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Understanding community engagement from practice: a phenomenographic approach to engineering projects

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Introduction: Engineering professors involved in community projects strive to enhance engagement through a combination of social sciences and engineering methodologies. Recognizing the growing importance of critical methodologies, particularly those rooted in social justice and community design, researchers have explored their impact on fostering meaningful collaborations between engineers, students, and community partners.

Methods: This study employs a phenomenographic approach to explore how a cohort of engineering professors, students, and community members conceptualize their participation in community-engaged practices.

Results: Our findings reveal a nuanced outcome space comprising five distinct ways in which individuals perceive their community engagement: as interdisciplinary endeavors, addressing community issues, engaging in co-design, and addressing systemic barriers. These conceptual frameworks elucidate a progression in the depth of engineers' involvement with the community, underscoring the significance of systems literacy and social justice in more intricate contexts.

Discussion: These results advocate for engineers to adopt an active membership approach, emphasizing collaboration, when working on engineering projects within communities, as opposed to adopting passive roles that may undermine the impact of community engagement.

Conclusion: In conclusion, a deeper understanding of the varied conceptualizations of community engagement among engineering professors, students, and community members underscores the importance of adopting proactive roles and fostering collaborative approaches in community projects.

KEYWORDS

engineering practices, social justice, higher education, community engagement, educational innovation, phenomenography

1 Introduction

In the continuum of history, engineering has consistently played a pivotal role in shaping social and cultural processes, evident in endeavors such as the construction of pyramids, the formation of empires in Europe and Asia, and the era of colonial expansion (Amadei and Wallace, 2009). Evolving perspectives on engineers' work within domains such as oil, food, commerce, infrastructure, and energy companies underscore the dynamic nature of engineering practices, inherently influenced by the social and economic conditions of each territory (Leydens and Lucena, 2014). The narrative of engineering, thus, positions its practitioners at the forefront of humanity's trajectory over ensuing years and centuries (Hersh, 2022; Merchán-Rubiano et al., 2023). Inextricably intertwined with technology and society, engineering reciprocally shapes and is shaped by societal dynamics (Osorio, 2003; Baillie, 2009).

Engineering's historical connection to society manifests through the creation of artifacts and the design of systems. These outcomes emanate from the multifaceted practices wherein engineers manipulate, refine, enhance, or eliminate material, social, and organizational elements globally (Ostrom, 1980; Wright et al., 2017). While engineering serves as an agent for environmental degradation and societal disruption under the influence of social forces, it concurrently harbors transformative potential to dismantle systemic barriers hindering access to the benefits of modernity (Kabo and Baillie, 2009).

Initiatives fostering societal development through engineering trace back to 1968, marked by the seminal work "Silent Spring," which catalyzed movements for sustainable development globally (Gilbert et al., 2015). Subsequently, engineering movements focused on humanitarian action gained momentum, exemplified by initiatives like Engineers Without Borders, first established in France in 1982 (Natero et al., 2010). This trend proliferated to encompass countries like the United States (1992) and Global South nations such as Colombia (2007) (López et al., 2019). These initiatives spurred the establishment of Engineering for Social Justice and Peace, aiming to create equitable and democratic engineering practices (ESJP, 2021), and Humanitarian Engineering, dedicated to enhancing the well-being of marginalized populations (Borys, 2019; Queiroz et al., 2022).

The recent global pandemic has prompted a reevaluation of engineers' roles, compelling a critical examination of their professional practices. Root causes of pandemics, like Covid-19, tied to issues such as deforestation and capitalist societies, underscore the interconnectedness between engineering pursuits and global challenges (Brancalion et al., 2020; Laster Pirtle, 2020). The pandemic's aftermath, characterized by heightened social inequalities, accentuates racial disparities in healthcare access and educational inequities (Abedi et al., 2020; Saavedra, 2020; Smith, 2020; van Dorn et al., 2020; Jung et al., 2021; Salinas-Navarro et al., 2022). In this context, engineering assumes a pivotal role in addressing systemic issues and necessitates a paradigm shift towards responsible and critical action. The article argues for the inclusion of diverse actors in addressing pandemic-induced consequences, emphasizing the imperative for engineers to engage in social and environmental movements.

Community-engaged practices connect what students learn in engineering with real-life problems discussed earlier. Students gain hands-on experience in real communities (Jayasinghe et al., 2013), understanding how engineering impacts society, the environment, and health. Through collaborative projects with community partners, students not only apply their technical skills but also develop effective communication and teamwork abilities (Lloyd et al., 2021). This type of learning helps students become socially responsible and ethical engineers, equipped to address challenges with empathy and innovation. It also encourages lifelong learning and community engagement, empowering students to make positive contributions wherever they go (Amadei, 2019). Thus, integrating community-engaged practices into engineering education enhances learning outcomes and prepares students to make meaningful contributions to society. While theoretical perspectives on "community-engaged practices" abound, an exploration of how engineering professors and students define and implement these practices is notably absent. This article seeks to fill this gap by examining the motivations of engineers and soon to be engineers involved in social and environmental projects within the field of engineering. Despite theoretical conceptualizations, the absence of a singular definition for "community-engaged practices" requires a closer examination of vital aspects from an engineering education standpoint. The article tries to understand how engineering professors, students and community members define their practices in the field and their relationship with the concept of "community engagement" is essential.

In Colombia, community-engaged engineering projects have been underway for approximately two decades, with notable research-led developments blurring the demarcation between engineering and social needs (Ramírez et al., 2011). This study focuses on three projects in Colombia, done by three different universities, dedicated to improving social and environmental conditions in rural areas. Employing phenomenography, the research explores how engineering, practitioners and students reflect on their practices, aiming to provide insights into the collective human experience within the context of engineering practices (Akerlind et al., 2005; Collier-Reed and Ingerman, 2013). Phenomenography in higher education research reflects the approach's focus on how differing conceptualizations of phenomena are situated within and related to a given context (Vandersteen et al., 2009; Jorga et al., 2018). The outcome space, identified through iterative analysis, delineates different conceptualizations of engineering practices, offering a comprehensive understanding of their underlying meanings (Hales and Watkins, 2004; Baillie et al., 2013). Following iterative analysis and re-analysis, researchers aim to identify a logically inclusive structure in their findings, referred to as an outcome space. Furthermore, some categories are related to others (Andretta, 2007).

The subsequent sections of this article detail the methodology employed, emphasizing its significance. Results derived from the implementation of phenomenography illuminate diverse conceptions of engineering practices. The concluding section discusses the utility of these conceptions in addressing socio-environmental conflicts, offering insights into the transformative potential of community-engaged engineering practices.

2 Literature review

2.1 Engineering practice

According to the National Academy of Engineering of the United States of America:

> "The profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind" (ABET, 2018).

Other authors indicate engineers as people "finding the answers to the challenges that confront society" (Try Engineering, 2015), "problem solvers" (Pawley, 2009), and people who "work in almost every area that affect people" (The Royal Academy of Engineering, 2018). In a broad sense, each of these definitions encompasses some of the discourses on which engineering is commonly understood (Pawley, 2009; Stevens et al., 2015). Some of these discourses, widely studied in the last 20 years, include "knowing how to transfer and translate scientific knowledge into practical applications" (Monteiro et al., 2018) and "a desire to help" (Riley, 2008), among others.

Through these possible definitions of engineer and engineering, people from other careers or just pedestrians understand how engineers can create solutions for the people or the environment they develop, understanding the complexity that the systems entail, and using different tools from the branches comprise engineering knowledge. However, based on the literature review and my professional experience, engineering is also a social practice on which the conception, design, implementation, production, and maintenance of complex technological devices, processes, methodologies, models, or systems are pivotal to the engineering process, engineers connect needs with their knowledge for the design and implementation of diverse artifacts. These needs are also associated with society and the environment. The characteristics of each engineer's answers to these needs become their own personal way of doing engineering, their engineering practice. However, the first point we should address is what engineering practice is? Even when several authors have tried to define engineering practice (Trevelyan, 2007; McNeill et al., 2012; Brown and Barner, 2017), the definition used in this document was described by Sheppard, Colby, Macatangay, and Sullivan (Chua, 2018).

The definition presented by Sheppard et al. (2006) study differs from previous definitions of engineering practice. The author complements qualitative work to identify consistencies and errors between the evaluated literature and the conceptions of the engineers' work (Baillie and Walker, 1998). This definition of engineering practice was chosen to integrate knowledge, practical skills, and ethical judgments that have been removed so far from the current practices of engineers and ethics codes in several countries. These authors distinguish between three main visions of engineering practice, which are explored based on divergent perspectives, but only one will be used as a working definition. This analysis reveals some of the engineers' assumptions and lenses, such as several flaws identified during previous years. These visions are (1) engineering as problem-solving, (2) engineering as knowledge, and (3) engineering as the integration of process and knowledge:

- Engineering work in terms of problem-solving: In a very reactive way, the engineer's practice aims to solve undesired situations. This definition relates to engineers' ability to change reality and the processes, systems, and artifacts surrounding them (Jonassen, 2015). However, this engineering perspective has remained anchored in time and has generated some detractors (El-Zein and Hedemann, 2016) since the common good is ignored with this short-term vision. Moreover, Pawley (2009) criticizes that engineers believe they can "pick" problems already constructed, and the solutions to these problems are engineering practices without any relation to society. Finally, this kind of engineering practice tends to "break" the problem into pieces, even when it is proven that a holistic approach always has better problem-solving results (Midgley, 1992b).
- The work of engineering as specialized knowledge: This vision indicates that the engineers in their practice must focus on "knowing that" and "knowing how." This notion has been broadly discussed (Ryle, 1945), emphasizing the relationship between the intelligent application and the principles, rules, and reason employed. Some interesting characteristics about engineering work are that knowledge is put into play, dynamic, and grows as work is done. This view is particularly problematic when we speak in terms of engineering and its social dimension. As Baillie and Catalano (Baillie, 2009) point out, engineering cannot be seen as a process that takes place in a vacuum without any relation to reality. Instead, the relationship between society and knowledge changes over time, as the engineers' responsibility (Baillie, 2006). Besides, there is now a global call to detach ourselves from this general vision and return to the roots of research and knowledge from a more in-depth, philosophical level (Bosch, 2018; Ramírez et al., 2018).
- The engineering work integrates processes and knowledge: This approach to engineering practice emphasizes table three relevant engineering aspects. First, it does not limit engineering knowledge and practice to a single field but allows integrating other disciplines and expertise. Second, it recognizes that engineering solutions are immersed in an intentional process that affects other systems that are complex by nature (Gallegos, 2010). This characteristic also shows tacit knowledge of the engineers, frameworks on which they develop their practice, and previous experience (Ramírez et al., 2012). Finally, this integration allows us to put the social dimensions of engineering practice on the table, hidden behind a technical façade for a long time (Eizenberg and Jabareen, 2017).

Although with multiple applications and examples of problems, such as environmental sustainability, the idea of improvement tied to the chosen engineering practice definition poses critical challenges about what it means to be and do engineering. However, there is limited research that emphasizes how engineering can improve society's living conditions. This research aims to understand engineering practices, their interaction with society, and how these practices can be transformed over time, as Trevelyan (2010) affirmed to transform the engineers' praxis (Lave, 2012).

2.2 Community engaged engineering practices

Community engaged practices involve collaboration between academic institutions, students, educators, and community members to address real-world challenges and create positive social impact. These practices emphasize active engagement with local communities to understand their needs, priorities, and perspectives (Reina-Rozo et al., 2019). By working together, stakeholders co-create solutions that are contextually relevant, culturally sensitive, and sustainable. Community engaged practices encompass a wide range of activities, including service-learning projects, community-based research, participatory design processes, and outreach initiatives (Oguro et al., 2023). The goal is to foster mutually beneficial relationships (Armstrong and Baillie, 2012), promote civic engagement (Brown et al., 2016), and empower communities to be active agents in their own development (Arias et al., 2016). Through community engaged practices, participants gain valuable skills, insights, and connections while making meaningful contributions to society (Chen et al., 2022).

In STEM areas, community-engaged theories serve as frameworks that link academic learning with practical application in real-world contexts (Nguyen, 2021). These theories emphasize collaboration between educators, students, and community members to address complex scientific, technological, engineering, and mathematical challenges. By integrating community perspectives into STEM education, students gain a deeper understanding of how scientific principles intersect with societal needs and aspirations (Barlow and Brown, 2020; Kersey and Voigt, 2021). Through hands-on projects and partnerships with local organizations, students not only develop technical skills but also cultivate critical thinking (Zhou et al., 2023), problem-solving (Karwat et al., 2015), and communication abilities essential for STEM careers (Nafchi et al., 2019). This approach fosters a sense of civic responsibility and empowers students to become active contributors to scientific innovation and community development (DeCoito and Estaiteyeh, 2022).

In engineering, community-engaged theories play a pivotal role in transforming traditional education paradigms into dynamic learning experiences that resonate with real-world issues and contexts (Quiroga et al., 2019; Reina-Rozo et al., 2019). These theories underscore the importance of integrating community needs, values, and perspectives into engineering curricula and practices. By immersing students in authentic engineering projects that address local challenges (Hinds et al., 2020), educators foster a sense of social responsibility and ethical consciousness (Monteiro et al., 2018). Through collaboration with community stakeholders, students develop not only technical proficiency but also interpersonal and cross-cultural competencies crucial for effective engineering practice (Denton and Borrego, 2021). Community-engaged engineering education empowers students to apply their knowledge and skills to create sustainable solutions that benefit society while instilling a commitment to lifelong learning and civic engagement (Indumathi et al., 2019). Thus, community-engaged theories in engineering education serve as catalysts for preparing a new generation of socially conscious and globally minded engineers.

From the group of theories previously presented, one prominent theory in community-engaged practices is the Community of Practice (CoP) theory, originally proposed by Jean Lave and Etienne Wenger in the 1990s (Smith et al., 2017). CoP theory posits that learning is inherently social and situated within a community where members share a common domain of interest, engage in joint activities, and develop shared understandings over time (Peña-Torres and Reina-Rozo, 2022). In the context of STEM education and engineering, and particularly for this research, CoP theory emphasizes the importance of creating learning environments where students, educators, and community partners collaborate to co-create knowledge and solve real-world problems (Carvalho-Filho et al., 2020). By fostering a sense of belonging and participation within a community of practice, CoP theory supports the development of both technical expertise and socio-cultural competencies essential for addressing complex challenges. Through active engagement in authentic projects and interactions with diverse stakeholders, students not only acquire disciplinary knowledge but also learn how to navigate the complexities of professional practice and contribute meaningfully to society (Bolu et al., 2019). Thus, CoP theory provides a powerful framework for integrating community-engaged practices into STEM education and engineering, ultimately preparing students to become competent and socially responsible professionals in their fields. However, while theories such as the Community of Practice offer conceptual frameworks for understanding community engaged practices, the practical implementation and nuanced dynamics within these communities often remain elusive and underexplored. Thus, further research and dialogue are needed to fully grasp the intricacies and potential of community engaged practices within diverse contexts.

3 Materials and methods

3.1 Participants

Based on the community-engaged practices described in the literature review, the phenomenon under study is the implementation of community-engaged practices in engineering education. The focus will be on understanding how these practices are conceptualized, enacted, and experienced within educational settings, with an emphasis on their impact on learning outcomes, community engagement, and societal contributions.

To study this phenomenon, the research team approached three Colombian academic organizations engaged in community-oriented initiatives or supporting engineering involvement in community-engaged activities at undergraduate and graduate level. Engineers Without Borders Colombia (from Universidad de los Andes, in Colombia) suggested immersion in the "La Liga del Agua" project, where engineers and students collaborate with high school students in rural areas to promote water-saving practices through information technologies and prototypes. The selection was guided by the project's distinctive features, including active engagement with rural communities for water conservation, the democratization of engineering knowledge, and the application of critical theory within engineering education.

The Center of Humanitarian Engineering at Universidad Sergio Arboleda recommended the Artisanal and Small Mining Project, where engineers, undergraduate students and economists collaborate with informal gold miners in Antioquia, Colombia, aiming to eliminate mercury use during extraction. The project's allure lies in its systemic community model, collaborative creation of engineering solutions, and integration of humanitarian engineering principles.

The Scientific Park of Social Innovation at Corporación Universitaria Minuto de Dios extended an invitation to explore the Empreverde project. This initiative involves engineers, undergraduate students and professionals supporting the transformation of small rural businesses into environmentally sustainable entities, encompassing product commercialization. Key features of interest include the establishment of democratic, heterarchical networks for knowledge and resource sharing and the incorporation of non-hegemonic engineering practices by the research team.

Each project contributed to identifying three participant groups. The first group comprised engineering professors and students actively involved in the projects, offering insights into their activities and practices. The second group consisted of professionals from diverse fields different to engineering areas, providing a complementary perspective on the practices undertaken by the engineers. Finally, members of the beneficiary communities or project participants from the beneficiaries were included to enrich the understanding of the applied practices and the possible conceptualization of community-engaged engineering practice.

3.2 Data collection

The first part of the data analysis was a phenomenographic study. Phenomenography is a qualitative research approach that explore and understand the variation in individuals' experiences and perceptions of a particular phenomenon (Collier-Reed and Ingerman, 2013; Cibangu and Hepworth, 2016). It aims to uncover the different ways in which people understand and make sense of the same phenomenon, highlighting the range of qualitative differences in their perspectives (Hales and Watkins, 2004). Through in-depth interviews, observations, or other data collection methods, phenomenography identifies and categorizes the various ways individuals conceptualize and interact with the phenomenon (Khan, 2014).

Considering that this research looks for descriptions from the previously described community of practices, phenomenographic research highlighted the central aspects of the vision of community engagement and engineering practice. Prior to the interviews, individuals were invited to participate, ensuring a diverse representation of perspectives and experiences. Each participant underwent an in-depth interview with several questions related with interviewees answered a basic questionnaire related to the types of projects and activities they work or worked on. Afterwards, participants were asked about their perceptions of how they convey the topic of community engagement and its relationship with their practices. Finally, the participants were inquired how community-based projects influenced interviewees' professional practices (or student experience) and requested situated examples. At any point, interviewees could include meaningful topics outside the required questions, prompting a range of unstructured items to elicit their responses. An excerpt of the questions is available in Annex 1.

The responses and interactions were recorded in audio format. Detailed notes were taken to guide subsequent coding and analysis of the data. Additionally, due to the challenges posed by the global pandemic, some interviews were conducted remotely via platforms such as Zoom, allowing for continued data collection while adhering to safety protocols. Following the interviews, all recordings were transcribed verbatim, ensuring accuracy and completeness of the data for thorough analysis. This rigorous approach to participant selection and data collection is essential for capturing the nuances and variations in individuals' experiences, ultimately enriching the depth and breadth of the phenomenographic study.

Adhering to the principles of phenomenographic research, diversity within the sample group is imperative. The goal is to maximize insights into how the outcome space logically relates to the broader population as collectively represented by the sample group (Harris, 2011; Baillie et al., 2013). Thirty-five participants from the three projects willingly participated in semi-structured interviews, with demographic variations meticulously documented and presented in Table 1.

TABLE 1 Demographic variation in the sample.

Demographic characteristics	
Roles	Entrepreneur, university professor, engineering student, freelancer, researcher, dean, project manager
Categories	Engineering professors: 10 Engineering students: 8 Other areas: 10 Community participants: 7
Disciplines	Industrial engineer, environmental engineer, electronic engineer, business studies, economics, mechanical engineer, ecology, sociology, agroecologist, computer science, mathematics
Gender	Woman: 14 Man: 21

3.3 Data analysis

The method used to analyze the collected data was based on the work of Caroline Baillie. Baillie's phenomenography methods are dedicated to show the multifaceted perceptions and experiences individuals hold regarding a specific phenomenon (Kabo and Baillie, 2009; Armstrong and Baillie, 2012; Baillie et al., 2013). It meticulously examines the diverse ways in which individuals comprehend and engage with this phenomenon, accentuating the nuanced qualitative disparities in their perspectives. Through rigorous data collection methods such as interviews and observations, Baillie's approach systematically organizes and scrutinizes participants' viewpoints, striving to capture the entirety of their understanding. Diverging from conventional research paradigms, phenomenography prioritizes the granularity of individual experiences over the pursuit of consensus, employing iterative analysis of transcribed interviews until thematic saturation is attained. This methodological rigor fosters an in-depth and varied understanding of the phenomenon under investigation.

Early in the process, two research team members and one external researcher met to read the same transcript excerpts. In addition, we interrogated one another's analysis to achieve some form of consistency in the categories. Furthermore, the investigation was iterative and continued for several months as the researchers revisited the data. We created the number of categories to five by focusing increasingly on the critical variations within the practices discussed by interviewees (Collier-Reed and Ingerman, 2013). Broadly, the conceptualizations we identified differentiate the level of community engagement, the engineers' participation, and the inclusion of critical perspectives of the practices.

Additionally, Terra and Passador's (2015) insights regarding the systemic aspect of phenomenographic studies will inform the creation of description categories. Initially, the interrelationships among concepts were meticulously examined and excluded from the analysis. Acknowledging any potential correlations is crucial when aiming to identify the core concept. Secondly, the researcher's own relationship with the system under study was acknowledged. The resultant analysis, drawn from the transcripts, focuses solely on the essential concept units necessary for a true perception of the problem at hand.

3.4 Trustworthiness

To ensure trustworthiness, two methods were employed (Leydens et al., 2004). Firstly, triangulation of the results and categories was conducted by cross-referencing available literature, other theses, and students' works. This process helped validate and corroborate the findings through multiple sources. Secondly, member checking was implemented, allowing participants to review and critique the results and categories. These methods enhance the credibility and reliability of the analysis by incorporating the perspectives of those involved.

4 Results

The phenomenographic analysis revealed five distinct qualitative conceptions that individuals within engineering projects with social

10.3389/feduc.2024.1386729

impact in Colombia hold regarding community-engaged practices (Table 2). It is noteworthy that, given the complexity of the phenomenon, interviewees articulated different facets of these conceptions. Crucially, emphasis should be placed on the hierarchical nature of these categories, with higher categories being more comprehensive than their preceding counterparts. In other words, each top category subsumes the previous ones, resulting in enhanced completeness in terms of engagement. Furthermore, each category is underpinned by illustrative quotations that encapsulate critical aspects associated with that category. Due to space constraints, only a select few samples are presented here, as not all excerpts can be included.

The initial conceptualization identified in the study revolves around the theoretical consideration of social issues within engineering practices. In this perspective, community engagement is characterized by a low level of involvement, stemming from the perception that social problems arise solely from data or individual perceptions. The subsequent conceptualization broadens the scope by incorporating collaboration with professionals from other fields in engineering practices, reflecting a vision of community engagement contingent upon relationships with individuals beyond the engineering domain. However, the engagement with communities remains limited in these first two concepts, as engineers tend to maintain their positions without fully acknowledging their inherent privileges.

The subsequent conception reflects a more personal relationship with the community. Within this category, practices are geared towards establishing a fundamental connection with the community to develop engineering solutions, wherein the community is involved but primarily as an information source. Moving forward, the following conception encompasses a collaborative process in engineering projects, termed co-design. This process allows engineers and communities to actively participate in identifying, designing, and implementing solutions.

Ultimately, the top conception, the most comprehensive in this phenomenography, envisions engineering as a potent force capable of dismantling barriers imposed by systemic structures on communities. Here, a profound understanding of community engagement transcends mere inclusion, aiming to transform existing inequalities within the context. The last three conceptions demonstrate a progressively closer relationship between engineering practices and community engagement, with a heightened and more active involvement as the category ascends.

4.1 Category 1: engineers theorizing social issues

In the first category, we can find engineers who focus their practices on applying their knowledge, skills, and competencies in theoretical problems, especially in the social sphere: "If my work does not connect me with society, it is not considered work but a waste of time" (professor from project 2). This group of practices seems to be born of personal motivation to contribute with a social interest to participate in community engaged practices. In terms of one of the interviewees (professor from project 1):

> "After graduating from the career as such, then I had some visions, but as very short of the reality of the engineer, of which I could see that fieldwork all those things that were not necessarily being in an office, no I know dressed in suits, meeting a schedule but that other types of things could be done, but I felt that they were a little more fun what can be put in that category."

It is then essential to characterize this type of practice since it does not only correspond to a unitary process or an attitude toward social problems, +but it is evident in this category that exist at least four different approaches to this practice. First, a difference must be found between the engineer's reality and the expectation about what should happen to determine a social problem, a gap which in the words of one of the interviewees (student from project 2):

> "Then, through engineering and the solutions that can be generated, begin to close those gaps that exist between the different groups. These families that were affected and can achieve the same level as the people who were not affected. These families have the same conditions of quality of life, education, health, so, for example, it seems that there in many municipalities the whole issue of health is total, it will sound horrible, very poor. These

TABLE 2 Categories of description.

Categories of description	Summary	Key aspects
Category 1: Engineers theorizing social issues	Community-engaged practices are based on the contribution from theory to solve social problems	Engineers as problem solvers Theoretical solutions
Category 2: Engineering practices as interdisciplinary work	Community-engaged practices are based on their contribution to other professions in their projects	Knowledge contribution Collaboration Conceptual capital
Category 3: Engineers as consultants in projects with communities	Community-engaged practices are based on the recognition of the community as a problem source	Consultee models Life improvement Communication skills
Category 4: Co-design as a professional practice for engineers	Community-engaged practices are based on the joint development of artifacts to solve social issues	Community knowledge Knowledge transfer Shared responsibility
Category 5: Engineering practices that eliminate systemic barriers for communities	Community-engaged practices are based on the system recognition and social mobilization	Systemic thinking Life transformation Social fabric

> conditions generate disease and discontent, so I believe that engineering can play an important role by prioritizing those places where conditions are not the best."

According to the text, these differences or gaps shows a need that can be solved: "I believe that as an engineer, I think that this is the current design, what would be the idealized design and what I want is to close that gap and look for the best options or the process to be done to close that gap." (Professor from project 3) Once the need is identified, the engineer applies his knowledge to close this gap with models and new theories.

To solve this need, it is necessary to recognize the contribution that engineering knowledge can make to solve this gap; In other words, it is necessary to find the meaning that engineering has to fill these empty spaces: "the ability to interpret what they are requesting and manage, that is, it is like how to look at how to solve things even if you do not have complete knowledge" (student from project 1). Therefore, the practices in this category connect the perception of the engineer about a social issue and translate engineering work into tangible and intangible products: "to translate these social and cultural variables into a product or a service that became a game. It ended up being a game; so of course, the question was do the gathering of social information, cultural information and turn it into actionable things for a video game"(professor from project 2).

Finally, we see that these practices have an early approach to positive contributions to society: "Also, as said, it depends on the project, but I also support a lot because, as right now. What we did right now was to make an application of accounts for people whom they do not know, let us say the things they sell (...) and that once it begins to lose, then if at some point the different applications that we are doing should benefit people, what benefits that project" (student from project 2).

Consequently, this first category presents a personal, but theoretical, connection with existing social problems, then the engineers are contributing from their expertise in possible solutions that could fill gaps in social contexts. Some authors (Moskal and Gosink, 2007; Leydens et al., 2014) have identified training projects, such as undergraduate or modelling jobs, as part of this category. Here we see a more traditional vision of engineering work, where any specific community is included, and the problems and solutions are disconnected with reality.

4.2 Category 2: engineering practices as interdisciplinary work

In this second category, the interviewees' reflections pinpointed on the participation of engineers in projects in which they are part of interdisciplinary teams, and they are contributing from their area of knowledge to solve problems. These practices are framed in the spaces in which engineers converge with other professions and other professionals for the solution of the issues: "Let us do one thing where we integrate the private sector, the public sector and the community in one single operation where we share transparent information and create a prototype (...). Then we said we need economists, engineers, systems engineers, mathematicians, architects and lawyers, and we did an interdisciplinary job and put together the first prototype" (student from project 2).

The first fundamental point is the recognition of the need of other professionals from further areas for the development of engineering practice because engineers "are super-concentrated in the technical part and they do it very well, but they cannot, they cannot do it alone because if they do it, they die alone" (Project manager in project 1). In other words, engineering requires a component of work with other disciplines of knowledge to be effective when it is carried out. In terms of one of the interviewees, the result of engineering work comes (social worker related with project 2):

> "From a very interdisciplinary component, I mean, I believe that the engineer alone cannot come and do everything, right? Nevertheless, I believe that the social sector cannot do everything either or the ecologist. I believe that this type of project should be approached in an interdisciplinary way, right?"

Once the need for active collaboration is recognized, the first challenge is generating spaces for collaboration and learning with other professions, as indicated by the following interviewee: "my difference, let us say, from an outside engineer, Well, that one way of working here, let us say there is much collaboration in the sense of work."

Additionally, this work allows us to join efforts in solving problems and, in a particular way, to produce shared conceptual capital: "interdisciplinary is fundamental, that is to say, do not stay with a single reading because when I speak with engineers, urban planners, and economists of different perspectives that are very useful because you add much more conceptual capital, yes?" Other vision, from areas such as tourism, shows that: "Both engineering and other sciences can be complemented with tourism."

Also, it can be noticed that this type of collaborative work with other professionals allows organization and efficiency to be improved, creating better results:

> Community member from project 2: Engineering continuously improves processes, procedures, stipulates methods, methodology, and you know that we are in a changing environment, yes? Organizations must have a flexible structure, yes? Help the market's behavior and give the dynamics of the economy, the social issue, and how from the structure from engineering I can strengthen it to carry the organization's strategy and objectives, yes? That's what engineering is for.
>
> Andres Acero: And do you think engineering is a fundamental part of this project to be much better, and do you think it already has it?
>
> Community member from project 2: Not yet, obviously everything must be something, I can be better today but tomorrow more and I should aim for more if we say today not only see the engineering issue if we do not speak other careers that make a multidisciplinary team that from all engineering angles, they manage everything they can contribute to consolidate an organization.

Finally, this interdisciplinary work for the development of engineering allows building bridges in knowledge (student from project 2):

> "It was such a project that had so many institutions involved. I think that also building bridges and building ties was another of

> the implicit tasks that the position had, which was to communicate with the schools, communicate even though it was a project of engineers without borders."

Finally, we can see that the engineers' practices in this category focus on the contribution from theoretical and practical knowledge to the development of engineering projects. This type of task can positively influence a particular social context, although these teams could be related to these initiatives without the engineers being directly involved. It should be noted that the practices in this category are mainly focused on working with their peers, focused on generating contributions with a particular interest in social issues inside the concerns of their institutions.

4.3 Category 3: engineers as consultants in projects with communities

The third category corresponds to engineering practices that focus on developing activities to solve problems for a specific community. Like the previous one, this category focuses on searching for solutions from engineering to social problems that exist. However, in this category, contact with the communities is reinforced, giving more space to get useful information to solve more specific and relevant issues.

First, we see that the interests of the engineers who carry out this type of job are motivated to contribute to society and touch people's lives more closely: "I see the whole reality of the country. Not only in us as engineers and not in all kinds of professions, I see that we can touch the reality of other people, right? When they decide, I do not know, for example, to build a house in favor of a low-income family because there it is they make many decisions to get people involved" (student from project 2).

Once personal interest is identified, an acknowledgment of the impact engineering work has on people is essential; As one of the interviewees indicates: "One of my practical obsessions and I think it continues to be how to bring the engineering world closer to working with the most vulnerable people and above all to give authentic help, support, solutions or whatever we call it to the problems of vulnerable communities. When I say authentic, I mean no philanthropy and no welfare" (professor from project 2). Furthermore, this mostly positive impact allows generating engineering solutions that improve the quality of life of vulnerable communities: "We are helping the community because it is a project to help them improve their quality of life" (student from project 3).

On the contrary, in other cases, we can show that many of these initiatives seek to break companies' or academia's traditional scheme. This rupture occurs by allowing a fundamental approach to these institutions' problems, giving a leading role to the community in the engineering process: "I have worked with indigenous communities, rural communities, Afro-Colombians, right now with a focus on climate change. Obviously, being in academia, the time available to work in the field is not as much as it could have been before, right? However, let us say that the approach from the type of projects that I work on are projects with people" (professor from project 2).

First, to carry out this type of practice, it is necessary to start with the community's recognition. Generally, many engineers recognize that the problems belong to people: "The projects that are done here in the park are guided to people, that is, to solve problems that people have." Also, it includes recognizing the importance that the process of design and construction of technological solutions have for communities: "I want to be the engineer who applies in his projects for the benefit of the community, people and society" (student from project 2).

Once they have been recognized, it is necessary to establish a relationship with this community, which occurs when communication is generated, first from listening: "Listen and understand the real needs before proposing a solution." Furthermore, it is necessary to ask and generate a two-way relationship: "then you go reviewing what you need, you go on developing the activity you need. Then, for example, there are places that you need to do a little research. There are other parts that, for instance, you need to talk to the community to get some information or to give them some kind of information, so you generally speak to them, and after that, you start to systematize that information, and you are generating or enriching by saying so a document or deliverable, OK? (professional engineer from project 1).

From these conversations, a gap or problem can be raised that must be resolved; Therefore, communication is established with people in a specific context, allowing to identify needs. "One is working for the other, but the verification of the needs is done from the dialogue. You have ideas with the other depending on that dialogue as well, because in the context that the other person is also different than I am going to work for example, with another team of engineers or professionals to whom I meet and need to identify needs for example, of a vulnerable community."

Then, engineering solutions are generated to solve the identified problem. These solutions can, for example, increase the capacities of the community: "an ecosystem is being created to improve the capacities of women miners and scrap metal workers and some miners in general in the region so that they can access an inclusive economy (professor from project 3) or, allow the existence of equity in the context (professional engineer from project 1):

> "Precisely people want those aspects of justice to be much more evident in everything social. That is why they work so that there is equity, and they work so that there is equality. Look, it is valid that, for example, I tell you because of how close we are to the Lego contest now. Before it came to us, it was an elitist contest; they had access only to high-class schools that had the possibility of entering with a special payment. We took it and said no, if we have worked with public schools, we want to show that public schools have all that potential. So, we have involved public schools because, also, we are consistent with our mission and vision, which is to change lives, change lives for the positive."

Furthermore, in this variation, we can see the emergence of three aspects that are considered relevant to carry out these practices. First, adequate training is required to carry out work with the community, especially by academia: "We are simply trying to do to close a gap between the academic community and the real sector, close a gap between vulnerable people and the solutions they require for their problems and also close a gap between training students. We need students more aware of their environment, their context of the country in which we live, and the needs. They also need to acquire skills that are not easy to receive in a classroom, working with real people, solving real problems and finding real difficulties that any professional is going to face" (professor from project 3). Second, we see the importance of transparency in working with the community: "making things transparent for people, that is, everyone who is involved, the people who are going to benefit from the project know what is being done" (student from project 2)- Finally, we see that the professionals who carry out these practices also comment on the importance of developing a sense of belonging: "It is a beautiful experience because you learn from different people both as professionals and people, so you also get very involved with the community, they involve a lot which in a sense, how do I say, it is a sense of belonging" (professor from project 1).

In summary, this variation in engineering practices has a purposeful connection with communities. The traditional idea of working with communities is reflected in this category, in which the engineer works to create an engineering solution that arises from a need evidenced by a communication process. However, the community's role is to give information to the engineer, eliminating any space to comment and contribute ideas to the solution's design. In this author's opinion, this category stills perpetuate some ideas of privilege and power inside engineering.

4.4 Category 4: co-design as a professional practice for engineers

First, as in the previous variation, we find a recognition of individuals and communities. However, this recognition comes from understanding people as subjects of rights and owners of traditional and empirical knowledge. Regarding the recognition of rights, one of the interviewees commented: "the person is consistently recognized not as an object but as a subject of law, in which one is continually reminding that they are people, that we can do things differently. It is not like the daring engineer arrives but rather I believe that there is equal treatment, a construction treatment and also the result is always that it is something participatory "(master student from project 2). On the other hand, in terms of knowledge, it can be linked to mutual recognition from both engineers and community (professor from project 2):

> "In this case, at this point as a researcher, you have the opportunity, right? To link the two types of knowledge, yes? From their ancestral knowledge, their knowledge is ingrained, even let us say what one has as an academic. What goes away developing in the country obviously, because not all communities think that all have super good use of resources? It is not always like the indigenous imaginary, the Afro-Colombian, rural people making such a super appropriate use of their territory. This does not always happen, but you have to know how to link that territorial knowledge, ancestral knowledge, with the knowledge that academia has."

Afterwards, it is essential that the design and construction process be carried out in a participatory manner, that is, with constant work with the participants throughout the entire process:

> Andres Acero: Thinking about the projects in which you have worked, what do you think are those things that have made these projects successful if they have been and, if they have not been successful, why not?
>
> Professional engineer from project 1: I believe that participatory action, seeking that the communities become part of the solution or the design, has led to the projects' success. When the opinion of the actors is not taken into account, the projects may fail because the actors are the ones who have really had the problem, have lived with it, and somehow have experience in what has already been done and has not been worked. They also know their interests, who will use the solutions, which is crucial. It is related to empowerment, so if they do not co-design the solutions, they will not be empowered, and these solutions may be created in limbo."

Therefore, if this constant exchange of knowledge exists between the parties, it is necessary to open constant communication channels. In this regard, one of the interviewee's comments: "Just taking the communities into account when designing, we have justice. We are fair because the problems are in the communities. Hence, it would be somehow unfair to lack the way for the communities to solve external issues regardless of your opinion." On other occasions, engineers must carry out the role of facilitator of the design process: "what I want to be like in the end to help many people to solve problems, to empower themselves and solve their problems. Not I because I do not have all the knowledge to solve the problems, but I do have the skills to act as a facilitator so that the same communities or the same people solve their problems" (student from project 3). However, the most important thing is to create spaces for dialogue that allow a good joint design process: "Each system was unique, but in the end, we began to see what we improved. Then we realized that one of us generated spaces for dialogue for people to solve their differences, their discrepancies. We generated those spaces where those stakeholders will generate agreements, commitments" (professor from project 3).

In addition to a proper technology solution for the context, this collaborative process generates both parties' gains. Whether in the construction of new knowledge, the generation of durable solutions, or the strengthening of the relationship between the parties, this kind of practice promotes a win-win: "It generates value to what you are doing, and then you take advantage of the opportunities. I know that sometimes they ask for many requirements and that, but you have to comply. But it is also a win-win." Another of the interviewees also commented: "the idea was that a methodology would remain from this. However, the thesis was going to stay in the library; nobody was going to read it. The idea was really to leave something to the community, a deliverable to the community, and empower them."

The fourth category found in the text tells us about engineering practices focused on collaborative work with the community to design and build engineering solutions with the community. Some authors (López et al., 2019; Acero and Cajiao, 2023) describe this collaborative work as co-design or co-construction, in which both engineers and community contribute on solving the problem with knowledge, experience, and skills. Consequently, we see that this category strengthens some of the central aspects seen in the previous one. First, the work of the community already takes place from a peer-to-peer perspective within the engineering practices. This aspect allows a model based on the community's active participation in developing, designing, and implementing technological solutions. Furthermore, these solutions come from the confluence of different forms of knowledge, both from the community and from engineers. Thus, there is a transfer of knowledge that makes solutions more sustainable over time, including shared responsibility from the solution's users. Therefore, this variation of the practices allows a constructivist participation model based on the parties' knowledge and supported by technology's relationship.

4.5 Category 5: engineering practices that eliminate systemic barriers for communities

First, before starting to recognize the relationship with the community, we find that there is a recognition of engineers about the power they have within their profession:

> Andres Acero: OK, so that justice is reflected in social terms, let us say what you think that what you apply is related to social justice, that's what you just said, right?
>
> Engineer from project 3: Yes, if I feel that part of the objective of what I wanted to do, I do not know if I am achieving it and that is part of my research if it is effectively achieved is to create those or perhaps break down those barriers that generate inequities that generate that feeling of maybe forgetfulness, disconnection, lack of access to opportunities, to resources.

Then, we see that engineers connect this perceived power and its relation to the context changes. This connection is characterized as an opportunity to contribute to the transformation of people and communities:

> Andres Acero: How did this work on engineering projects come to you?
>
> Project manager from project 1: Well, because here I started my professional internship last semester then, and later I liked seeing how engineers in general other careers contribute a lot to transforming people's lives, so you kind of get involved a lot, and you start to like the topic.

The first fundamental difference with the previous categories is a systemic understanding of these communities' problematic situations. In other words, understanding the actors, the relationships between them, their dynamics, and the culture of the place is a fundamental skill (professor from project 3):

> "Jackson had defined in 2004 the different types of systems. He said that there were simple, complex, unitary, pluralistic, and coercive systems, yes? But he separated them, separated them, and there is a problem, and it is cool because they are in the new book. The one who wrote last year he makes a reflection, systems are dynamic and changing, yes? However, in those tables, I characterized them as static then, what I do in my doctoral thesis is that with an intervention from the appropriate engineering for a particular system, yes? I can go from a coercive system where we say the actors are not willing to work together. They do not have a common goal. They are not aligned to a perhaps pluralistic system where there is a common goal, yes?"

This recognition is not limited to social dynamics, but in some cases, environmental aspects also cross it (director from project 3):

> "The world already needs sustainable solutions; in the matter of mining, there is occasionally a very strong problem. I speak specifically about gold mining; what mercury is used. You cannot say no to mining because many families live from mining, and also mining is necessary. That is, gold is essential; we use it even for cell phones, cell phones also require gold. Then, it is to understand in a systemic way that are the environmental variables that are affected, the social ones, and see them connected. It cannot be that we see the ecological, the socially disconnected because they go very hand in hand. They are problematic but related to the environmental issue because it is currently being needed; what is required from humanitarian engineering what we seek is to address current problems. At this moment, the planet earth says, hey, we are not able."

Consequently, these engineering solutions make it possible to dynamize the social fabric:

> Andres Acero: do you think that you are currently doing help improving society in something?
>
> "Engineer from project 1: Yes, clearly, I believe that here there is an essential vocation of service and respect for the communities that personally my objective is very honest in my work, I need my job. I live from my work, but there is also a significant connotation of wanting to do things. The interventions that one makes in the communities dynamizes their social fabric, generating their development processes. Thus, produce one kilo more is one kilo more that represents an increase and a possible improvement in the quality of life for their families. However, the most important thing is how that change management role that one can have with them of insisting, persisting and never giving up that changes begin in mind and that there is the possibility of making many things is going to happen then we start attacking the consequences from their roots."

Finally, this last category corresponds to all engineering practices that help to eliminate the systemic barriers for communities. This last category is closely related to concepts such as engineering for social justice, in which solutions and knowledge are seen as forms of contribution from the profession to social transformation, the creation of opportunities, and the elimination of barriers.

5 Discussion

This phenomenographic exploration of how engineers, non-engineers, and the community conceptualized engineers' community-based practices has yielded an outcome space of five conceptualizations of increasing complexity and relevance for responsive engineering (David and Newell, 2016). This study does not suggest that individuals exemplified each conceptualization, and because the result is an outcome space, the participants can be located through this spectrum. Nonetheless, the five categories of understanding related logically to one another in the broad context of engineering practices for social and environmental justice (Monteiro et al., 2018). These categories make sense since each is readily described and related to several engineering practices, from traditional versions to more critical versions. The hierarchical relationship between categories need not imply that some categories have more significant social value but could suggest developing complexity in how a phenomenon is experienced or made sense (Akerlind et al., 2005).

Figure 1 depicts the outcome space illustrating engineering professor and students' comprehension of community engagement. The structural component charts the evolving development of interviewees' knowledge, capturing the categories of phenomena elucidated in the results section. The hierarchical presentation of categories in the outcome space delineates a progression from simpler to more comprehensive conceptions of the phenomenon. Notably, the conceptions manifest two primary dimensions contingent on the respondent's focal point regarding the phenomenon: (1) perspectives accentuating knowledge-intensive practices and (2) perspectives accentuating social work and community relationships.

This work's outcomes included five different ways of conceptualizing community-engaged practices for engineers—these conceptions and the relationship among them and the relationship with the community shaped the outcome space, which represents a hierarchy of how the conceptions move from simpler to solid concepts and passive to the engineer's active roles.

The ordering of the outcome space is a construct of the researchers, framed by the theoretical framework used. The conceptions were also categorized into two main domains: Perspectives that emphasize using the engineer's knowledge and perspectives emphasizing social work and relationships with the community involved, giving priority to the transfer and social mobilization.

An engineering problem solver discourse was particularly apparent in our data, and it is widely present in the literature (Kuhn, 1998; Jonassen, 2015). From an engineering perspective, such representations lean towards a vision of value-free design (Olaya, 2012), although generally, these are simultaneously underpinned by personal values. Engineering work in terms of theoretical problem-solving was studied by Sheppard et al. (2006) and Tonso (2015), where engineer's practice aims to solve undesired situations, primarily using technologies and artifacts. Therefore, problem-solving is a fundamental skill defining engineering practice (Downey, 2005). However, Pawley (2009) criticizes that engineers believe they can "pick" problems already constructed, and the solutions to these problems are engineering practices without any relation to society. Finally, this kind of engineering practice tends to "break" the problem into pieces, even when it is proven that a holistic approach always has better problem-solving results (Midgley, 1992a).

A widely spread conception of community engagement of engineers as participants of interdisciplinary groups appears in this phenomenography. There has been an extensive debate occurring in projects related to the role of multidisciplinary work (Skokan and Gosink, 2005; Jonassen, 2015), and the main takeaway is that interdisciplinary is needed in every engineering endeavor. However, if engineers conceptualize their role in the community-engaged practice as 'experts' sharing their knowledge in a group of people working for a greater good on, for example, design matters, implications arise for community and partners. Although espoused values to contribute and inform the community, the role or status is to disappear behind the idea of group knowledge sharing. Additionally, if the other professional disciplines in these projects conceptualize their participation as learning sharing facilitators from the engineers, it may seem appropriate for them to handle the contact with the communities.

The following categories in the outcome space suggest that interviewee perceptions of their involvement include an appreciation of engineering as people working or getting involved with the community during the project duration. These categories incorporate more closely the social approach to engineering discourse as a conception of community engagement. Professional areas of engineering, for example, have reflected this extent and included the idea of community processes, modeling or inside their way of operating, such as System Dynamics (Hovmand, 2014) or Operations Research (Midgley et al., 2018). On the other hand, some educators have described the importance of this engagement process for the engineers' learning outcomes (Gilbert et al., 2015). Therefore, those who took society's conscience described being engaged with society, giving community space of the engineering practices' beneficiaries. However, the community engagement process can be viewed from two perspectives in the outcome space. First, a

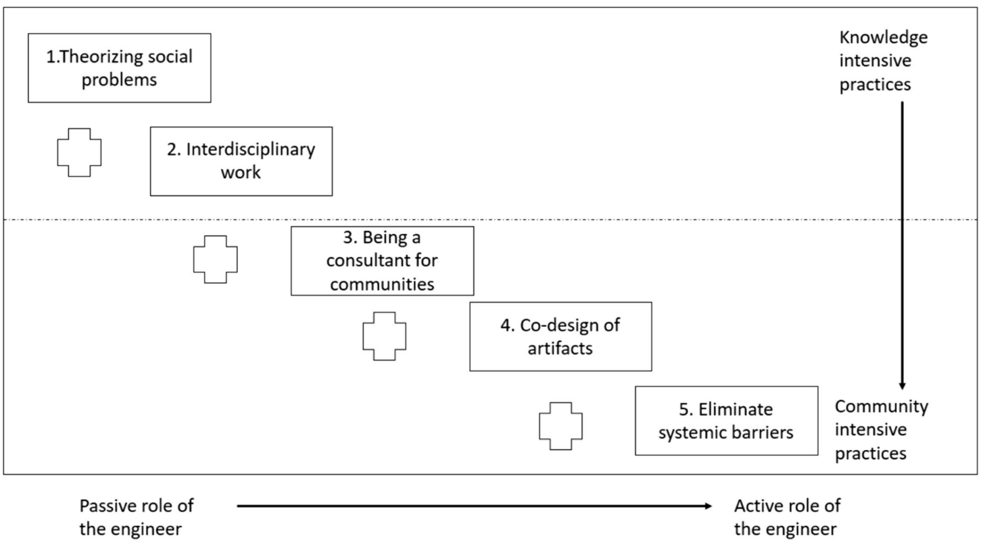

FIGURE 1
The outcome space.

consulted version can be viewed in the third category, where engineers work with the community mainly in the early stages, such as problem identification or community listening. The idea of community work on engineering has been studied previously by other authors (Kalibo and Medley, 2007; Ramírez et al., 2015), describing the process as an approach to connect engineering solutions to problems and including some participatory models. Instead, the fourth category includes more closely the community taking part in the design and construction of the solutions. This category is closely related to the idea of co-design and co-construction, in which community is included throughout the whole project (Maru and Woodford, 2001; Flórez et al., 2018). Finally, empowerment is one of the results of the co-construction process because the knowledge and tools used in the project were shared with the community (De Freitas and Cesar, 2019).

Our most complex conception represents those engineering practices that create artifacts and knowledge that reduce or eliminate the contexts' barriers. This category can be related to the idea of engineering for social justice, for example, Leydens and Lucena's definition (Leydens et al., 2012, 2014) focuses on connecting the study of engineering practices with human capabilities in terms of opportunities and resources. Then, each practice of the engineer that advocates for the creation, maintenance, or reinforcement of the capabilities can be envisioned as an opportunity to eliminate the barriers to access opportunities. For some interviewees, this kind of engineering practice, also, includes the understanding of the system where the community is embedded. Provision of systemic thinking and practice inside engineering projects is more likely to lead to community mobilization and dispositions inclined towards learning and greater societal engagement (Ramírez et al., 2015; López et al., 2019; Acero and Cajiao, 2023). Consequently, conceptualizing engineering practices as social justice advocacy facilitates the development of engineering projects as enablers of higher-order social transformation (Karwat, 2020).

Although categories arise from the pool of meaning provided by the interviewed people, it is essential to highlight that each participant can be scribed just to one of the categories. Given that a heterogeneous group of interviews was included in this study, a further exploration about how groups or individuals expressed different conceptions will be carried out in the next chapter. While some interviewees moved back and forth between the conceptions, some interviewees from non-engineers and community members expressed only the first or second conception. These participants believed knowledge integration and problem-solving are the best options for engineers in this kind of project. Engineers working with the community is the conception held by most of the interviewees. Finally, a few interviewees with more experience working in projects with social impact held the last two conceptions.

6 Conclusion

Phenomenography emerges as a valuable methodology for researchers, providing a reflective lens for understanding intricate social phenomena like community engagement (Brown et al., 2016) and social justice (Kabo and Baillie, 2009). This study underscores the absence of a universally "correct" understanding of social phenomena, as individuals engaged in collaborative efforts bring diverse perspectives shaped by their experiences, contextual nuances, political beliefs, cultural backgrounds, and social standing. The recognition and exploration of varied conceptions within local communities contribute significantly to the insights gained during cross-cultural collaborations, offering researchers an opportunity to refine and adapt their approaches as necessary. Phenomenographic analysis serves as a reflective tool, empowering researchers and activists to acknowledge discrepancies in commonly held views, fostering the co-creation of alternative and meaningful approaches to address local challenges.

The outcomes of this study unveil diverse conceptions held by individuals working on socially impactful projects, ranging from the perception that engineers merely impart knowledge to the conviction that engineering practices can instigate social transformation. The application of phenomenography, a methodology predominantly employed in educational research, proves effective in unraveling the complexities of social phenomena. This revelation emphasizes the potential of understanding varied conceptions of engineering practices in community-engaged projects, informing decision-making processes and facilitating the development of teaching and education strategies that can yield more favorable outcomes for both students and professionals. Aligning with Marton's (1986) insight, a meticulous exploration of the diverse ways people conceptualize phenomena becomes instrumental in uncovering conditions that promote transitions toward qualitatively "better" perceptions of reality.

The examination of community-engaged practices through the lens of phenomenography not only contributes to our understanding of social phenomena but also holds profound implications for education. This methodology, traditionally entrenched in educational research, demonstrates its versatility and efficacy in unraveling the intricate fabric of community engagement within engineering practices.

The educational implications of this study are manifold. Firstly, the recognition of diverse conceptions within community-engaged projects underscores the necessity for educators to cultivate an inclusive and culturally sensitive pedagogy. Understanding that individuals may perceive their role in community-engaged practices differently informs the development of educational strategies that accommodate varied perspectives. This acknowledgment aligns with the broader call for culturally responsive teaching approaches, emphasizing the importance of understanding and valuing diverse worldviews within the educational context.

Secondly, the study accentuates the role of education in fostering a transformative mindset among engineering professionals. By uncovering the qualitatively different ways in which individuals view community engagement, educators can tailor their curriculum to instill a more comprehensive understanding of the societal impact of engineering practices. Integrating diverse perspectives within engineering education becomes paramount, not only for nurturing well-rounded professionals but also for addressing the complex challenges that arise in community-engaged projects.

Moreover, the study highlights the potential for phenomenographic analysis to serve as a pedagogical tool. Incorporating phenomenographic approaches into educational research methodologies could enrich the learning experiences of students and professionals alike. This methodology provides a framework for educators to guide students in critically reflecting on their own perspectives and evolving towards more nuanced and inclusive understandings of complex social phenomena.

In conclusion, the intersection of phenomenography and education emerges as a fertile ground for enhancing the efficacy of community-engaged practices. Educators, armed with insights from phenomenographic analyses, can play a pivotal role in shaping the perspectives of future engineers, fostering a culture of inclusivity, and equipping them to navigate the intricacies of community engagement with sensitivity and efficacy. This study underscores the symbiotic relationship between phenomenography and education, advocating for their collaborative application to advance both scholarly understanding and practical outcomes in the realm of community-engaged engineering practices. This study employs Baillie's phenomenography methodology to delve into the conceptualizations of engineers, non-engineers, and the community regarding community-engaged practices. Through meticulous analysis and categorization of participants' viewpoints, five distinct conceptualizations emerge, spanning from simpler to more complex understandings of engineering's role in social and environmental justice. These conceptualizations are not mutually exclusive, and participants can be situated along a spectrum within the outcome space, reflecting the diverse perspectives within the community. Importantly, the hierarchical presentation of categories does not imply varying social value but rather underscores the evolving complexity in how the phenomenon is experienced and interpreted. This research sheds light on the multifaceted nature of community-engaged practices in engineering, emphasizing the importance of considering diverse perspectives and fostering active engagement with communities. Ultimately, it advocates for a pedagogical shift towards more socially conscious and responsive engineering practices, aligning with broader goals of social justice and equitable societal development.

Adapting this study to other regions or contexts outside of Colombia involves several considerations: Firstly, researchers need to recognize and understand the cultural nuances and societal norms of the target region, including language, customs, and social structures that may influence perceptions of community-engaged practices. Secondly, identifying and engaging with local stakeholders, including engineers, non-engineers, and community members, is crucial to ensure representation and diverse perspectives in the study. Thirdly, tailoring the research methodology to suit the context and objectives of the study, such as adjusting interview protocols, data collection methods, and analytical frameworks, is essential. Additionally, conducting a thorough literature review to understand existing research and scholarship relevant to community-engaged practices in the target region helps contextualize the study and identify gaps or areas for further exploration. Adherence to ethical guidelines and protocols relevant to the target region, fostering collaborative partnerships with local organizations, academic institutions, and community groups, and considering conducting comparative analyses between different regions or countries are also vital aspects to consider. By addressing these factors, researchers can adapt and conduct similar studies in other areas, contributing to a broader understanding of community-engaged practices in diverse cultural and geographical contexts.

The current study might have several limitations. First, the sample size and composition of participants may not fully represent the diversity of perspectives within the target population, potentially limiting the generalizability of the findings. Second, the study's reliance on self-reported data, such as interview responses, may introduce biases or inaccuracies based on participants' subjective interpretations and recall abilities. Additionally, the study's focus on a specific geographical context, such as Colombia, may restrict the applicability of findings to other regions with different cultural, social, and institutional dynamics. Moreover, while efforts were made to ensure rigor and trustworthiness through methodological approaches like member checking and triangulation, inherent subjectivity in data interpretation and analysis could still influence the study's outcomes. Finally, the study's cross-sectional design may not capture changes or developments in participants' perspectives over time, highlighting the need for longitudinal research to provide a more comprehensive understanding of community-engaged practices in engineering.

In conclusion, this study not only contributes to the scholarly understanding of community-engaged practices but also highlights the transformative potential of phenomenography in analyzing and enhancing complex social phenomena. The implications extend beyond research methodologies, emphasizing the need for educators, researchers, and activists to be attuned to diverse perspectives within collaborative projects for more effective and inclusive outcomes. The study reinforces the symbiotic relationship between phenomenography, education, and community engagement, advocating for continuous reflection and adaptation in the pursuit of meaningful societal impact.

Data availability statement

The datasets presented in this article are not readily available because the data cannot be accessed because individuals can be identified through the stories presented. Requests to access the datasets should be directed to andres.acero@tec.mx.

Ethics statement

This project was approved by the IRA of Universidad de los Andes, as a project without risk. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

AA: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. MR-C: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. CB: Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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ANNEX 1: Excerpt of the questions for the participants

About motivation in engineering

- For you, what is engineering?
- Why did you decide to study engineering?
- What motivated you to choose your chosen branch of engineering?
- What were your expectations about engineering before starting your studies?
- What was your process like to become an engineer?

About his work as an engineer

- What will make your practice different from other engineers?
- How do you think your work will respond to a need?
- How do you think your work will connect you with society?
- How do you think your work has connected with the environment?

About his relationship with community engagement

- What is, according to your experience, community engagement?
- How have you experienced community engagement in engineering?
- How does that justice have to do with the social issues of the project you will develop?
- What practices of yours do you think would help to be involved successfully in the project to be developed?