Journal of Biosafety and Biosecurity 3 (2021) 22–27

Contents lists available at ScienceDirect

Journal of Biosafety and Biosecurity

journal homepage: www.elsevier.com/locate/jobb

Research Article

Laboratory biosafety and biosecurity related education in Pakistan: Engaging students through the Socratic method of learning

Sahrish Muneer [a,b], Hammad Afzal Kayani [b], Kashif Ali [b], Ehtesham Asif [c], Raheela Rehmat Zohra [c], Furqan Kabir [a,b,*]

[a] Department of Paediatrics & Child Health, Aga Khan University, Karachi, Pakistan
[b] Department of Biosciences, Shaheed Zulfiqar Ali Bhutto Institute of Science and Technology, Karachi, Pakistan
[c] Department of Biotechnology, University of Karachi, Pakistan

ARTICLE INFO

Article history:
Received 30 June 2020
Received in revised form 26 February 2021
Accepted 29 March 2021

Keywords:
Laboratory biosafety
Biosecurity
Philosophy of containment
Bio-risk management
Socratic method of learning

ABSTRACT

Background: Laboratory biosafety is currently a major global issue in clinical research and academic laboratories. To alleviate these concerns, subject-specific education of standardized laboratory practices is essential and should be delivered in a comprehensible, interactive, and appealing manner. The objective of the present study was to engage university-level students in laboratory biosafety and biosecurity related education through the Socratic method of learning. A pre/post-test model was implemented to assess the knowledge improvement after the workshop.
Methods: Two workshops were conducted individually at a public and private educational institute in October 2019 and December 2019, respectively. Important concepts were delivered in an interactive engagement format to ensure substantive understanding. Pre- and post-training scores were computed, and a paired *t*-test was used to assess knowledge gain.
Results: Out of the 357 students from both institutes, 320 (90%) provided consent and completed the pre- and post-test questionnaires. The participants lacked a baseline knowledge of laboratory biosafety. A statistically significant increase (14% to 84%) in knowledge was reported among students, with a p-value of < 0.001. Scores improved in the post-test assessment, where 87% were high performers, and only 1% were low-performing students. The difference between the pre- and post-test mean scores was indicative of a substantial 70% improvement in education. Students exhibited high levels of satisfaction with the Socratic method of teaching style.
Conclusion: The study highlighted the significance of the Socratic style of learning for engaging students and improving their knowledge and awareness of laboratory biosafety in academic settings in Pakistan.

1. Introduction

Laboratories play a pivotal role in health systems, academia, and research. In clinical settings, accurate, reliable, and timely diagnostic information is of fundamental importance for making therapeutic and evidence-based decisions about communicable and non-communicable diseases. At the academic and research levels, the health sciences laboratory facilitates scientific and technological exploration with living organisms to gain a conceptual knowledge about the nature of science. Numerous diagnostic, research, academic, public health, and reference laboratories are functional globally, contributing to healthcare improvement. In doing so, researchers, students, technicians, and pathologists working in these laboratories are being exposed to potentially biohazardous agents and are at greater risk of acquiring laboratory-associated infections (LAI). The initial reports of LAI emerged as early as the beginning of the twentieth century, causing more than 4,000 LAIs and over 160 deaths between 1930 and 1978.[1] Similar to diagnostic laboratories, concerns related to LAI have been reported in academic and research laboratories. A report published by the Centre for Disease Control and Prevention (CDC) in 2012 indicated 109 cases of human *Salmonella typhimurium* infections linked with exposure to clinical and teaching microbiology laboratories.[2]

With the advancement of knowledge and data in applied microbiology and biotechnology, challenges besides LAI have been reported. In contrast to LAI, which mainly resulted from unintentional exposure and malpractices, there were multiple incidences

* Corresponding author at: Department of Paediatrics & Child Health, Aga Khan University, Karachi, Pakistan.
E-mail address: furqan.kabir@aku.edu (F. Kabir).

https://doi.org/10.1016/j.jobb.2021.03.003
2588-9338/

of intentional use of microorganisms as biological weapons. Pathogens for diseases such as anthrax, smallpox, plague, and hemorrhagic fever, have been exploited for malevolent intent particularly for bioterrorism and bio-crime over time.[3]

In light of these high-profile incidences, the terms laboratory Biosafety and Biosecurity had surfaced that urged the responsible conduct of science and negated dual-use concerns. International guidelines on laboratory biosafety and biosecurity have been established during this period. Among them, the Laboratory Biosafety guidelines by the World Health Organization,[4] Biosafety in Microbiological and Medical Laboratories (BMBL) by CDC,[5] The Clinical Laboratory Improvement Amendment (CLIA) of 1988, guidelines by the National Institute of Health (NIH), College of American Pathologists (CAP), and Joint Commission (JC) are the most prominent. The main focus of these guidelines is to promote a culture of biosafety and responsibility, both at the individual and organizational levels, to guarantee the health and well-being of work personnel. This can be achieved through safe practices, behavior change education, relevant training, establishing policies, ethics, development of containment principles, and designing appropriate facilities.

A huge gap in knowledge, awareness, and standardized training related to biosafety and biosecurity persists regionally[6] and nationally.[7] This severe lack of education and suboptimal practices among biomedical laboratory staff paved the way for the establishment of the Pakistan Biological Safety Association (PBSA), a non-governmental professional organization in 2008.[8] With the main objective of enhancing the knowledge and practices of professionals and organizations, PBSA has made efforts toward instigating a bio-safe and bio-secure culture through workshops and symposia over time. Unfortunately, the implementation of these guiding principles in clinical laboratory settings remains relatively low in the country. The situation is even more disappointing in educational institutes where biosafety is not a part of the regular curriculum in the government and private sectors. This deficiency of standardized training and knowledge in our setting at the academic level could potentially put students and their immediate environment at the risk of exposure to biohazardous agents. Hence, to ensure maximum compliance toward laboratory biosafety, students should be continuously involved and trained at all stages of their education and research.

The Socratic method (also called the Elenchus or elenctic method) is a pedagogic technique of learning in which students are engaged in reflective and critical thinking. Through this interactive approach, students are exposed to systematic and probing questions intended to activate their thought processes and develop the rationale of concepts under consideration.[9,10] In contrast to traditional instructor-focused and authoritative teaching methods (counting mainly on passive-student lectures), the Socratic method is more learner-centered, giving an opportunity to actively participate in classroom discussions and grasp comprehensive knowledge of issues or concepts. The key to the effectiveness of the Socratic method lies in its potential to co-operatively engage learners and deliver training content in a perspicuous manner, ensuring ample understanding of the subject explored. Thus, it is more likely that these learned attributes are well retained and put into sustainable practice by learners.

Unfortunately, there is a lack of data regarding biosafety practices, applications, and effectiveness of subject-related education and training among students in our context. Therefore, the current study was undertaken to deliver biosafety-related knowledge to students at the University of Karachi (UoK), one of Pakistan's largest universities in the government sector, and at a private institute, Shaheed Zulfiqar Ali Bhutto Institute of Science and Technology (SZABIST), Karachi. We employed the Socratic approach of learning because of its usefulness in enhancing the learning ability of participants, followed by knowledge assessment through pre- and post-test. With this perspective in mind, the present study aimed to engage the students at the institutional level through the Socratic method about the concepts and importance of laboratory biosafety and to assess an increase in awareness through implementing pre-and post-test models.

2. Methods and materials

Two workshops of 3 h each were conducted separately in the Biotechnology Department (UoK) and Biosciences department (SZABIST) in October 2019 and December 2019, respectively.

Students were first administered a pre-test questionnaire to assess their baseline knowledge, followed by a series of interactive questioning by the facilitator to trigger students' thought processes to attain the desired knowledge along the way. Finally, concepts related to laboratory biosafety and biosecurity were clarified, and a post-workshop knowledge assessment was conducted.

2.1. Workshop participants and trainers

A total of 318 students registered for the workshop conducted in October 2019 belonging to multiple life sciences departments at UoK. For the December 2019 workshop at SZABIST, 39 students, mainly from the Biosciences program, had enrolled. Participants were undergraduates (first to fourth year) and postgraduates (M. Phil). These workshops were conducted by a biosafety professional certified by the International Federation of Biosafety Associations (IFBA) and International Bio-containment Training Center, University of Texas Medical Branch (UTMB), US. The trainer has been recognized as an "IFBA Global Mentor" with extensive experience in the field of biosafety, biosecurity, bio-risk management, and proficiency in teaching through the Socratic method. In addition, the trainer had completed several courses on biosafety, including the 52-week biosafety program provided by the American Society for Microbiology (ASM), USA, and has been serving as "ASM Advanced Bio-risk Training Facilitator."

2.2. Workshop content

The workshop focused on providing awareness regarding four primary controls of biosafety and biosecurity, the philosophy of containment, and bio-risk management in laboratories. These topics were part of the curriculum designed by "ASM 52 weeks of Biosafety program" and "Safer Behaviors".[11]

Biosafety, as per WHO is "the containment principles, technologies, and practices that are implemented to prevent unintentional exposure to pathogens and toxins, or their accidental release".[12] Laboratory biosafety comprises four basic controls: engineering control, personal protective equipment (PPE), standard operating procedure (SOP), and administrative controls.

Biosecurity is defined by WHO as "the institutional and personal security measures designed to prevent the loss, theft, misuse, diversion or intentional release of pathogens and toxins".[12] The four primary controls of biosecurity include physical, personnel, material, and information controls.

*The philosophy of containment (*POC) is the study of the theoretical basis of biosafety and the application of its principles in laboratory settings. It encourages the idea of working in a direction from "clean to unclean" in laboratories. This can be achieved by dividing the laboratory area into three hypothetical zones: green (clean zone), yellow (buffering zone), and red (unclean zone).

Laboratory bio-risk management (BRM) refers to the active management of risks and the development of strategies to curtail their occurrence posed by handling infectious agents and toxins. The main components of bio-risk management include hazard identification, risk assessment, risk management, and risk communication.[13]

Alongside these topics, the workshop consisted of a practical demonstration of the "Beaking Method" for doffing gloves, which is considered the safest method for removing gloves. This minimizes the risk of incidental contact with contaminated materials doffing.[14]

2.3. Workshop assessment

A simple subject-specific questionnaire (Appendix A) was developed to assess the knowledge and education levels related to laboratory biosafety and biosecurity measures among participants. The first part of the questionnaire comprised 10 objective-type questions (true/false) with one point awarded for each correct answer. The second part contained three subjective type questions (four blanks for each question), where students were asked to name four primary controls of biosafety, biosecurity, and bio-risk management components. The maximum possible score for all 13 questions was 22. The same questionnaire was administered before (pre-test) and after (post-test) the workshop to evaluate an increase in the understanding of biosafety and biosecurity in students after being exposed to the Socratic learning style.

Participants were asked to sign an informed consent form before the workshop, which guaranteed their data confidentiality. Basic information on age, sex, education, previous working experience in any laboratory, and awareness about terms of biosafety, biosecurity, and philosophy of containment were also gathered from the students.

2.4. Workshop evaluation

An end-of-session feedback in the form of ratings was obtained from the participants to evaluate their satisfaction with the trainer's competency, mode, and quality of information, and the general impression of the session. Moreover, students' perceptions about attending related programs in the future and recommending them to others were also recorded.

2.5. Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics version 19. Students scoring ≤ 7 were considered low performers, between 8 and 15 as average performers, and those scoring ≥ 16 were graded as high performers. The paired Student's *t*-test was used to compare pre- and post-test scores, and $p < 0.05$ was considered significant. The difference between pre- and post-test scores was checked for normality of data. Percentages were computed for ratings from the feedback forms. As the students in both workshops received similar training content of 3 h by the same trainer, participants' data were considered homogeneous. Therefore, the results of the two training sessions were combined and analyzed together.

3. Results:

A total of 357 students, 318 (89%) from the government university (UoK), and 39 (11%) from a private institute (SZABIST) attended the workshops in October and December 2019, respectively. Of the 357 participants, 89% (282/318) from UoK and 97% (38/39) from SZABIST provided consent for the study participation and completed the pre- and post-test assessment forms. Thirty-seven participants (10%) were excluded based on incomplete pre- and post-test forms and failed to consent to the study participation. Students from the first to final years self-registered for the workshop, with the maximum number of students belonging to the first year (38%) (Fig. 1). The male-to-female ratio was 1:4, with a mean age of 21 ± 2.2 years. About 70% of the students had previous work experience in a laboratory for either educational (61%) or professional (7%) purposes. The majority of students (52%) had worked in government sector laboratories, while only 16% had working exposure to private sector laboratories. Only 2% reported having worked in both educational and professional settings. The mean working duration of participants was 8.9 ± 11 months. Almost 79%–92% of the students reported having heard about biosafety and biosecurity; however, more than half (55%) were completely unaware of the "philosophy of containment" before the training session.

Students' mean scores displayed a highly significant improvement from 3 in the pre-test to 19 in the post-test results. Marks improved in the post-test assessment, where 87% of the students were high performers scoring ≥ 16, and only 1% scored ≤ 7 (Table 1). The final evaluation indicated a substantial increase (14% to 84%) in awareness of laboratory biosafety. Fig. 2a and 2b display the students' correct responses in the objective and subjective type questions, respectively. Among the four components of training, a major improvement in knowledge was observed for bio-risk management (84%), followed by biosecurity (80%), philosophy of containment (60%), and biosafety (59%). The difference between the pre-test and post-test mean indicated an overall 70% increase in the post-workshop understanding levels of the students and exhibited a normal distribution (Fig. 3). Further analysis through a paired *t*-test yielded a highly significant result (p-value < 0.001, 95% CI) (Table 2).

Feedback forms revealed an increased level of satisfaction among students about the quality of information delivered through the Socratic method, trainers' proficiency, and overall impression of the workshop (Fig. 4). Likewise, a substantially high percentage of students (98%) recognized the importance of the workshop and agreed to attend and recommend related training programs to others in the future.

4. Discussion

Biosafety is a major issue in every medical and biomedical laboratory globally, and most notably in developing countries. Despite established guidelines, laboratory biosafety remains the most

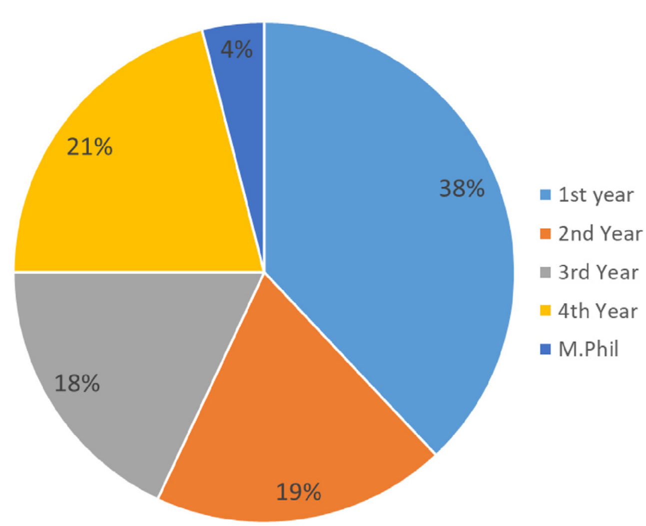

Fig. 1. Percentages of under graduate and post graduate students.

Table 1
Pre- and Post-test Performance of Study Participants.

Scores	n (%)	
	Pre-test Scores	Post-test Scores
≤7 (Low performer)	314(98%)	3(1%)
8–15 (Average Performer)	6(2%)	39(12%)
≥16 (High Performers)	0 (0%)	278(87%)

neglected domain in the local scenario, be it diagnostic, educational, or research. Subject-specific education, relevant training, and capacity building in laboratory biosafety and biosecurity can play a fundamental role in overcoming these obstacles.[16]

The present study was conducted at two educational public and private sector institutes in Karachi to provide laboratory biosafety and biosecurity related education by implementing the Socratic method and evaluating knowledge gain in students. Many undergraduate and postgraduate students registered for the workshop, with the majority belonging to the Biosciences department. Participants were predominately females in concordance with the male-to-female ratio of the university.[15] Regardless of the past working exposure and laboratory setting type, the baseline knowledge of all participants concerning biosafety was quite low. This agrees with multiple studies that indicated a serious lack of awareness and training among laboratory personnel in the local context.[16,17] Furthermore, students self-reported having heard of biosafety, biosecurity, and bio-risk management terms; however, they were completely unacquainted with the background concepts as reflected by their pre-test. The content and mode of the training workshop were carefully selected to deliver fundamental concepts in laboratory biosafety.

Like most Asian countries,[18,19] the culture of passive learning, rote memorization, and teacher-centered education prevails in Pakistan. Failure to actively engage students in critical thinking and providing adequate opportunities to assess their comprehension appears to be the main disadvantage of passive-type learning. The Socratic approach has been widely employed in medicine and law over time.[20–22] Its preferences have been well documented, as opposed to the traditional didactic method.[23,24] Moreover, enhanced enthusiasm toward learning has been reported when the teaching style was well aligned with the students' preferred learning styles.[25] Therefore, this interactive learning technique of student engagement was incorporated, reflecting a paradigm shift that is considered lacking in our context of teaching and learning. We further supplemented the Socratic method with pre- and post-test models to assess knowledge expansion through the

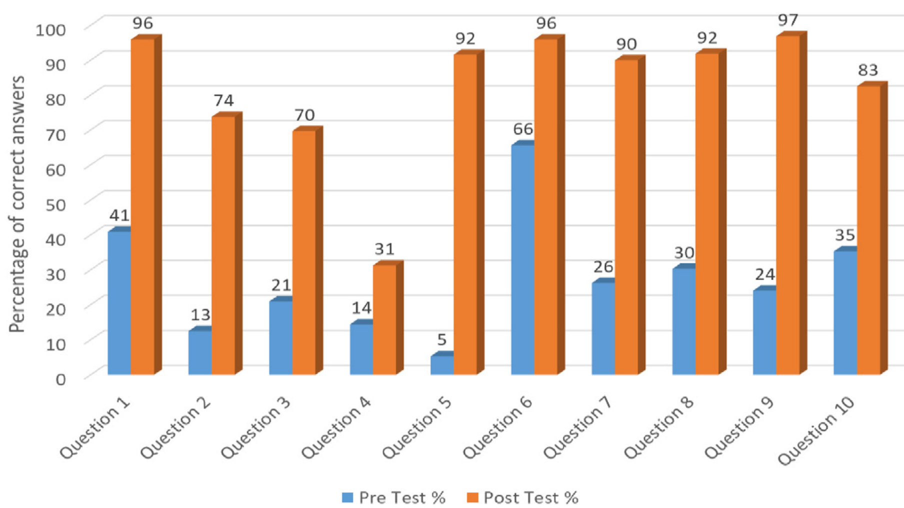

Fig. 2. Percentages of correct responses among student in objective type questions of pre and post test.

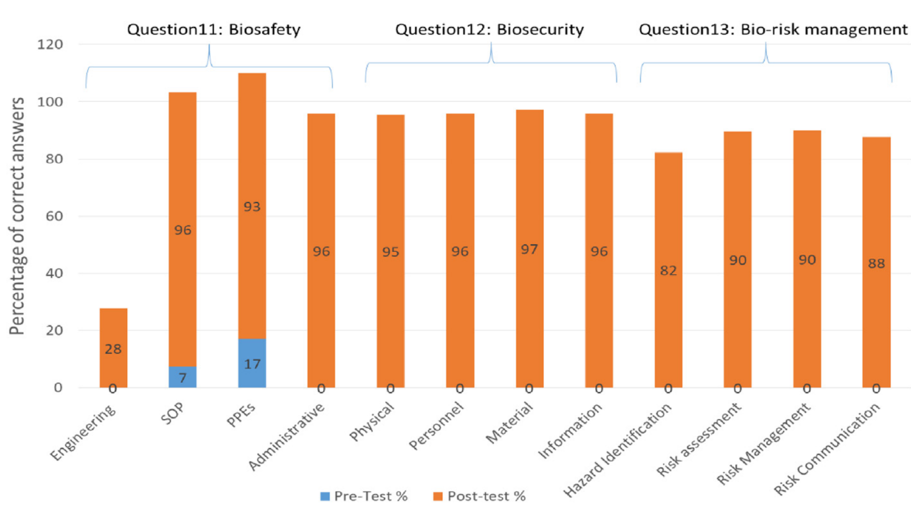

Fig. 2 (*continued*)

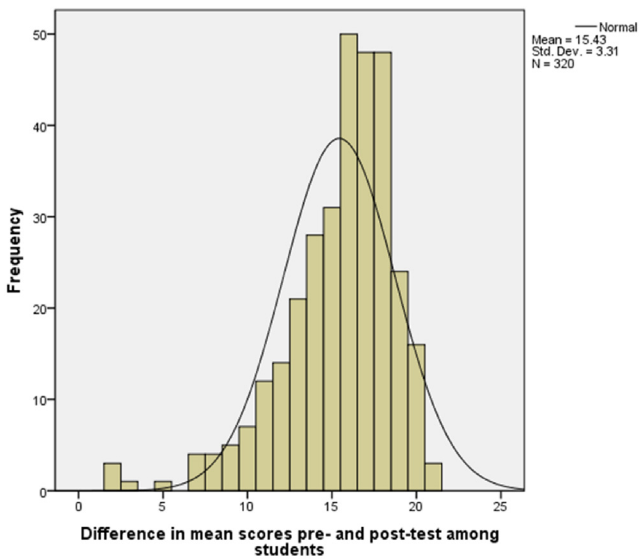

Fig. 3. Normal distribution of difference between pre and post test mean scores.

educational workshop. The main strength of this approach is that pre-test exposure analyzes former knowledge on the topic and supports in triggering factors that improve the focus and concentration of individuals to be more attentive and receptive during training.[26,27] The success of the Socratic Method was evident from the statistically significant improvement in knowledge post-workshop, where the difference between pre- and post-test scores represented data normality. These findings suggest that knowledge gain is independent of participants' earlier exposure and is attributed to the provision of education. Our study results are in concordance with those of similar studies establishing the usefulness of biosafety-associated educational training sessions.[28–32]

4.1. Strengths and limitations

The study was one of its kind at the university level, which predominantly focused on creating biosafety awareness among students through Socratic learning. Students were not only actively engaged but exhibited substantial knowledge improvement and expressed a high level of satisfaction with the workshop content and facilitator's competency. However, this study had limitations, which includes a small sample size of participants. As both institutes cater to an extensively large number of biosciences students, the study size mainly comprising a single department was not representative enough. Second, our pre- and post-test questionnaire contained only subjective-type questions for BRM and objective-type for POC. The questionnaire design might have affected the overall knowledge gain for each section of the training module. The study findings indicated the highest improvement in BRM and the lowest improvement in POC. Owing to the subjective type questions of BRM, students may not have had an opportunity to provide precise responses in the pre-test. This contrasts with the true or false type questions for POC, where students, despite a low baseline knowledge, were likely to guess the correct response and thus displayed less improvement subsequently. In contrast, knowledge gain in laboratory biosafety and biosecurity aspects appeared to be representative of both subjective- and objective-based questions. Finally, the current study only assessed knowledge gain and not the impact of education on their general practices. Testing the effectiveness of training would require a follow-up study and would be very intriguing.

Table 2
Paired sample T test analysis of pre- and post-test assessment.

Paired Samples Test	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pre Test Scores - Post Test Scores	−15.431	3.310	0.185	−15.795	−15.067	−83.403	319	0.000

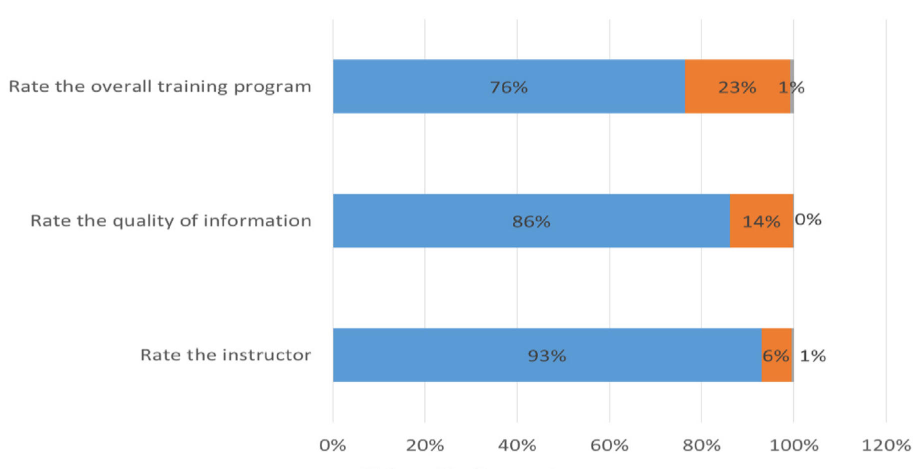

Fig. 4. Students level of satisfaction related to workshop, its content and trainers proficiceny.

4.2. Future recommendations

Students should be trained during an academic career, being potential future laboratory workers and researchers. Laboratory biosafety should be prioritized and included as a compulsory course in academic organizations teaching life sciences to ensure maximum compliance. Emphasis should be placed on promoting the safe handling of biohazardous agents and their products alongside adopting preventive measures that minimize the risk of personal, community, and environmental exposure. In conjunction with theoretical content, relevant hands-on practices should also be integrated into the curriculum. The importance of practical training has been acknowledged widely as it contributes to individual behavioral changes that may actively influence organizational biosafety culture.[11] Furthermore, there persists a dire need for the academic organization's leadership to take responsibility and ownership for capacity building at an institutional level to address the impending needs concerning laboratory biosafety.[30]

5. Conclusion

The study highlighted the significance of relevant education, training, and a practical demonstration in augmenting knowledge and understanding pertinent to laboratory biosafety and biosecurity. The Socratic approach of learning was found instrumental in student engagement and knowledge gain. Conducting such educational workshops periodically should be emphasized in academic settings to promote and sustain biosafety culture at an individual and organizational level.

CRediT authorship contribution statement

Sahrish Muneer: Data curation, Writing - original draft. **Hammad Afzal Kayani:** Writing - review & editing, Visualization. **Kashif Ali:** Resources, Supervision. **Ehtesham Asif:** Project administration. **Raheela Rehmat Zohra:** Resources, Supervision. **Furqan Kabir:** Conceptualization, Methodology, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgment

We would like to thank Sean G. Kaufman, Dr. Aamir Ikram, Dr. Zeba Rasmussen, Ms. Shahida Mumtaz Qureshi, along with the American Society of Microbiology (ASM), Department of Chemistry and Biotechnology at the University of Karachi (UoK), Dept. of Biosciences at Shaheed Zulfiqar Ali Bhutto Institute of Science and Technology (SZABIST), Pakistan Biological Safety Association (PBSA), and Aga Khan University (AKU).

References

1. Cruz CP, Bakr ESAA, Thazha SK, Cruz JP. Biosafety Knowledge and Perceptions of Clinical Laboratory Science Educators in A Saudi University. *Int J Health Sci Res.*. 2015;5(6):196–204.
2. Centers for Disease Control and Prevention. Human *Salmonella* Typhimurium Infections Associated with Exposure to Clinical and Teaching Microbiology Laboratories (Final Update) Available from: https://www.cdc.gov/salmonella/2011/lab-exposure-1-17-2012.html, 2012.
3. Barras V, Greub G. History of biological warfare and bioterrorism. *Clin Microbiol Infect*. 2014;20(6):497–502.
4. World Health Organization. Laboratory biosafety manual. World Health Organization; 2020.
5. Chosewood LC, Wilson DE. Biosafety in microbiological and biomedical laboratories. US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institutes of. *Health*. 2009.
6. Odetokun IA, Jagun-Jubril AT, Onoja BA, Wungak YS, Raufu IA, Chen JC. Status of laboratory biosafety and biosecurity in veterinary research facilities in Nigeria. *Safety and Health at work.*. 2017;8(1):49–58.
7. Nasim S, Shahid A, Mustufa MA, et al. Biosafety perspective of clinical laboratory workers: a profile of Pakistan. *J Infect Dev Ctries*. 2012;6(08):611–619.
8. Shakoor S, Shafaq H, Hasan R, et al. Barriers to implementation of optimal laboratory biosafety practices in Pakistan. *Health Security*. 2016;14(4):214–219.
9. Whiteley TR. editor Using The Socratic Method and Bloomâ€™ s Taxonomy of the Cognitive Domain to Enhance Online Discussion, Critical Thinking, and Student Learning. *Developments in Business Simulation and Experiential Learning: Proceedings of the Annual ABSEL conference*, 2014.
10. Paraskevas A, Wickens E. Andragogy and the Socratic method: The adult learner perspective. *J Hosp Leis Sports Tour Educ*. 2003;2(2):4–14.
11. Kaufman SG, Berkelman R. Biosafety, "Behavioral-Based" Training for High Biocontainment Laboratories: Bringing Theory into Practice for Biosafety Training. *Appl Biosaf*. 2007;12(3):178–184.
12. Staff WHO, Organization WH. Laboratory Biosafety Manual: World Health Organization; 2004.
13. Organization WH. Principles and methods for the risk assessment of chemicals in food. 2009.
14. Mumma JM, Durso FT, Ferguson AN, et al. Human factors risk analyses of a doffing protocol for Ebola-level personal protective equipment: mapping errors to contamination. *Clin Infect Dis*. 2018;66(6):950–958.
15. Kaleem R, Rathore K. Trends of higher education among female students: the case of university of the punjab.
16. Jan Muhammad F, Siddiqui N, Ali N, Kazmi SU. Analysis of Biosafety Performance in Selected Hospital Medical Laboratories in Karachi, Pakistan. *Appl Biosaf*. 2018;23(1):39–46.
17. Nasim S, Shahid A, Mustufa MA, et al. Practices and awareness regarding biosafety measures among laboratory technicians working in clinical laboratories in Karachi, Pakistan. *Appl Biosaf*. 2010;15(4):172–179.
18. Zhenhui R. Matching teaching styles with learning styles in East Asian contexts. *Int TESL J*. 2001;7(7):5.
19. Wang V, Farmer L. Adult teaching methods in china and bloom's taxonomy. *Int J Scholarship of Teaching and Learning.*. 2008;2(2) n2.
20. Grant O. Teaching Law Effectively with the Socratic Method: The Case for a Psychodynamic Metacognition. *S Tex L Rev.*. 2016;58:399.
21. Dickinson JA. Understanding the Socratic method in law school teaching after the Carnegie Foundation's Educating Lawyers. *W New Eng L Rev.*. 2009;31:97.
22. Chang L, Popovich NG, Iramaneerat C, Smith Jr EV, Lutfiyya MN. A clinical nutrition course to improve pharmacy students' skills and confidence in counseling patients. *Am J Pharma Educ*. 2008;72(3).
23. Adib-Hajbaghery M, Aghajani M. Traditional lectures, socratic method and student lectures: Which one do the students prefer? 2011.
24. Zou L, King A, Soman S, et al. Medical students' preferences in radiology education: a comparison between the Socratic and didactic methods utilizing PowerPoint features in radiology education. *Acad Radiol*. 2011;18(2):253–256.
25. Zhu H-r, Zeng H, Zhang H, Zhang H-y, Wan F-j,Guo H-h,, et al. The preferred learning styles utilizing VARK among nursing students with bachelor degrees and associate degrees in China. *Acta Paulista de Enfermagem.*. 2018;31(2):162–169.
26. Shivaraju PT, Manu G, Vinaya M, Savkar MK. Evaluating the effectiveness of pre-and post-test model of learning in a medical school. *National Journal of Physiology, Pharmacy and Pharmacology.*. 2017;7(9):947.
27. Dabade SK, Dabade KJ. Effectiveness of pre-and post-test model of learning among MBBS students-An evaluative study. *National Journal of Physiology, Pharmacy and Pharmacology.*. 2019;9(1):58–61.
28. Medina P, Padua A, Casagan M, Olpindo R, Tandoc III A, Lupisan S. Development and pilot implementation of a ladderized biosafety training program in a specialty infectious disease hospital and research institute. *Philippine Journal of Pathology.*. 2017;2(1):5.
29. Muriithi B, Bundi M, Galata A, et al. Biosafety and biosecurity capacity building: insights from implementation of the NUITM-KEMRI biosafety training model. *Tropical medicine and health.*. 2018;46(1):30.
30. Qasmi SA, Zafar M, Pirzada S, Saldera KA, Turabi A. Assessment and impact of a biosecurity course in raising the awareness of students at the Jinnah post graduate Medical Center. *Pakistan. Journal of Biosafety and Biosecurity.*. 2019;1(2):93–97.
31. Shafaq H, Qureshi SM, Shakoor S. Biosecurity-related biomedical laboratory practices in Pakistan: Educating personnel regarding transportation of biohazardous substances. *Biomedical and Biotechnology Research Journal (BBRJ).*. 2019;3(1):35.
32. Fiester S, Redfearn J, Helfinstine S, Meilander T, Woolverton CJ. Lab safety and bioterrorism readiness curricula using active learning and hands-on strategies as continuing education for medical technologists. *Journal of Microbiology & Biology Education: JMBE.*. 2010;11(1):14.