thus, its conclusions cannot be extended to all women residing in Hueyapan or to other communities. While the insights gained are rich, a broader study with a representative sample would be necessary to understand the wider impact of these interventions. Additionally, because the data collection took place only two months after ICS implementation, it was not possible to analyze how sustainable this shift to a different fuel source is. One final limitation is that data collection and analysis were conducted by different members of the research team, which may have introduced some variation in interpretation. However, this process also allowed for a broader perspective in analyzing the findings.

However, it is important to acknowledge a unique contextual factor that challenges the conventional framing of limitations: the presence of these local CSOs in Hueyapan has

spanned more than two decades. Their sustained engagement has fundamentally transformed community life through participatory methods and the development of social economy models tailored to the needs of Indigenous women. These longstanding relationships and co-created processes have produced multidimensional, context-specific outcomes that are not easily replicable in other settings.

Future directions for the research should address the permanence of the stove use and whether women continue to use them as they originally intended. Any new factors that have impacted their behavior around stove use and adoption should be identified. Additionally, it would be important to follow up with the participants to see how far their health literacy has come (or has changed) since the data were collected. Finally, future publications will include the participants as co-authors to continue disrupting knowledge creation.

5 Conclusion

Our research exemplifies the process of "doing" intersectionality and its translation into practice [75], where the promotion of women's rights to health and gender equity by CSOs can occur through social cohesion, cultural empowerment, and technological innovation. Sometimes large-scale interventions don't succeed completely, as they might miss some of the on-the-ground concerns and realities. Here we provide an example of a small-scale effort that does succeed, supported by rich, in-depth qualitative data. This project is significant as it emerges from collaborative participatory methods with participants from within the community rather than being designed and implemented by outsiders. We provide needed data on the effect of gender equity and empowerment among rural Indigenous women in Mexico exposed to ICS interventions. The embeddedness of the CSOs in the local community highlights both the strength and the specificity of the intervention. While the model cannot be simply exported, it offers valuable insights into how sustained, community-led CSO involvement can generate lasting change and foster empowerment. The impact of this intervention extended beyond the original goals of the CSO. Participants seemed to feel increasingly empowered to advocate for themselves in medical spaces, value the worth of their labor, understand women's rights, be assertive about their abilities, and seek out new skills and experiences.

Understanding why certain aspects of empowerment interventions are more susceptible to change and identifying the contextual factors and interventions that effectively influence these processes become essential. Additionally, policy and legal reforms that have enabled women's workforce participation and questioned traditional male breadwinner roles have already led to shifts in behaviors and societal expectations [76]. Our study highlights the importance of gender-sensitive intervention strategies. We argue that CSOs can play a crucial role in facilitating participatory methodologies involving men and families in community dynamics, ultimately empowering women. CSOs can have a significant and potentially transformational role in facilitating the co-design, implementation, and support of improved cookstoves to promote health equity and gendered empowerment. Targeted interventions by CSOs for vulnerable individuals or groups can be more effective in promoting the use and adoption of ICS compared to community-wide initiatives. We thus present CSOs as a positive example of initiatives that can work towards breaking gender inequities in vulnerable contexts.

A final conclusion is that one must take into account the broader structural factors impacting people's lives. Limited access to social security programs constrains Indigenous women's health decisions. Cooking and dyeing practices expose them to smoke for long periods, affecting their eyes and respiratory system. As other scholars, especially those within the Latin American social and collective medicine group, have argued, concepts of health and medicine have to be reconceptualized for greater justice [44, 47, 64, 77]. Because there is a lack of quality access to primary healthcare across Mexico, particularly for Indigenous populations, families face financial burdens due to deficiencies in the fragmented healthcare system. There is a dire need for universal coverage and improved social health programs to address these issues and uphold the right to health. We argue that the Mexican government needs to find mechanisms to facilitate quality health access at the primary level of attention in Indigenous communities, incorporating community leaders, CSOs, stakeholders, and institutions to create a sustainable health program. Ultimately, this process would integrate technological tools with local cultural practices to enhance women's health and reduce inequities. It is important to recognize the importance of CSOs in strengthening Mexico's primary health system. These communities face high exposure to health risks like smoke from traditional cooking, yet low health literacy delays care-seeking until conditions become chronic. However, Indigenous communities must be the protagonists in any of these conversations. CSOs can bridge this gap by designing culturally appropriate interventions that improve risk perception and early engagement with healthcare and where Indigenous people play a key role in determining their future. CSOs' integration into national health strategies, such as in the current IMSS-Bienestar program, is crucial to advancing universal coverage and reducing health inequities.

Abbreviations

A.C.	Asociación Civil (Nonprofit Organization)
COVID-19	Coronavirus disease
CSO	Civil Society Organization
GDP	Gross Domestic Product
ICS	Improved cookstoves
IRB	Institutional Review Board
SARS-CoV-2	The causative agent of COVID-19
UIA	The Iberoamerican University
UND	The University of Notre Dame
45 CFR 46.102	Code of Federal Regulation of the U.S. Department of Health and Human Services, for the protection of human subjects in research

Supplementary Information

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Supplementary Material 1: Appendix 1. Interview Guide.

Supplementary Material 2: Appendix 2. Analytic Codes and Illustrative Quotes.

Supplementary Material 3: Appendix 3. Improved Cookstoves Project Timeline.

Supplementary Material 4: Appendix 4. Quantitative Data.

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Author contributions
Conceptualization: AGM, GM, and VSO Interviews: RSM and GM performed the interviews and data collection. Data curation: VSO Formal analysis: AGM handled the quantitative data analysis and creation of tables. VSO, EH, and KB handled the qualitative analysis and identification of key quotes. Resources: AGM and GM Supervision: AGM, GM, and VSO Writing—original draft: VSO and AGM wrote the majority of the draft, supported by input from GM, RSM, EH, and KB. Writing—revisions: VSO and AGM.

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Data availability
The dataset supporting the conclusions of this article is included within the article (and its additional file).

Declarations

Ethics approval and consent to participate
The study adhered to the Declaration of Helsinki. The University of Notre Dame reviewed the protocol for secondary data analysis (Protocol ID: 24–06-8642). Because these are secondary, de-identified data, the IRB determined that the protocol did not meet the definition of research with human subjects set forth in Federal Regulations at 45 CFR 46.102. Thus, the project could proceed without further review from that office. Fourteen women voluntarily agreed to participate, scheduling home visits for data collection. Verbal informed consent was obtained at that time, including permission for audio recordings and photographs. To ensure ethical rigor, verbal consent was reaffirmed during each home visit, respecting participants' autonomy and ensuring their continued voluntary participation in the research.

Consent for publication
Because these are secondary, de-identified data, the authors could not identify individual participants during data analysis so no consent was required.

Competing interests
The authors declare no competing interests.

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