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Exploring the Female Students and Teachers' Problems in Conducting Laboratory Practicals

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Abstract

Science laboratories play a crucial role in the modern knowledge society by providing hands-on experience and developing scientific knowledge. However, female students and teachers often face unique challenges in laboratory environments, especially in developing countries like Pakistan. This study explores these challenges, examining cultural and systemic factors that impede female engagement and success in science laboratories. Using a qualitative research design, the experiences of 20 female students and 10 science instructors from a major university in Pakistan were analyzed through semi-structured interviews and focus group discussions. Thematic analysis revealed that laboratory work enhances experiential learning, builds confidence, fosters collaboration, and challenges gender stereotypes. Despite these benefits, female students face significant barriers, including gender bias, inadequate infrastructure, and safety concerns. Effective coping strategies such as seeking mentorship, developing technical skills, and advocating for inclusivity were identified. The findings underscore the importance of creating inclusive and supportive laboratory environments to promote gender equity in STEM fields. Recommendations include developing mentorship programs, enhancing laboratory infrastructure, conducting unconscious bias training, and promoting work-life balance for female students. Addressing these issues will contribute to greater diversity in STEM disciplines and foster a scientifically literate society.

Keywords: Science Education, Female students, STEM, Experiential Learning, Laboratory Environments.

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1 Introduction

We must ensure the sustainable creation of scientific information and, even more importantly, the sustainable development of the raw materials used to create this knowledge since science is the bedrock of our contemporary knowledge society (Shibayama, 2019). Here, universities and colleges are crucial for developing cutting-edge scientific understanding, passing it on to future generations, and generally influencing the field of science (Akhigbe & Adeyemi, 2020; Kinyota, 2020). Consequently, a lot of money has been poured into universities in order to increase the number of scientists (Shana & Abulibdeh, 2020). On the other hand, many believe that today's schools are too rigid to keep up with the times and the demands of society. Universities and colleges often employ interdisciplinary teams of scientists in their labs to teach future researchers and conduct original scientific investigations (Shambare & Simuja, 2022; Shana & Abulibdeh, 2020). Students and other less experienced scientists work as apprentices under the supervision of more seasoned scientists on various research projects as part of this kind of training (Shibayama, 2019).

The use of laboratories is a defining aspect of scientific education at all levels (Sari et al., 2023; Sahin & Oren, 2022). Virtually every scientific class you may take at a school probably includes some hands-on lab (Luse & Rursch, 2021; Steger et al., 2020). On the other hand, their continued existence in modern times is hardly explained. It is considered to be vital and required. Concerning lab courses, the most pressing question is whether or not a laboratory program is necessary. Even though chemistry labs have been around for a long time and are impossible to replace, nobody knows for sure what students learn from them (Bruck & Towns, 2013; Jumamuratov & Kobeysinovich, 2021; Seery et al., 2019).

In the realm of science education, conducting laboratory practicals is a cornerstone for developing scientific understanding and skills among students (Casad et al., 2021; Shibayama, 2019; Oliveira & Bonito, 2023). However, female students and teachers often face unique challenges in this domain, which can impede their engagement and success in laboratory environments (Ahmed et al., 2020; Oliveira & Bonito, 2023). This article delves into the specific barriers encountered by female students and teachers in Pakistan during laboratory practicals, examining both cultural and systemic factors. Gender stereotypes and the societal norms that support them are a major obstacle to more women pursuing careers in STEM. Girls' self-esteem and lab performance might take a hit when society discourages them from pursuing STEM careers (Ahmed et al., 2020; Jabeen & Afzal, 2020).

Another factor that might make this problem worse is the dearth of positive female role models in STEM fields; without these relevant figures, young girls may have a more challenging time seeing a future for themselves in science (Ahmed et al., 2020; Casad et al., 2021; Shibayama, 2019; Oliveira & Bonito, 2023). Furthermore, female pupils are hit harder than male students by the inadequate infrastructure at many schools. When funds are tight, male students are often given preference over female students, and many institutions lack adequate or even nonexistent laboratory facilities. Nkemakolam et al. (2018) found that female students may not have as many chances to participate in hands-on scientific experiments due to the gender gap in funding (Day et al., 2016; Wang et al., 2017). These experiments are vital for students' learning and enthusiasm for the topic. There are many obstacles that female educators encounter when they are in charge of laboratory practicals (Ahmed et al., 2020). The absence of options for professional development that are specifically designed to meet their requirements is a major concern. Many female educators fail to get sufficient professional development, which limits their capacity to lead successful practical sessions in the lab, despite the fact that this is essential for effective laboratory instruction (Supovitz et al., 2000).

Furthermore, the time and energy that female instructors may devote to preparing for and leading laboratory practicals is typically limited due to the simultaneous weight of professional and family tasks (Darman et al., 2024). Another major obstacle is the prevalence of safety issues in laboratory settings. In under-resourced environments where safety rules are not strictly implemented, female instructors and pupils may feel even more exposed when it comes to handling chemicals and equipment (De Jong et al., 2023). If we want more women to take part in scientific classes, we need to make sure they can do so in a safe and welcoming setting. A combination of structural reforms and creative solutions is necessary to tackle these difficulties. One way to provide students with more options when it comes to doing experiments in the lab is to include technology in scientific lessons.

For example, according to Mihindo et al. (2017), female students may get practical experience without the limits of physical labs thanks to virtual laboratories, which provide a safe and resource-efficient approach to performing research (Darman et al., 2024; Jumamuratov & Kobeysinovich, 2021; Shambare & Simuja, 2022). There is a gender gap in laboratory practicals, but these digital technologies may help close it and make excellent scientific education accessible to everyone (Day et al., 2016; Wang et al., 2017). In addition, there may be a notable difference in efforts to improve female teachers' professional development. Female educators may enhance their laboratory teaching methods and create a more welcoming classroom climate by participating in professional development programs that provide ongoing, inquiry-based training (De Jong et al., 2023; Kinyota, 2020; Supovitz et al., 2000). One way to help female science instructors overcome the obstacles they encounter is to encourage them to connect with mentors and form support groups (Ahmed et al., 2020; Emeka et al., 2021).

1.1 Background and Context

It has long been believed that hands-on experience in scientific laboratories is an essential component of a well-rounded science education (Ahmed et al., 2020; Oliveira & Bonito, 2023). Management techniques that work in scientific laboratories as well as classrooms promote and improve student learning. Among the most essential things a scientific lab instructor can do is to maintain order in the classroom, as this has a direct impact on students' performance (Kinyota, 2020). Teachers who excel in science classes are those who have a good grasp of how their students typically perform in the lab and who use both proactive and reactive methods of classroom management to address disruptive student conduct (Sari et al., 2023; Sahin & Oren, 2022). This study will shed light on practical techniques for managing classrooms, specifically in science labs, and will consider this from the standpoint of teacher effectiveness. It will then suggest some implications for practice, focusing on both knowledge and practice of classroom management strategies (Supovitz et al., 2000).

Gender imbalance persists in the educational achievement of men and women in developing nations at all levels despite advances towards gender parity. First, in developing nations, there is still a significant gender gap when it comes to the educational achievement of men and women (Day et al., 2016; Wang et al., 2017). Hey there! The educational attainment gap between men and women persists across all stages of development in developing nations despite ongoing efforts to achieve gender parity (Akhigbe & Adeyemi, 2020). Teaching undergraduates the fundamentals of physics helps shape their minds to think scientifically and technologically, which is essential for meeting the demands of today's world (Usman & Yakubu, 2020). Theorizing electrical circuits, computer science, information technology, radio electronics, microelectronics, and higher mathematics are all intricately related to physics in higher education (Jumamuratov & Kobeysinovich, 2021; Usman & Yakubu, 2020).

You cannot get a degree in engineering or science without taking laboratory classes, which help put what you learn in the classroom into practice. However, students sometimes begin lab work without fully understanding the theoretical background they will need to use, which slows down the progress of the practices. Additionally, students pursuing a Chemical Engineering Degree (Ched) are required to handle vapors, fuel distillation, vast quantities of chemical reagents, and other similar tasks on a semi-industrial scale. Therefore, it is essential to be familiar with the established operating procedures, chemical safety data sheets, and laboratory safety standards. Nonetheless, guaranteeing this has been challenging so far (Borreguero et al., 2020).

1.2 Statement of the Problem

According to the numerical studies, a considerable number of female issues inside science laboratories in conducting practical literature show the essential importance of addressing female issues for better-conducting experiments and broadening their understanding of science concepts. Unfortunately, developing countries like Pakistan are less equipped to address female issues in laboratories are needed. Teachers conduct experiments and conduct practical work with female students in laboratories (Shana & Abulibdeh, 2020). However, they do not consider the problems female students face in science laboratories (Oliveira & Bonito, 2023) and how they can put their efforts into reducing these problems. As a result, the research focuses on female students who face problems in conducting practicals and also teachers to address the female problems they face. This research aims to learn more about this phenomenon and close a gap in the literature.

1.3 Significance of the Study

The importance of teachers doing experiments in laboratories is emphasized in this study. It investigates teachers' perspectives on female issues they faced while conducting experiments. Addressing these issues will be helpful for teachers and students as well. It will enhance the education system and provide teachers with the resources to develop their understanding to cope with female issues while conducting experiments. The main aim contribution is unique and notable because it gives teachers a comprehensive knowledge of how they can work with female students in laboratories effectively during experimentation and practicals. In addition, the study outcomes will undoubtedly aid the teacher and students in furthering are technical skills or will also increase confidence and knowledge of doing experiments in laboratories in Pakistan. As a result, the findings of this study will contribute to the growing corpus of education research.

In addition, the study might serve as a model for other female students and teachers looking to reduce the problems they face in science laboratories. In the age of gaining hands-on experiences, this study and its practical implications are intended to help all females work confidently in science laboratories, excel in their practical knowledge, and become fully qualified instructors. Female students' perspectives on working in scientific labs and overcoming challenges during practicals are the focus of this research. Their perspectives could provide light on the dynamics between instructors and their female students in the lab if we dig into their stories. Teachers' and students' perspectives on challenges encountered in science labs are, hence, the primary foci of this study. A teacher has the" capacity to improve their female students' problems in science lab through professional development throughout the educational process.

The following Research Objectives serve as the Study's guidelines:

1) To establish the role that science laboratories play in science education.
2) To feel the experience of teachers in the laboratories while experimenting.
3) To find out the problems students go through in the lab while in a practical session.
4) To address how this may be resolved if students and teachers are competent in practicing laboratory-based science investigations.

The following research questions serve as the Study's guidelines:

1) What purpose does a Laboratory in a science education setting serve for science?
2) What is your experience of lab experiments?
3) What are some of the problems that female students experience when in the science laboratory

during practicals?
4) How do these problems get solved by female students in science experiments or laboratories?

2 Review of Theoretical Literature

Scientific educators have argued that students learn a great deal more when they participate in hands-on activities in a laboratory setting, which has led to the laboratory's elevated status in the field of scientific education. Historically, high school science curricula have relied heavily on laboratory activities because of the unique nature of the learning environment, which is a scientific laboratory (Liu et al., 2017; Vadapally, 2014). Teachers of science have reached a consensus: their pupils have benefited much from these exercises. When students asked questions and received answers to their concerns, they were able to acquire and comprehend scientific concepts in the lab (Ahmed et al., 2020; Oliveira & Bonito, 2023; Vadapally, 2014). Experience curricula are now widely accepted as fundamental in our modern elementary schools, and educators have been striving to provide purposeful experiences for children in every area of study; no field of work offers as great an opportunity for enriching children’s experience as science (Emeka et al., 2021; Shibayama, 2019). The laboratory is an integral part of science instruction at the secondary and college levels (Gamage et al., 2020).

The science laboratory has always been regarded as the place where students should learn the process of doing science (Luse & Rursch, 2021; Steger et al., 2020). However, summaries of research on the value of laboratory for learning science did not favor laboratory over lecture demonstration, and more recent studies also show an appalling lack of effectiveness of laboratory instruction. Our studies showed that most students in laboratories gained little insight either regarding the key science concepts involved or toward the process of knowledge construction (Ahmed et al., 2020; Casad et al., 2021; Shibayama, 2019; Oliveira & Bonito, 2023). The traditional expository laboratory has been designed so that the activities can be performed simultaneously by a large number of students, with minimal involvement from the instructor, at a low cost, and within a two- to three-hour time span. It has evolved into its present form from the need to minimize resources, particularly time, space, equipment, and personnel (Ahmed et al., 2020).

Lab instruction primarily aims to instruct students in the "doing" of science. Additionally, it is advantageous to prepare pupils for studying in a laboratory setting. Teaching experimental procedures should be explicitly included as a third point. In laboratory settings, it is essential to take into account the emotions, motives, and expectations of the learners (Seery et al., 2019). The most crucial aspect of good physics instruction is including practical laboratory exercises to back up theoretical concepts. In most cases, the goal of laboratory exercises is to help students become better scientists by observing them while they carry out experiments (Usman & Yakubu, 2020; Waters, 2012). For a long time, students of physics have participated in hands-on laboratory exercises, and teachers of the subject have argued that their pupils would gain much from such an approach to learning. Additionally, it was emphasized that inquiry methods, when used in physics laboratory courses at the university level, show that students are more engaged and that they are more inductive than conventional methods (Ojediran et al., 2014).

Students often spend a lot of time collecting data in conventional laboratory work and then undertake fundamental analyses and manipulations with that data. Multiple types of technology-assisted laboratory work, such as simulation-based laboratory (SBL) and mobile-based laboratory (MBL), arose to address these concerns (Liu et al., 2017). The benefits of SBL are many, and they include being easy to regulate, safe, economical, pollution-free, adaptable, extensible, and efficient with time (Usman & Yakubu, 2020). Nonetheless, learners may be led astray by their innocent assumptions and misunderstandings caused by this tactile learning experience. Students would not learn enough about practical experimental design or critical thinking skills to understand the outcomes of such an event. So, using MBL in a controlled environment is still seen to be the best method. In a flash, students may change the experimental data. Providing experimental data alongside model predictions expedites data gathering and the acceptance of the manuscript (Liu et al., 2017).

Laboratory exercises are efficiently designed to fit into restricted student schedules (Waters, 2012). The results of the exercise are predetermined, allowing assessment of the student's performance. Conducive and manageable for courses with large student enrollment. It can cover multiple biological concepts within a course. Laboratory exercises can be created into modular exercises that correspond with classroom lectures (Waters, 2012). In a laboratory setting, students work in groups and engage in a variety of activities, including problem-solving, negotiation, and the development of their scientific vocabulary to articulate and communicate ideas. Students work together in groups to complete laboratory tasks and come up with detailed explanations (Oliveira & Bonito, 2023).

Students should get a solid grounding in experimental physics and data analysis with the support of the laboratory's comprehensive set of resources. Students need to get much practice with different kinds of lab equipment, but it is hard to say what every physics lab should contain. Additionally, it is recommended that students have access to a wide variety of laboratory equipment for the purpose of conducting observations. Students are expected to get a solid grasp of fundamental physics topics in the laboratory. There is mounting evidence in the field of physics education that traditional classroom practices, textbook issues, and experiment verification make it difficult for most students to grasp fundamental physical ideas. According to this research, students' learning is enhanced when they actively tackle challenging ideas (Ojediran et al., 2014).

Participation in laboratory activities has the potential to foster intellectual growth by providing opportunities to practice inquiry and problem-solving. In addition, they said that engaging in laboratory activities might facilitate the acquisition of specific manipulative and observational abilities, as well as a comprehension of scientific ideas. Students may get a better grasp of the complexities and uncertainties of empirical work and hone their practical abilities in a laboratory setting. The success rate in achieving these objectives in laboratory settings varies between educational levels. It is influenced by factors such as teacher expertise, classroom resources, how healthy labs are integrated with other lessons, and student's background knowledge and experiences. There can be no uniform justification for the many scientific learning objectives. Students may construct molecular-level explanations of macroscopic events and build upon intuitive concepts in science labs (Chiu et al., 2015). Day et al. (2016) found that although male and female students equally share lab equipment, female students spend more time on non-technological activities like writing and chatting with classmates.

2.1 Female Issues Regarding Science Laboratories

Even though these cookbook verification experiments have their limits in instruction, they are nevertheless used as the basis for most organic chemistry labs at the undergraduate level (Bruck & Towns, 2013; Jumamuratov & Kobeysinovich, 2021; Seery et al., 2019). The chance for students to understand how their experiments relate to a real-world situation is often absent from these laboratories. Our current programs and experiments need to be rethought so that we may use questions as springboards for lab studies. Students will be able to actively engage in the process of organic chemistry experimentation using this question-driven, guided-inquiry method of laboratory instruction (Casad et al., 2021; Jabeen & Afzal, 2020). Lesotho, a country that tolerates female subordination, has many girls who do not like science because of gender discrimination. As a result of male dominance, male teachers create an unwelcoming learning environment for girls in science classes by, among other things, harassing, harshly reprimanding, and denying them opportunities to participate in class and use laboratory equipment. This has led to a number of suggestions for dealing with the issue (Avolio, 2020).

Traditionally, science educators have relied on students' written reports submitted either during or after laboratory exercises to evaluate their performance. The minimal information on the student's behavior and performance during the practical exercise is provided by this assessment approach, which is unfortunate (Shambare & Simuja, 2022). In high school, there are two main issues with labs (Liu et al., 2017; Vadapally, 2014). First, students pay close attention to how to fit experimental data into existing theories as they follow the lab instructions step-by-step. Scientific model fitting to data is not a common assignment for students. Second, accuracy and sampling rates are both negatively affected by the generally sluggish data recording techniques. So, rather than concentrating on helping students learn to think and ask questions critically, science educators place an excessive emphasis on the memorization of facts and figures found in textbooks. This leads to pupils having trouble with scientific inquiry, explanation, and formulation, as well as with collecting evidence to back up scientific theories. We need to rethink how we teach science because of this. According to previous studies, students' proficiency in scientific laboratory work was improved when they learned by conducting their experiments (Liu et al., 2017).

2.2 Gaps from the Previous Studies

The following limitations were found in the previous research.

- The previous studies in the context of Pakistan are limited to this concept of addressing female issues faced in science laboratories. There were fewer studies related to this concept. Previous research mostly used quantitative methods for data collection. However, less emphasis is given to qualitative research design.
- In underdeveloped Nations, including Pakistan, female issues in a science lab are a reasonably recent phenomenon in science education.
- Female issues in science laboratories are less discussed in Pakistan. Science education programs are highly organized and center around apparent apprenticeships.
- When students and teachers were asked about science laboratories during practical teaching, most of them had little idea of this concept and about operators.
- Few research studies have addressed female issues in the science lab to improve their practical knowledge and help them become more confident towards the sciences.
- Female issues in a science lab are a major problem in science education. The concept has been well established in various developed countries; however, it still has to be organized into developing contests such as those in Pakistan.

3 Methodology

3.1 Research Design

This study employs a qualitative research design to explore the role of science laboratories in science education at the university level, focusing on the experiences of female students and their instructors. The qualitative approach allows for an in-depth understanding of the participants' perspectives, providing rich, detailed data on the educational impact of laboratory environments, the challenges faced, and the coping strategies employed.

3.2 Participants

The study involved a purposive sample of female students and science instructors from various university departments, including biology, chemistry, physics, and engineering, at a major university in Pakistan. A total of 20 female students and ten science instructors participated in the study. Their enthusiasm for sharing their experiences and active participation in scientific laboratory activities were the deciding factors in the participants' selection.

3.3 Data Collection

The information was gathered by means of focus groups and semi-structured interviews. To further understand the ten science teachers' perspectives on student difficulties and their own experiences with lab experiments, we administered semi-structured interviews to all of them. Two sets of 10 female students participated in focus groups designed to promote candid discussion about laboratory experiences, difficulties, and coping mechanisms.

3.4 Interview and Discussion Guides

The interview and discussion guides were developed based on the study’s objectives and relevant literature. Key topics included:

- The role of science laboratories in enhancing scientific understanding and skills.
- Instructors' experiences in conducting laboratory experiments.
- Challenges faced by female students during laboratory practicals.
- Strategies for coping with these challenges.

4 Data Analysis

Using thematic analysis, which involves discovering, analyzing, and reporting data patterns (themes), we analyzed the data. Audio recordings of the interviews and focus groups were then transcribed word for word. Subsequently, important topics pertinent to the study's aims were extracted from the transcripts using a rigorous coding process.

4.1 Thematic Analysis Process:

1) Acquaintance with Data: The transcripts were read many times in order to understand the data fully.
2) Creating Initial Codes: The first step was to create initial codes that would help us discover the most critical data elements that were pertinent to our study topics.
3) Themes Searching: All pertinent data was gathered under each topic once codes were compiled into possible themes.
4) We double-checked the themes to make sure they made sense and gave a true picture of the facts.
5) Coming Up with Clear Names and Definitions for Themes: We made sure that every theme had a clear name and explanation.
6) Report Preparation: Finally, the data had to be analyzed by picking out strong instances and connecting them to the study objectives and the literature.

4.2 Trustworthiness and Validity

The use of many strategies guaranteed the study's validity and reliability:

- Triangulation: To ensure a thorough grasp of the study subject, data were gathered from many sources, including students and teachers. This technique is known as triangulation.
- Member Verification: The transcripts of the interviews and conversations were made available to the participants so they could verify that the data was accurate.
- Peer debriefing: Researchers checked in with other professionals in the field and their colleagues to make sure their interpretations were credible and reliable.

4.3 Ethical Considerations

The participants' rights and welfare were safeguarded by the study's adherence to ethical norms. Prior to data collection, all participants were asked to provide their informed permission. The participants were given the assurance that their replies would be kept secret and that they may withdraw from the research whenever they wanted without facing any repercussions. An appropriate institutional review board gave its stamp of approval before the research could begin.

5 Analysis

5.1 Experiential Learning and Skill Development

An evident pattern in the participants' feedback is the essential significance of hands-on learning in scientific labs. Participants stressed the importance of practical experience in translating academic knowledge into practical comprehension. A participant emphasized that doing experiments and directly viewing scientific phenomena significantly improves cognitive comprehension and long-term recall of intricate scientific ideas. Participating in this hands-on experience enables female students to cultivate vital competencies such as critical thinking, problem-solving, and analytical reasoning. These abilities are not only crucial for scientific investigation but also applicable to several academic disciplines and potential professional paths. Science labs enhance understanding of intricate scientific topics by offering a practical framework for visualization and comprehension, therefore making abstract ideas more remembered. Participants emphasized the need to cultivate technical expertise, asserting that being well-versed in laboratory equipment and processes is essential for conducting studies with efficiency. This practical approach fosters a solid basis for scientific literacy, empowering female students with the necessary practical skills for academic and professional achievement. The topic emphasizes that hands-on learning in science labs is crucial for improving female students' understanding and practical use of scientific information.

5.2 Confidence Building and Overcoming Stereotypes

The laboratory setting is crucial in fostering self-assurance and questioning societal preconceptions. Participating in laboratory work enables female students to acquire proficiency in techniques and procedures, promoting a feeling of achievement and self-confidence. A participant highlighted that female students can challenge the prevailing male-dominated narrative of the sciences by engaging actively in experiments and perceiving themselves as competent scientists. The change in perspective is crucial for motivating a fresh cohort of female scientists who possess self-assurance in their capabilities and are enthusiastic about making contributions to scientific progress. Laboratory experiences can help female students challenge stereotypes and overcome societal barriers related to gender roles in science. Throughout history, there has been a lack of female representation in scientific disciplines, and engaging in laboratory activities can be instrumental in dismantling these obstacles. Female students can develop the necessary self-assurance to pursue additional studies and careers in STEM fields by engaging in scientific investigations. This theme emphasizes the significance of establishing an all-encompassing and encouraging laboratory setting where female students are esteemed and empowered to make equal contributions to scientific pursuits.

5.3 Collaboration and Teamwork

Another notable topic is the potential for cooperation and teamwork facilitated by the laboratory environment. Participants emphasized that collaborating with colleagues in a laboratory setting fosters effective communication, cooperation, and the sharing of ideas. "Engaging in collaborative experimentation facilitated the incorporation of varied viewpoints and resolutions, thereby enhancing the educational experience," one participant said. The collaborative nature of this environment reflects the dynamics of real-world scientific research settings and aids in the development of female students' readiness for future professional engagements in scientific disciplines. The laboratory setting promotes a feeling of camaraderie and reciprocal assistance, establishing it as a place for collaborative exploration and education. Participants highlighted the significance of cooperation in labs for the development of crucial skills, including communication, coordination, and conflict resolution, which are needed for success in any professional domain, particularly for female students. In addition, collaborating in groups may foster a nurturing environment where female students are encouraged to express their thoughts, seek clarification, and investigate scientific inquiries without any reluctance. This feeling of belonging and reciprocal support is especially crucial in combating the lack of representation of women in STEM fields. The subject emphasizes the significance of cooperation and teamwork in improving the learning experiences of female students in scientific labs.

5.4 Challenges Faced by Female Students

Although there are advantages, female students often encounter several obstacles in scientific labs. Participants repeatedly highlighted the presence of gender prejudice and stereotyping, acknowledging that these biases have the potential to erode confidence and foster feelings of exclusion. A participant explained that evaluation and assessment techniques might be influenced by unconscious bias, which could impact the perception and rating of their work. These prejudices might appear subtly, for example, in the form of preconceptions about the technical capabilities of female students or preferences for specific positions in group work. Furthermore, female students may be disproportionately impacted by practical considerations pertaining to physical infrastructure and safety concerns. Factors such as insufficient seating, unfavorable temperatures, or inadequately built equipment might hinder the ability to fully engage in laboratory tasks. Issues related to safety, such as misconduct from classmates or teachers, poor safety procedures, or lack of proper protective gear, may lead to feelings of vulnerability or unease. Participants emphasized that female students have a particularly difficult task in managing academic obligations with personal commitments and cultural expectations. Family duties, community standards, or cultural expectations might exert pressures that hinder individuals from fully participating in laboratory work or pursuing scientific interests. To tackle these difficulties, it is necessary to take proactive measures to encourage diversity, provide good examples to follow, guarantee accessibility and safety, and assist in maintaining a healthy work-life balance.

5.5 Coping Strategies and Support Systems

In order to address these difficulties, participants proposed several ways. Developing self-assurance and demonstrating one's abilities in the laboratory environment is of utmost importance. One participant recommended that female students engage actively in group discussions, pose questions, and share their thoughts during investigations. Obtaining mentoring from female role models who have successfully overcome comparable obstacles may provide vital direction and support. Participants highlighted the significance of cultivating proficient technical abilities and being well-acquainted with laboratory apparatus. Acquiring knowledge of laboratory processes, safety standards, and equipment operation helps boost confidence and proficiency in conducting experiments with efficiency. Furthermore, it is crucial to always have a proactive stance towards ensuring safety and well-being. Female students should acquaint themselves with safety practices, don suitable protective equipment, and quickly notify laboratory personnel or teachers of any safety issues. By prioritizing personal safety and advocating for a safe learning environment, one exhibits responsibility and promotes a focused pursuit of scientific inquiry, free from distractions or threats. Participants emphasized the need to maintain a harmonious equilibrium between academic obligations and personal well-being. By establishing attainable objectives, using stress-mitigation strategies, and seeking assistance when necessary, individuals may decrease stress and improve their overall state of well-being. By using these tactics, female students may proficiently handle difficulties encountered in scientific experiments or labs, establishing themselves for triumph in their scholastic endeavors and prospective professions in STEM sectors.

6 Findings

The thematic analysis of the role and experiences of female students in scientific labs yielded some noteworthy results that underscore the varied impact of laboratory settings on the education of female students in the sciences. These results might be beneficial in addressing gender disparities in STEM education and promoting more inclusive and supportive learning environments.

- Science labs are crucial for experiential learning, enabling students to put theoretical knowledge into practice and acquire tangible comprehension. Active engagement in hands-on activities enables female students to develop essential skills such as critical thinking, problem-solving, and analytical reasoning. These qualities are crucial for scientific exploration and may be readily applied to other disciplines of study and future careers. Laboratories augment the grasp and retention of abstract ideas by making them more tangible and indelible, so fortifying classroom instruction and heightening overall knowledge.

- Laboratory work significantly boosts confidence and self-efficacy in female students. By acquiring expertise in laboratory techniques and processes, students develop a profound feeling of accomplishment, hence enhancing their drive to pursue higher studies and careers in STEM areas. Engaging in laboratory experiences is crucial for challenging and interrogating traditional assumptions and biases related to gender. Active participation in experiments empowers female students to see themselves as capable scientists, breaking down traditional gender barriers and inspiring them to make significant contributions to scientific advancement.

- Science labs provide a collaborative environment that fosters the development of teamwork and communication skills. Engaging in collaboration with colleagues promotes the exchange of ideas and diverse perspectives, therefore enriching the educational experience. The collaborative character of this partnership mirrors the real-world setting of scientific research, providing female students with the essential skills for future professional involvement in scientific fields. The camaraderie and reciprocal assistance cultivated in labs provide an amicable atmosphere where students are motivated to openly share ideas and engage in scientific inquiries without any hesitation.

- Female students may face challenges in scientific labs, including gender bias, stereotyping, and practical concerns related to physical infrastructure and safety, despite the benefits. Unconscious bias within evaluation and assessment procedures may undermine confidence and cultivate a sense of exclusion. Female children may be more affected by practical difficulties, such as a lack of seating, uncomfortable temperatures, or badly constructed equipment. Moreover, the existence of safety concerns and the need to balance academic responsibilities with personal engagements pose significant challenges.

- Female students may use several strategies to effectively deal with these challenges. Cultivating self-confidence and asserting one's expertise in the laboratory setting is crucial. Seeking mentorship from female role models and actively promoting diversity and equality in the laboratory environment are essential strategies for overcoming hurdles. Gaining advanced technical skills and embracing a proactive approach to safety and well-being may enhance confidence and expertise in laboratory work. Ensuring long-term success necessitates maintaining a harmonious equilibrium between academic obligations and personal well-being via the use of effective time management and stress-management strategies.

- In order to achieve gender parity in STEM fields, it is essential to provide female students with well-equipped labs and friendly learning environments. Enforcing proactive strategies to address gender bias, fostering influential female figures, ensuring equal opportunities and security, and advocating for a healthy work-life equilibrium is crucial in motivating female students to flourish in the area of science. Encouraging the creation of learning environments that are open to everyone and treat everyone reasonably may support the growth of aspiring female scientists and improve the representation of diverse individuals in STEM areas.

- Participating in laboratory activities can cultivate a long-lasting interest and curiosity in science among female students. The excitement of discovering new information and the invigorating process of performing experiments ignite a profound passion for science that goes beyond the boundaries of the educational environment. Long-term engagement in scientific research and occupations relies on the presence of intrinsic drive. Establishing dynamic and captivating learning settings in science labs cultivates a genuine inquisitiveness in scientific exploration and innovation.

- Science labs are essential for enhancing the academic performance and professional readiness of female students. Laboratories bolster the practical aptitude of female students by reinforcing theoretical concepts and fostering crucial laboratory competencies, so equipping them for academic and professional accomplishments. Providing female students with easier access to supportive and inclusive laboratory environments may improve their academic achievements and empower them to pursue fulfilling careers in STEM fields.
- Laboratory experiences play a vital role in helping female students overcome social barriers related to gender norms in the scientific profession. By actively participating in scientific initiatives, female students may challenge traditional gender stereotypes and develop a strong belief in their talents as scientists. Altering perspectives is essential for enhancing women's self-assurance and inspiring them to actively contribute to scientific advancements. This will contribute to the advancement of gender equality in STEM disciplines.

7 Discussion

The findings from the thematic analysis of female students' experiences in scientific labs underscore the importance of hands-on, experiential learning in enhancing their educational performance. Laboratories provide a vital environment where theoretical knowledge is transformed into practical understanding, significantly boosting the acquisition and retention of scientific concepts. This aligns with previous research that highlights the benefits of hands-on learning in STEM education (Feder et al., 2016). Observers noted that these environments not only foster essential skills such as critical thinking and problem-solving but also prepare students for real-world scientific research situations. Participating in hands-on activities is crucial for cultivating a thorough understanding of scientific concepts and advancing the overarching objective of scientific literacy.

Moreover, the laboratory setting plays a vital role in promoting confidence and challenging conventional gender conventions. Female students reported experiencing a sense of accomplishment and self-assurance as they gained proficiency in laboratory operations. This, in turn, serves as a catalyst for their increased engagement in STEM fields. Recent studies have shown that good experiences in laboratory settings may successfully mitigate gender biases and increase women's motivation to pursue careers in STEM disciplines (Banchefsky et al., 2016; Wang & Degol, 2017). The collaborative nature of laboratory work also fosters a supportive community, which is essential for empowering female students to participate actively in scientific inquiries. However, despite these benefits, female students still face challenges such as gender bias, inadequate resources, and concerns about safety. In order to address these issues, it is imperative to implement proactive strategies that promote inclusivity, provide mentoring opportunities, and provide equitable access to resources.

Key strategies to tackle these challenges are seeking guidance from female mentors, gaining proficiency in technology, and advocating for inclusivity. A recent research conducted by Moss-Racusin et al. (2015) has shown that mentoring and supportive networks have a significant positive impact on the academic and career accomplishments of women in STEM disciplines. In order to enhance the achievement of female students in scientific pursuits, educators and organizations may create laboratory environments that are both inclusive and supportive. These efforts are crucial for advancing gender equality in STEM fields and nurturing the next generation of female scientists.

7.1 Conclusion

This research underscores the vital importance of science labs in the education of female students, emphasizing how these environments translate theoretical knowledge into practical comprehension, hence enhancing the comprehension and retention of scientific ideas. Science labs not only provide female students with essential skills such as critical thinking, problem-solving, and analytical reasoning but also prepare them for authentic scientific research settings. The findings underscore the significance of experiential learning in fostering a thorough understanding of scientific concepts and advancing broader educational objectives.

Furthermore, the study indicates that participating in laboratory experiments significantly contributes to the development of self-confidence and the challenging of gender prejudices among female students. Acquiring expertise in laboratory methods fosters a sense of accomplishment and self-assurance, hence encouraging more engagement in STEM fields. The collaborative nature of laboratory work fosters a supportive environment, enabling female students to participate actively in scientific inquiries with confidence. However, the challenges faced by female students, such as gender bias, inadequate facilities, and concerns about safety, need proactive actions to promote inclusivity and provide equitable access to resources.

Effective strategies for addressing these obstacles include seeking guidance from female mentors, enhancing technical expertise, and advocating for diversity. Mentorship and supportive networks play a crucial role in enhancing the academic and career accomplishments of women in STEM. To boost the success of female students in their scientific pursuits, instructors and institutions may create laboratory settings that are more inclusive and friendly, thereby helping to overcome hurdles. These efforts are crucial for advancing gender equality in STEM fields and nurturing the next generation of female scientists. To summarize, addressing these issues will result in more diversity in STEM professions and cultivate a scientifically literate community.

7.2 Recommendations

- It is recommended that educational institutions facilitate the connection between female students and female scientists and professionals in the field of STEM. These programs have to include frequent engagements, seminars, and chances for professional connections.
- The curricula should emphasize the achievements of female scientists and include teaching methods that are sensitive to gender differences.
- Institutions must guarantee that laboratory infrastructure is easily accessible, constructed with ergonomics in mind, and equipped with sufficient safety precautions.
- Educational institutions should include unconscious bias training to enhance instructors' and students' understanding of gender prejudices and stereotypes.

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