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Laboratory Anxiety: Prevalence and Overcoming the Challenges among Indian Secondary School Students

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Abstract

The association of negative emotions with the triumph of scientific inquiry requires focus as an area of research, since it has long been established that learning by doing is the highest form of engagement in science. This study addresses laboratory anxiety, its prevalence, and the barriers that inhibit students' full participation. It also proposes a self-directed learning strategy to mitigate anxiety. An initial sample of 121 students, selected through purposive sampling, was studied to measure the prevalence in a study primarily conducted using a sequential explanatory mixed-methods approach. Then, 19 students who showed a high level of anxiety were interviewed to understand the cause behind anxiety, and they were further administered a self-directed learning strategy containing elements derived from the conclusions of student interviews. A significant prevalence of laboratory anxiety was found among school students. Based on the self-directed learning strategy, the results revealed a significant decrease in overall laboratory anxiety, and individual improvement was observed for components of the execution of experiment, laboratory safety, use of chemicals, and use of material and equipment. These findings highlight the need for curriculum interventions and revised teaching methodologies that support emotionally safe and effective science learning environments.

Keywords: Laboratory Anxiety; Laboratory Safety; Science Education; Secondary School Students; Self-directed Learning

Introduction

Anxiety, as a concept, is commonly referred to as an unpleasant emotional state characterised by excessive degrees of fear, worry, and apprehension without a specific object or cause; it is initiated by feelings as a response to a perceived threat (Casbarro, 2005; Putwain, 2008). Anxiety is a complex phenomenon that has been defined and understood differently across various fields of study and disciplines. Mallow (1986) defined science anxiety as the disgust or fear of science concepts, scientists, and scientific activities. Mallow (2006) has also shown science anxiety to be a phenomenon that can impede learning. The distinctness of science anxiety from general anxiety lies in the ability of students to stay calm in non-science courses as compared to science courses.

Anxiety has been studied extensively across all three major branches of science, both in the classroom and laboratory environment. These anxieties are accompanied by various causes, such as a fear of chemicals and chemistry classes (McCarthy & Widanski, 2009), incapability to perform experiments involving living specimens, unclear biological concepts, poor handling of laboratory equipment (Kurbanoğlu, 2014), apply theoretical knowledge in situations based on practice, manipulate laboratory materials, and make comments on results (Berber 2013). Moreover, the other causes of science laboratory anxiety include past bad experiences in science classes, exposure to science-anxious teachers who are teaching science in elementary and secondary schools, lack of role models, gender and racial stereotyping, and scientists' stereotyping in the popular media. The symptoms of anxiety are reflected as students' emotional reactions, such as timidity and shyness, and the physical indications of these emotions (Turner & Lindsay, 2003).

Anxiety about the laboratory has been known to influence students' performance (Eddy, 2000; Wynstra & Cummings, 1993). This fear towards laboratory activities can also be characterised by a disappointment among the students regarding the subject (Jegede, 2007), which can also eventually make them lose interest in that subject area (Keeves & Morgenstern, 1992). Though some degree of anxiety may be helpful in the learning process, a high level of anxiety impedes optimum performance on science learning (Udo, Ramsey, & Mallow, 2004). Therefore, to overcome anxiety, it is pertinent to generate a belief in one's ability to perform. Bandura's theory highlights that perceived self-efficacy directly relates to their task performance and choice behaviour (Bandura, 1986). Among high school students, science self-efficacy is a better predictor of achievement and engagement with science-related activities than gender, ethnicity, and parental background (Kupermintz, 2002; Lau & Roeser, 2002; Lodewyk & Winne, 2005).

Many researchers have highlighted and studied methods for overcoming anxiety and its impact on student learning. Ercan (2014) assessed the role of 5E learning cycle and V diagrams in decreasing anxiety. Güven, Cam, and Sülün (2015) used an approach based on case-based laboratory activities in reducing chemistry lab anxiety among preservice teachers. Damo et al. (2020) proposed overcoming anxiety among undergraduate students with the help of technology-related activities. Action research by Sesen and Mutlu (2014) highlighted a strategy to overcome challenges faced by undergraduate students in science laboratories. Although the review suggests implications of research in reducing anxiety, not much research has been conducted that deals with addressing laboratory anxiety among school students. Overall challenges in an integrated science laboratory in the context of laboratory anxiety need to be explored, especially in the context of the Indian education system, since in most circumstances, laboratories remain a very unexplored territory for students.

Most studies have emphasised that the use of a project-based learning process for self-learning in a chemistry laboratory (Alkan & Erdem, 2013) requires a lot of time in the laboratory for performing experiments (Erokten, 2012), and uses effective educational strategies (Kaya & Cetin, 2012). Moreover, approaches or methods in the laboratory, such as argumentation and reflection based on the activities, can reduce anxiety towards laboratory. Apart from these methods, the development of self-belief can play a major role in reducing the anxiety of students related to participation in laboratories (Chan et al., 2021; Ekici, 2011). Research has confirmed that science self-efficacy, which is students' "belief in their ability to succeed in science tasks, courses, or activities" (Britner & Pajares, 2006; Gunes & Ozsoy, 2016), influences a variety of factors related to student achievement. Studies also suggest that students with higher science self-efficacy are more engaged and successful in science than their peers with lower science self-efficacy (Bouffard-Bouchard, Parent, & Larivee, 1991; Lau & Roeser, 2002). Therefore, building self-efficacy was considered a beneficial option for overcoming anxiety among school students (Kapici et al., 2020; Makransky et al., 2020). Pre-laboratory preparations in the form of simulations or discussions can positively affect laboratory participation, as they can promote students' readiness for exploring. Hence, research was designed based on this principle, which could identify and address the gaps associated with the following research questions:

1) What are the anxiety levels of students towards science laboratory?
2) What are the probable causes for the incidence of laboratory anxiety among students?
3) Does a self-directed learning strategy influence laboratory anxiety of students?

Therefore, this study has used an explanatory mixed-method design to measure the anxiety levels and understand the underlying causes for their prevalence. Also, a self-directed learning strategy has been proposed to mitigate anxiety among students. The self-directed learning strategy was devised based on conclusions for probable causes derived from interviews conducted in the qualitative phase of the study. The identified elements of learning strategy can be actively integrated into the curriculum and implemented for the creation of a positive learning environment.

Methodology

Participants

The sample for the study consisted of 57 (47%) girls and 64 (53%) boys from secondary schools. A purposive sampling design was used since only those schools were selected that had a functional laboratory available and were easily accessible to both students and teachers. A nested design of sampling was selected, wherein sample members selected from the quantitative phase were used for conducting interviews and for carrying out the experimental research. Therefore, 19 students falling in the range of higher anxiety levels were selected for the interview. After obtaining necessary consent and permissions, these students also agreed to be a part of the experimental group.

Design

A sequential explanatory mixed-method study design was implemented in which a quantitative descriptive survey was used to assess the prevalence of laboratory anxiety among secondary school students. As a part of the qualitative strand, subsequent follow-up interviews were conducted to establish the causes of anxiety. Taking the causes as a basis, a self-directed learning strategy was implemented as a pretest-posttest design. The 19 participants for the experimental design were selected from the quantitative phase and were the ones reflecting high levels of anxiety. These participants formed part of a single group, which was assessed before and after the intervention.

Instruments

The Laboratory Anxiety Scale was developed to measure the incidence of laboratory anxiety among secondary school students. A pool of 36 items was generated based on the theoretical dimensions of the construct and a review of literature. Items were prepared that dealt with feelings and emotions that can be felt altogether in subjects of Physics, Chemistry, and Biology. A Likert scale was used with options ranging from 1 to 4 (Always to Never). The midpoint or neutral option was not used in the current scale, as it has been recommended that the removal of midpoint acts as a better measure for assessing the intensity of participants' attitude. Moreover, midpoints are used by respondents as dumping grounds (Stone, 2004), so that such respondents tend to appear as non-committal. In total, 15 items were reverse-scored to lessen the acquiescence bias generated by the respondents while answering the scale items. The initial item pool was reviewed by eight experts, including science educators, Psychology professors, and language experts, to establish the content validity of the tool. Items were modified and retained as suggested by experts, and an item-total correlation was used to reveal a final scale with 20 items. The dimensions of scale were as follows: anxiety related to the use of chemicals (6), use of materials and equipment (5), laboratory safety (5), and execution of experiment (4). The reliability coefficient of Cronbach's Alpha was found to be 0.81.

The learning strategy based on Bandura's theory was used for designing the experimental strategy to be implemented. Development of self-efficacy has been known to reduce laboratory anxiety (Chan et al., 2021). The main idea behind selecting the different components and elements to be a part of the learning strategy was based on the causes of incidence, derived from interviews and extensive deliberation on the review of proven techniques that have been pertinent in overcoming anxiety. To extract elements that were a part of the learning strategy, firstly, coding and categorising raw transcripts of information into meaningful phrases, sentences, and categories was done. Secondly, comparisons and linkages between various categories were carried out to draw major themes. Lastly, theoretical conclusions in the form of discussions were drawn out from the data (Cohen et al., 2002).

Therefore, the self-directed learning strategy comprises elements drawn from research interviews and review of literature that could enhance self-efficacy and allow students to be independent in dealing with anxiety, such as:

- Students were provided with access to web-based simulations in accordance with their curriculum for grades 10 to 12. Lab on laptop, Praxi lab, and virtual labs (Ministry of Education initiative) were a few of the applications used.
- Detailed information was given on lab safety, rules, and regulations.
- Myths about laboratory accidents were clarified, and first aid in case of laboratory accidents was discussed.
- Trips to science laboratories in government-led institutes and universities were planned.
- Information related to materials and equipment used in the laboratory.
- Self-help content about how to analyse and represent data after completion of experiments.
- Talks with researchers sharing significant research experience.

Results and Discussion

Incidence of Laboratory Anxiety among Secondary School Children

The results obtained after administration of the Laboratory Anxiety Scale showed that out of 121 students 16% (n=19) had high levels of anxiety, 28% (n=34) depicted moderate anxiety, and 56% (n=68) reflected low levels of anxiety for science laboratories. Various factors that contributed to the prevalence of anxiety towards science laboratories (the mean percentage as shown in Figure 1) were found to be the highest for execution of experiment (48%), followed by use of chemicals (44%), use of materials and equipment (42%), and lab safety (39%).

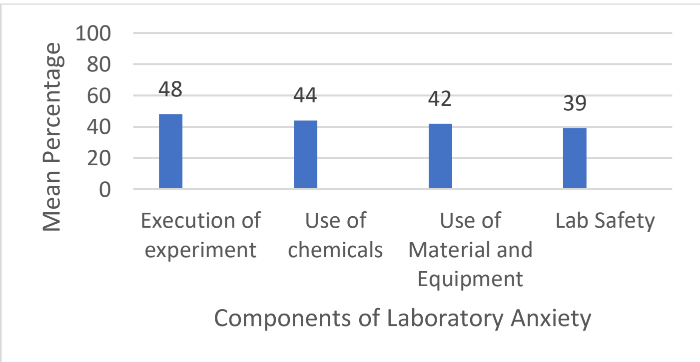

Figure 1. Percentage Distribution of Each Component of Laboratory Anxiety

Causes for the Incidence of Laboratory Anxiety among Secondary School Students

The students with high levels of laboratory anxiety were interviewed to discuss the factors responsible for the incidence of the current problem. On achieving a theoretical saturation, the data were coded and brought together in major themes, which are of the following nature. It was found that initially, the mental resistance of the child to not knowing what to expect was one of the reasons for being anxious. Low motivation prevailed among students as they felt actual learning could only happen from textbooks. The methodology followed for experimenting was a cookbook-type approach, which was considered equivalent to rote learning. They reinforced it into a procedure, involving meticulous recall of chemical quantities or the precise retention of electrical connections essential for a physics laboratory, demanding extensive memorisation. Therefore, the execution of experiment contributed as the highest factor towards laboratory anxiety as represented in Figure 2. Students often found it challenging to interpret the readings, which are crucial for depicting the results of an experiment. This difficulty made them apprehensive about potentially providing an incorrect evaluation of the outcome. Some individuals experienced anxiety merely being near glassware and expensive equipment, feeling ill-prepared to handle potential mistakes, which is reflected as a 42% contribution in mean percentage for use of material and equipment (Figure 2). These instances report nothing else but a lack of awareness of laboratory safety rules and regulations, working with equipment, and a general lack of practical manifestation of science principles. The idea of going to a laboratory was not a matter of hatred for the students, but not knowing what, how, and why things function in a laboratory made them disinterested in the concept.

Influence of Self-directed Learning Strategy on Laboratory Anxiety

By using student interviews as a basis for designing a self-directed learning strategy, the group of 19 students identified as individuals possessing higher levels of laboratory anxiety were administered the strategy as part of the experimental group. Pretest and posttest results showed significant variation (Figure 2). The mean score differences between the two groups were M (Pre) 57.31 and Post (47.84). This shows a decrease in anxiety levels of the students after undergoing a self-directed strategy to control laboratory anxiety. As represented in Figure 2, analysis of component-wise gain score reveals a major decrease in anxiety for lab safety (22%), followed by execution of experiment (19.1%), use of chemicals (11%), and use of material and equipment (7%). Gender differences were not found to be significant M(female)= 44.4 and M(Male)= 43.8.

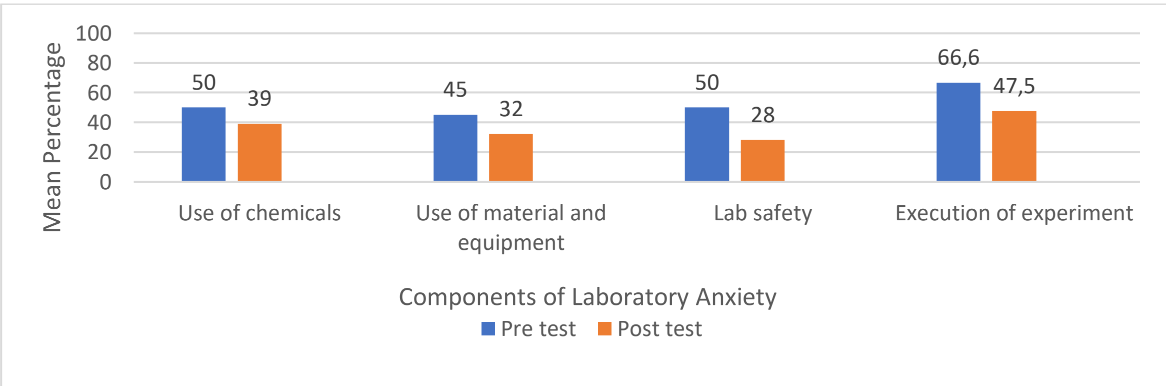

Figure 2. A Difference in Percentage of Laboratory Anxiety for Different Components Measured Before and After Administration of a Self-directed Learning Strategy.

Discussion

The prevalence of laboratory anxiety was reported to be 16% which is not something to be ignored, as increased anxiety is accompanied by a lower self-efficacy that allows for lesser sustainment in a task and lower achievement (Lorsbach & Jinks, 1998; Perry, 2016). Hence, assessment of students scoring lower grades in science can be done by teachers to interpret their anxiety levels towards laboratories.

The study showed anxiety towards the use of chemicals, materials and equipment, and challenges with laboratory safety (Figure 1). These issues have also been experienced and previously discussed in research based on students in India's schools (Sharma & Kumar, 2023). These challenges stem from the root cause of students not being provided with exposure to a laboratory in a true sense. Non-integration of practical and theory as well as using a cookbook approach are certain aspects that disagree with the maxims of inquiry-based learning using laboratory. These are being regularly followed upon in science laboratories and somehow manage to show the unpreparedness of the students (Pareek, 2019; Gupta et al., 2015). Overall, spending more time in the laboratory and performing experiments can help overcome anxiety (Erokten, 2010; Washbourn, 2024). Constructive changes can be brought about, as there was a missing link between the understanding of theoretical concepts and their implementation through a laboratory setup. The timing or duration of experimenting also plays an important role in satiating scientific curiosity (Hofstein & Lunetta, 2004). Since the laboratory classes were not well amalgamated with theory sessions, this seemed to have led to an erosion of interest in students' coherence with the concept, contributing to laboratory anxiety.

The self-directed learning strategy, which was very well supported by the virtual learning environment, has shown a significant improvement in anxiety scores as represented in Figure 2 (Gungor et al., 2022). The findings of the study showed that anxiety related to the execution of experiment and laboratory safety had been overcome in a high percentage (Figure 2). Thus, self-directed learning strategies can be used effectively for addressing anxiety-related issues (Sesen & Mutlu, 2014; Alkan & Erdem, 2013; Kurbangolu & Akin, 2012). The strategy involved technology integration for providing virtual lab experiences, which was less difficult to do as not all students had access to laptops or phones. Therefore, school computer labs were used to provide experience for the students. A detailed laboratory manual prepared for providing information and busting myths was gradually introduced, since immediately burdening students with content will create unnecessary pressure. School alumni were found to have a better connection and approachability with students during research experience sharing. Another observation found that while working with simulations, a few students found confidence initially, but failed to carry this preparedness to a real-life laboratory environment. This can be overcome if the training is provided with a longer duration.

Conclusion

This study confirms that progressive, scaffolded exposure to laboratory settings effectively reduces anxiety and improves competence in science education. Evidence shows that students who tackled increasingly complex lab tasks, with ongoing formative feedback, reported lower anxiety levels and better practical performance—supporting our initial hypothesis about gradual skill development. Based on this data, curriculum designers should incorporate incremental laboratory assignments and regular teacher feedback to boost students' confidence and skills. The findings also support using technology-enhanced simulations—such as augmented or virtual labs—as preparatory tools, especially for students who are initially intimidated by hands-on experiences, since participants who used these tools showed less nervousness during real lab tasks. While educators and curriculum experts can help implement these strategies, this recommendation directly follows from the study's results and not broader assumptions. However, exploratory practices like desensitisation protocols or mindfulness strategies—though promising—were not evaluated here and should be explored in future research. Longitudinal and qualitative studies are needed to understand how anxiety changes over time, identify specific triggers, and evaluate the impact of evidence-based interventions beyond self-directed approaches. Overall, aligning curriculum design with these findings and expanding on them through targeted follow-up research could greatly help reduce laboratory anxiety and promote positive science learning experiences.

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