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Basic biosafety knowledge among veterinary students in the Visayas, Philippines

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ABSTRACT

Veterinary students routinely handle animals and biological specimens during laboratory and clinical training, placing them at risk of exposure to zoonotic and other biological hazards. Yet, veterinary programs in the Philippines lack a systematic, multi-institutional evaluation of students' biosafety competence to inform competency-based training. This study examined the level and domain-specific profile of basic biosafety knowledge among veterinary students in the Visayas and identified perceived challenges and actionable curriculum needs. We conducted a cross-sectional online survey of 405 students from six veterinary schools using a validated 30-item instrument spanning four biosafety domains, complemented by open-ended questions. Descriptive statistics summarized knowledge levels and themes; Chi-square tests assessed associations with student profiles. Students demonstrated high knowledge in core biosafety principles (75.6%) and routine laboratory practices (73.1%), but weaker performance in biosafety infrastructure and emergency preparedness (49.9% high; 47.9% moderate). Overall, 98.5% had only moderate integrated biosafety knowledge, and none reached a high overall category. Practical application gaps and knowledge barriers were the most frequently cited challenges, and recommendations emphasized hands-on training, simulations, and strengthened institutional biosafety systems. These findings indicate that moderate, fragmented knowledge may not ensure safe practice; veterinary curricula should embed progressive, assessed biosafety competencies before clinical rotations.

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1. INTRODUCTION

Biosafety involves principles, practices, and containment strategies to prevent accidental exposure to biological agents and toxins and their unintended release into the environment [1]. It encompasses a wide

array of practices, including appropriate specimen handling, utilization of personal protective equipment (PPE), waste disposal, and compliance with laboratory procedures [2]. Within educational and research environments, biosafety concepts further incorporate institutional policies, infrastructure design, and training initiatives that synergistically reduce hazards to humans, animals, and ecosystems [3]–[5]. For students handling live animals, biological specimens, or infectious agents, good biosafety knowledge is essential to reduce occupational risks and prevent laboratory-acquired infections. Biosafety extends beyond technical requirements alone and is a fundamental part of all fields working with biological materials [2], [5].

Biosafety is critical in the veterinary medicine education as students may frequently encounter zoonotic pathogens. This necessitates a robust understanding about how to mitigate transmission risks and protect public health [6], [7]. Despite this need, veterinary students may lack sufficient knowledge regarding infection control and biosecurity measures, which may highlight significant gaps in the current curricula [7]. There can be discrepancies in biosecurity compliance, with student involvement often playing a pivotal role in adherence to established protocols [8]. This highlights the importance of comprehensive biosafety education because of the inherent risks associated with handling diverse biological agents in veterinary practice [9], [10].

Biosafety is important to practicing veterinarians because of their role at the intersection of animal, human, and environmental health. They routinely handle blood, tissues, secretions, and excretions from animals that may carry zoonotic pathogens, including those that generate aerosols or involve sharps [7], [11]. The veterinary curricula-including clinical rotations, fieldwork, and laboratory exercises-expose students to biological hazards. This requires solid biosafety knowledge, attitudes, and practices to mitigate risks. Veterinarians also contribute to public health, food safety, and outbreak investigations, where biosafety lapses can have serious consequences [7], [9], [12].

Integrating biosafety into veterinary education is essential for student safety and the one health initiative. Veterinary students must gain core biosafety knowledge early, including risk assessment, transmission routes, PPE use, decontamination, and spill/exposure responses. This can be embedded in pre-clinical and clinical courses [7], [9], [12]. Consistent early exposure promotes lifelong safe practices [7]. With diverse settings, veterinary students need adaptable biosafety skills to protect themselves, peers, clients, and communities [7].

Despite the critical role of biosafety in veterinary education, information about baseline biosafety knowledge among veterinary students in the Philippines is limited. Although some institutions may have implemented specific biosafety protocols, dedicated courses, or curriculum modules, students' understanding and application of these principles remain largely undocumented. Most current research focuses mainly on biosafety in medical, nursing, and laboratory contexts, with little attention to veterinary students [7], [13]. Hence, understanding the status of biosafety knowledge among veterinary students in the Philippines can be vital for improving the current curriculum.

The present study primarily aims to document the level of biosafety knowledge among veterinary students in the Visayas, Philippines. Information generated from the study can be used to optimize instructional approaches while integrating biosafety concepts, safeguarding the veterinary students' welfare. Assessing students' knowledge levels enables veterinary educators and administrators to identify strengths, weaknesses, and misconceptions requiring improved strategies [7]. These insights will help develop teaching innovations, faculty development programs, and hands-on activities and simulations to augment biosafety proficiency.

Recent evidence from veterinary and one health education highlights the need to treat basic biosafety competence as a minimum professional outcome rather than optional knowledge. Studies across veterinary students and veterinary services report persistent gaps in biosecurity readiness, occupational hazard prevention, and institutional preparedness. It emphasizes that training should be scaffolded (early-to-late curriculum), assessed objectively, and reinforced through practical drills and behavior-focused approaches to translate knowledge into safe practice [7], [8], [10], [13].

2. METHOD

2.1. Research design and environment

This descriptive-analytical study used an online survey platform to assess the basic biosafety knowledge of veterinary students in the Visayas, Philippines. The Visayas region is in the middle of the country, comprising several islands. Most of its administrative region has two veterinary schools. Western Visayas (Region VI) has Aklan State University and Capiz State University; Central Visayas (Region VII) has Cebu Technological University and Southwestern University-PHINMA; and Eastern Visayas (Region VIII) has Visayas State University and University of Eastern Philippines. These veterinary schools have been established for more than 10 years.

2.2. Selection of research respondents

A total of 405 veterinary students from the Visayas region participated in the study. The inclusion criteria included age (18 years and above) and current enrolment at a veterinary school in the Visayas. Prospective respondents were invited, regardless of gender, current year level, or status as veterinary students.

2.3. Research instrument

The questionnaire comprised three sections: i) profile of the respondent; ii) biosafety knowledge-related statements; and iii) open-ended questions about challenges and suggestions in understanding biosafety concepts. In section two, the statements were made into a 4-point Likert scale (1-strongly disagree, 2-disagree, 3-agree, 4-strongly agree) and divided into four domains: i) core biosafety principles and risk assessment (items 1, 2, 4, 5); ii) laboratory practices, PPE, decontamination and waste management (items 3, 6, 7, 8, 10, 21, 22, 24); iii) biosafety infrastructure, emergency preparedness and incident management (items 9, 11, 12, 13, 14, 23, 25, 26); and iv) institutional policies, training, occupational health and ethics (15, 16, 17, 18, 19, 20, 27, 28, 29, 30). Scores were computed per domain and for the overall knowledge level. The questionnaire was pre-tested, undergoing face validation and internal reliability analysis. Assessing per item and per domain revealed good internal consistencies, with an overall Cronbach's alpha of 0.916 [14]–[16]. The questionnaire was converted into a self-administered questionnaire using Google Forms.

2.4. Data gathering, processing, and analysis

Potential participants were contacted using purposive and snowball sampling techniques. After confirmation of participation, the Google Form link was sent. The online data were downloaded and imported into Microsoft Excel. After further coding, processed data were imported into the IBM SPSS software for analysis using descriptive statistics and the Chi-square test. Variables that were found to have p-values equal to or less than 0.05 were considered significant. Responses to the open-ended questions were analyzed using a qualitative approach, in which emerging themes were identified and subsequently coded before using descriptive statistics.

2.5. Ethical consideration

This study conformed to the ethical guidelines and regulations established by the Philippine Health Research Ethics Board and the principles of the Declaration of Helsinki updated in 2024. It was approved by the Local Research Ethics Committee with approval no. DB-2025-003. All respondents provided informed consent before completing the questionnaire. Responses were anonymized, guaranteeing confidentiality and reducing the possibility of identification.

3. RESULTS AND DISCUSSION

3.1. Profile of respondents

The majority of respondents were aged 18-24 (90.4%) and predominantly female (67.2%). Most were enrolled in universities in Cebu (50.2%), and came from Cebu (43.2%) and Aklan (21.7%). Over half of the students were classified as irregular (58.5%), with the majority in the middle years of their programs: 2nd year (23.2%), 4th year (24.2%), and 3rd year (17.3%). Only a small number (3.7%) were second coursers, as shown in Table 1.

The predominance of younger students and first-time degree seekers reflects a cohort primarily in the early stages of forming their professional identities. The substantial proportion of female participants reflects contemporary global patterns in veterinary medicine, where female veterinarians also dominate [1]–[3]. Hence, biosafety education, or its integration into current veterinary medicine course subjects, may be tailored to engage a predominantly younger, female student population. This will potentially leverage pedagogical approaches that resonate with their learning styles and career aspirations [4]–[6]. Addressing this concern requires pedagogical strategies that may emphasize experiential learning, given that a frequently cited challenge in biosafety education is the lack of opportunities to apply theoretical knowledge in practice [7]–[9]. However, this does not mean that the concerns of the male veterinary student population will not be considered. The teaching approach must also be inclusive and address potential gender-related differences in risk perception and learning engagement [10]–[13].

A considerable proportion of irregular students, distributed relatively evenly across year levels with concentrations in the second and fourth years, reflects heterogeneous academic pathways and exposure profiles [14]–[16]. Irregular students commonly face interruptions in enrollment or deviations in course sequencing, which may limit their engagement in essential biosafety-related training and laboratory courses [16]–[18]. Considering the inter-year variations, these dynamics elucidate the potential heterogeneous

distribution of knowledge across domains and the robust correlation between veterinary curricular advancement and competence in targeted biosafety domains [11], [19]–[21]. The varying academic trajectories highlight the need for flexible instructional designs that accommodate diverse student experiences without compromising biosafety competency outcomes [13], [15], [22].

Table 1. Profile of veterinary students surveyed about their basic biosafety knowledge in the Visayas, Philippines (n=405)

Parameter	Category	Frequency	Percentage (%)
Age	18-24 years old	366	90.37
	25-32 years old	34	8.4
	33 and above	5	1.23
Gender	Male	120	29.63
	Female	272	67.16
	Prefer not to say	13	3.21
Current veterinary school	Aklan State University	159	39.26
	Capiz State University	3	0.74
	Cebu Technological University	110	27.16
	Southwestern University PHINMA	93	22.96
	University of Eastern Philippines	28	6.91
	Visayas State University	12	2.96
Home location	Agusan Del Norte	1	0.25
	Aklan	88	21.73
	Antique	9	2.22
	Bohol	9	2.22
	Bukidnon	2	0.49
	Capiz	13	3.21
	Cebu	175	43.21
	Davao del Norte	2	0.49
	Iloilo	41	10.12
	Leyte	10	2.47
	Masbate	1	0.25
	Negros Occidental	17	4.2
	Negros Oriental	7	1.73
	Northern Samar	27	6.67
	Samar	1	0.25
	Siquijor	1	0.25
	Zamboanga del Sur	1	0.25
Type of student	Regular	168	41.48
	Irregular	237	58.52
Year level	1st year	67	16.54
	2nd year	94	23.21
	3rd year	70	17.28
	4th year	98	24.2
	5th year	51	12.59
	6th year	25	6.17
Second courser	Yes	15	3.7
	No	390	96.3
Previous finished course	Not applicable	393	97.04
	Bachelor of Science in Computer Science	1	0.25
	Bachelor of Science in Marine Engineering	1	0.25
	BS Agriculture	1	0.25
	BS Biology	3	0.74
	BSBA Business Management	1	0.25
	Clinical Microbiology	1	0.25
	Hospitality Management	1	0.25
	Nursing	2	0.49
	Veterinary Technology	1	0.25

3.2. Biosafety knowledge

The veterinary student respondents' perceptions of core biosafety concepts were generally positive. Many highly agreed that PPE is required when working with hazardous biological materials (90.6%), that risk assessment must be conducted before any experiment involving biological materials (77.0%), and that biosafety protocol training is necessary before working independently (83.5%). A substantial proportion (67.9%) also highly agreed that ethical considerations are important when designing experiments involving infectious agents, indicating that students appreciate both the technical and ethical dimensions of biosafety, as seen in Table 2.

Table 2. Perception of veterinary students about basic biosafety knowledge in the Visayas, Philippines (n=405)

Statements	No idea/ No comment		Highly disagree		Disagree		Agree		Highly agree	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
1. Biosafety levels (BSL) range from 1 to 4, corresponding to the risk level of pathogens handled.	61	15.1	3	0.7	5	1.2	184	45.4	152	37.5
2. The main objective of biosafety is to avoid accidental exposure to pathogens and toxins.	7	1.7	4	1.0	92	22.7	0	0.0	302	74.6
3. When working with hazardous biological materials, PPE is required.	1	0.2	3	0.7	1	0.2	33	8.1	367	90.6
4. Prior to initiating any experiment involving biological materials, a risk assessment must be conducted.	3	0.7	3	0.7	1	0.2	86	21.2	312	77.0
5. Effective risk assessment relies on comprehending how infectious agents spread.	3	0.7	4	1.0	1	0.2	107	26.4	290	71.6
6. Biohazardous waste can be effectively sterilized through autoclaving.	58	14.3	12	3.0	38	9.4	161	39.8	136	33.6
7. After handling biological materials, work surfaces can be adequately decontaminated using chemical disinfectants.	10	2.5	4	1.0	8	2.0	185	45.7	198	48.9
8. Following a spill of potentially infectious material, it is crucial to decontaminate all equipment and surfaces	5	1.2	3	0.7	1	0.2	92	22.7	304	75.1
9. To ensure proper functioning, biological safety cabinets require annual certification.	31	7.7	3	0.7	2	0.5	131	32.3	238	58.8
10. When working with infectious samples, the use of centrifuge safety cups is essential.	41	10.1	3	0.7	1	0.2	149	36.8	211	52.1
11. Biosafety cabinets employ HEPA filters to prevent airborne pathogen release.	65	16.0	3	0.7	1	0.2	127	31.4	209	51.6
12. It is vital to know the location and proper use of the emergency eyewash station.	6	1.5	3	0.7	0	0.0	70	17.3	326	80.5
13. Protocols should be established for reporting and addressing biological spills.	8	2.0	3	0.7	1	0.2	91	22.5	302	74.6
14. Following the institution's exposure control plan is crucial in case of a needlestick injury.	24	5.9	3	0.7	5	1.2	111	27.4	262	64.7
15. All laboratory staff must undergo biosafety protocol training before working independently.	1	0.2	3	0.7	0	0.0	62	15.3	338	83.5
16. Adhering to the institution's biosafety manual is mandatory for all personnel.	3	0.7	4	1.0	0	0.0	97	24.0	301	74.3
17. Compliance with safety standards is maintained through regular biosafety audits.	11	2.7	4	1.0	0	0.0	116	28.6	274	67.7
18. I have undergone formal training in biosafety for handling infectious agents.	52	12.8	29	7.2	105	25.9	145	35.8	74	18.3
19. All laboratory staff should be required to take regular refresher courses on biosafety.	21	5.2	3	0.7	4	1.0	166	41.0	211	52.1
20. My educational institution provides adequate and current biosafety training.	53	13.1	13	3.2	52	12.8	196	48.4	90	22.2
21. I am knowledgeable about the correct procedures for disposing of sharps and other infectious waste.	13	3.2	7	1.7	19	4.7	187	46.2	179	44.2
22. Effective waste management relies on separating biomedical waste at its source.	22	5.4	2	0.5	2	0.5	155	38.3	224	55.3
23. I am acquainted with the regulations governing hazardous biological material transportation.	48	11.9	8	2.0	55	13.6	195	48.1	99	24.4
24. I understand the steps to take if accidental exposure to infectious material occurs.	29	7.2	7	1.7	24	5.9	204	50.4	141	34.8
25. My institution clearly communicates incident reporting systems to all students and staff.	54	13.3	7	1.7	52	12.8	180	44.4	112	27.7
26. Proper documentation of biosafety incidents is essential for enhancing safety protocols.	7	1.7	3	0.7	3	0.7	139	34.3	253	62.5
27. Veterinary students should be vaccinated against potential occupational hazards.	22	5.4	3	0.7	2	0.5	99	24.4	279	68.9
28. I am aware of the health surveillance measures my institution offers for those working with biohazards.	58	14.3	8	2.0	43	10.6	152	37.5	144	35.6
29. Adherence to biosafety practices can be affected by stress and fatigue.	54	13.3	7	1.7	22	5.4	183	45.2	139	34.3
30. When designing experiments involving infectious agents, ethical considerations are important.	14	3.5	3	0.7	2	0.5	111	27.4	275	67.9

Domains: i) core biosafety principles and risk assessment (items 1, 2, 4, 5); ii) laboratory practices, PPE, decontamination and waste management (items 3, 6, 7, 8, 10, 21, 22, 24); iii) biosafety infrastructure, emergency preparedness and incident management (items 9, 11, 12, 13, 14, 23, 25, 26); iv) institutional policies, training, occupational health and ethics (15, 16, 17, 18, 19, 20, 27, 28, 29, 30)

The results demonstrate that veterinary students in the Visayas have a good conceptual grasp of biosafety principles in Tables 2 and 3. Pronounced agreement concerning the necessity of PPE, pre-experimental risk assessments, biosafety training, and ethical considerations shows the students' comprehension of the biosafety foundation and its critical role in promoting safe practices [23]–[25].

These dispositions form a crucial foundation, since the lack of appreciation for biosafety's importance can undermine even well-designed training programs' ability to drive behavioral change [10]–[12], [26], [27]. Furthermore, positive perceptions toward institutional policies and ethical responsibilities suggest that students are receptive to the professional norms that build a strong safety culture in veterinary practice [2], [28], [29].

However, moderate uncertainty appeared in several technical or system-related aspects. A considerable number of students reported "no idea" for specific items, including 14.3% for whether autoclaving can effectively sterilize biohazardous waste, 16.0% for whether biosafety cabinets employ high-efficiency particulate air (HEPA) filters to prevent airborne pathogen release, and 14.3% for awareness of health surveillance measures offered in their institutions. These findings suggest that while students recognize the importance of biosafety and endorse its principles, their understanding of some key technical details and institutional mechanisms may be incomplete.

The data revealed limitations in the depth and breadth of students' biosafety knowledge. The moderate uncertainty around autoclaving, HEPA filters, and health surveillance mechanisms indicates that students were not always confident in the criticality of biosafety systems and work procedures [26], [30], [31]. Some students appeared unfamiliar with autoclaves and HEPA-filtered biosafety cabinets as core engineering controls, as well as with health surveillance as a key institutional measure for protecting laboratory workers [7], [8], [32]. When a noticeable proportion of the veterinary students reported having "no idea" about such topics, it signals that theoretical teaching alone has not been sufficient to embed these concepts in a meaningful way [9], [11], [27]. This gap highlights the disconnect between declarative knowledge and the practical familiarity required for safe laboratory conduct [33], [34].

Analyzing by domain, the students appear to have a good functional knowledge in areas aligned with basic teaching and routine laboratory practice. In the domain of core biosafety principles and risk assessment, 75.6% were classified as having high knowledge, indicating strong familiarity with the purposes of biosafety and risk assessment and related concepts. In the domains of laboratory practices, PPE, decontamination, and waste management, 73.1% were likewise classified as having high knowledge, indicating that students are relatively confident about day-to-day safe practices, including the proper use of PPE and surface decontamination. Knowledge in institutional policies, training, occupational health, and ethics was also reasonably good, with 65.2% achieving a high level in this domain. This suggests general awareness of the need for institutional guidelines, training, and occupational protections in Table 3.

Table 3. Knowledge level of veterinary students about basic biosafety knowledge in the Visayas, Philippines (n=405)

Domain	Low		Moderate		High	
	Freq	%	Freq	%	Freq	%
Core biosafety principles and risk assessment	8	2.0	91	22.5	306	75.6
Laboratory practices, PPE, decontamination and waste management	6	1.5	103	25.4	296	73.1
Biosafety infrastructure, emergency preparedness, and incident management	9	2.2	194	47.9	202	49.9
Institutional policies, training, occupational health and ethics	6	1.5	135	33.3	264	65.2
Overall knowledge level	6	1.5	399	98.5	0	0.0

Students perform best in domains that reflect routine, individual-level practices, including core principles and basic laboratory safety, where explicit teaching and straightforward application are likely more common [7], [8], [35]. In contrast, knowledge of biosafety infrastructure, emergency preparedness, and incident management is less consistently high, suggesting that students have fewer opportunities to engage directly with these systems [15], [31], [36]. Experiencing a properly certified biosafety cabinet, reviewing clear incident-reporting flowcharts, or participating in spill-response drills can make these concepts concrete; without such experiences, students may have only a vague or theoretical understanding [7], [21], [31]. This pattern suggests that curricula often emphasize individual protective behaviors while underrepresenting the institutional and engineering controls that support comprehensive Biorisk management [17], [29], [37].

In contrast, it did not reach the majority (49.9%) who were classified as having high knowledge in biosafety infrastructure, emergency preparedness, and incident management. However, 47.9% had moderate knowledge levels. This makes it the relatively weakest domain for veterinary students compared to the others, even though it covers critical components such as safety equipment, incident reporting, and emergency procedures. When scores across all domains were combined, the overall knowledge level showed that 98.5% of students had a moderate biosafety knowledge level, 1.5% had a low knowledge level, and none had a high knowledge level. This pattern indicates that although many students demonstrate strong knowledge in individual domains, their integrated, comprehensive mastery of biosafety remains moderate.

The classification of biosafety knowledge as moderate for nearly all students, with none attaining the high category, highlights a shortfall in holistic, integrated proficiency despite relative strengths in individual domains [33], [34], [36]. Future veterinarians managing infectious agents require not only mastery of discrete concepts but also insight into their interconnections with real laboratory and clinical contexts [9], [24], [28]. The present findings indicate that this integrative comprehension has yet to mature fully. This suggests a need for pedagogical approaches that emphasize practical, real-world application of biosafety protocols and a deeper integration of biosafety principles throughout the veterinary curriculum [19], [33], [34]. This includes integrating biosafety into day-one training and clinical rotations to instill comprehensive biosecurity practices from the outset of their professional development [1], [23], [38].

3.3. Statistical associations between knowledge level and profile variables

Several significant associations between profile variables and specific biosafety knowledge domains were found. Biological sex was significantly associated with knowledge in the domains of institutional policies, training, occupational health, and ethics (p=0.025), suggesting that male and female students may engage with, or perceive, institutional policies and training materials differently. Students' year level showed significant associations across multiple domains, including core biosafety principles and risk assessment (p=0.003), laboratory practices, PPE, decontamination, and waste management (p=0.027), and institutional policies, training, occupational health, and ethics (p=0.046). These associations suggest that progression through the veterinary curriculum contributes to the accumulation of biosafety knowledge, as seen in Table 4.

Table 4. Statistical analysis results

Variables Domain	Profile	Chi-square value	df	p-value
Institutional policies, training, occupational health and ethics	Biological sex	11.17	4	0.025
	Year level	18.59	10	0.046
Biosafety infrastructure, emergency preparedness, and incident management	Age category	9.58	4	0.048
	TOS	6.86	2	0.032
Laboratory practices, PPE, decontamination and waste management	Year level	20.26	10	0.027
Core biosafety principles and risk assessment	Year level	26.82	10	0.003

Age category and student type (regular or irregular) were both significantly associated with knowledge in the domains of biosafety infrastructure, emergency preparedness, and incident management (p=0.048 and p=0.032, respectively). This indicates that older and irregular students may differ from their younger or regular counterparts in their exposure to, or understanding of, the institutional and infrastructural aspects of biosafety. Overall, these associations highlight that both academic progression and individual or academic characteristics influence knowledge level.

The significant associations between specific biosafety knowledge domains and profile variables offer further insight into how biosafety learning occurs. The consistent association between the student's year level and multiple domains indicate that exposure and experience accumulated across the program do contribute to better biosafety knowledge [15], [30], [38]. Students in higher years have likely spent more time in laboratories, encountered more diverse procedures, and been exposed to more detailed discussions of risk and safety [15], [21], [30]. However, the fact that the overall knowledge level remains moderate even among higher-year students suggests that curriculum progression alone is not enough to achieve high levels of competence [5], [36], [37]. This indicates that biosafety content may lack systematic progression across years or that reinforcement and assessment of skills in later years may be insufficient [5], [21], [37].

The association between biological sex and knowledge of institutional policies, training, occupational health, and ethics suggests that there may be gender-related differences in how students engage with or internalize institutional information [3], [6], [13]. This could reflect differences in risk perception, communication styles, or even attendance patterns in specific trainings, although further qualitative work would be needed to clarify these dynamics [6], [13], [39]. Likewise, associations between age category, student regularity status, and proficiency in the infrastructure and emergency preparedness domain indicate that older and irregular veterinary students may encounter unique challenges, such as discontinuous laboratory engagement or sporadic exposure to structured training [14], [16], [17]. These observations highlight the need to deliver biosafety education that is inclusive and effective for all student cohorts, regardless of academic trajectory or demographic characteristics [13], [15], [18], [22].

3.4. Emerging themes on challenges and recommendations

The most frequently cited challenge was the lack of application of concepts (25.7%), suggesting that students feel their learning is heavily theoretical and insufficiently reinforced by practical, hands-on

laboratory experience. Knowledge gaps (20.0%) were also commonly reported, reflecting persistent uncertainties about specific biosafety principles and procedures. Regulatory and language barriers (12.3%) emerged as another significant issue, highlighting difficulties in understanding the technical language and the complexity of formal biosafety regulations and guidelines. A smaller proportion (6.4%) identified lack of facilities as a challenge, directly linking limitations in laboratory infrastructure and equipment to their ability to practice and internalize biosafety procedures, as shown in Table 5.

Table 5. Emerging themes on open-ended questions about main challenges and suggestions in understanding biosafety concepts and their applications (n=405)

Key emerging themes	Total	%
Main challenges		
Lack of application of concepts	104	25.7
Knowledge gaps	81	20.0
Regulatory and language barriers	50	12.3
Multidisciplinary risks	44	10.9
Lack of facilities	26	6.4
Suggestions/recommendations		
Enhanced practical training	134	33.1
Development of institutional biosafety infrastructure	57	14.1
Early and integrated curriculum inclusion	51	12.6
Case-based learning	37	9.1
Active learning modalities	32	7.9

For recommendations, students most frequently called for enhanced practical training (33.1%), including more laboratory sessions, drills, simulations, and supervised practice to allow them to apply biosafety concepts in realistic settings. They also recommended further development of biosafety infrastructure (14.1%), emphasizing the need for functional and accessible safety equipment and facilities. Early inclusion of biosafety content in the curriculum (12.6%) and the use of case-based learning approaches (9.1%) was also highlighted, reflecting a desire for biosafety to be woven consistently throughout their training and connected to real-world situations.

Thematic patterns derived from veterinary students' open-ended responses closely align with the quantitative results, providing explicit directives for curricular enhancement [9], [11], [18]. The foremost challenge identified was the lack of practical application of concepts, underscoring the key concern that biosafety instruction is predominantly theoretical, with inadequate emphasis on experiential implementation [9], [11], [26]. Without recurrent opportunities to implement biosafety principles in practice, veterinary students' understanding and appreciation of biosafety's importance may remain superficial and vulnerable to gradual neglect, [8], [9], [11], [26]. The students' self-assessment of their knowledge level supports this notion, as they were not highly confident in their biosafety knowledge [30], [31], [36].

Regulatory and language barriers point to another critical issue: biosafety regulations and guidelines may be presented in complex, technical forms that are difficult for veterinary students to interpret and internalize [9], [11], [20]. If students struggle with terminology and key concepts, they may lose interest in crucial content or rely on oversimplified understandings [18], [27], [30]. On the other hand, the mention of lack of facilities further emphasizes the structural constraints faced by students, where limited access to functioning biosafety cabinets, autoclaves, or appropriate laboratory spaces hinders both practice and meaningful learning [25], [29], [32]. These infrastructure deficits, common in resource-constrained settings, represent a significant barrier to translating theoretical biosafety knowledge into practical competence [25], [29], [32].

Students' recommendations align strongly with best practices in biosafety education [11], [18], [33]. Enhanced practical training, their top recommendation, speaks directly to the need for more experiential learning that bridges the gap between classroom instruction and real-world application [7]–[9]. On the other hand, the calls for infrastructure development reflect an understanding that effective biosafety practice depends on having the right tools and facilities and not just knowledge [25], [29], [32]. Finally, the suggested early inclusion of the curriculum and case-based learning implies that students want biosafety to be integrated across subjects and year levels, and taught in ways that connect theory with realistic scenarios [18], [33], [34]. These recommendations align with recognized needs within veterinary education globally, where there is a consistent call for more hands-on training and improved facilities to strengthen biosafety and biosecurity capacities, especially in resource-limited settings [10], [12], [25], [29].

The veterinary students in the Visayas demonstrate appreciation for biosafety and familiarity with its core principles [10], [11], [23]. Yet, their proficiency remains moderately developed and inconsistent, particularly in domains concerning infrastructural resources, institutional mechanisms, and experiential

implementation [25], [32], [36]. The demographic characteristics portray a predominantly youthful, uniform cohort in its formative phase of professional maturation [3]–[5]. This implies that targeted interventions could engender sustained improvements in biosafety practices within veterinary practice [12], [24], [28].

The findings emphasize the need for veterinary institutions to transition from a predominantly theoretical biosafety education paradigm to an integrated, hands-on approach [7]–[9]. This entails incorporating biosafety principles from the early stages of the curriculum and reinforcing them across diverse courses, alongside investments in accessible infrastructure and equipment for routine student use [25], [29], [32], simplification and contextualization of regulations and institutional policies [11], [18], [20], and delivery of recurrent refresher training and simulations [17], [33], [38]. Addressing these challenges will augment individual student competencies and bolster institutional and regional resilience to biological threats [10], [12], [29]. These will ultimately help advance veterinary medicine by promoting secure, accountable, and enduring practices throughout the Visayas and wider regions [9], [10], [20], [29].

Educationally, the finding that nearly all students fall within a "moderate" overall category, despite strong scores in selected domains, signals fragmented learning rather than integrated competence [33], [36], [37]. In competency-based professional education, moderate knowledge may not be sufficient to ensure consistently safe laboratory and clinical practice, especially for time-critical events such as spills, needlestick injuries, exposure response, and incident reporting [24], [28], [38]. Program administrators can use domain-level results to prioritize early-year structured biosafety modules, scaffolded refreshers across year levels, and objective competency checks before students enter clinical rotations [10]–[12], [21]. Beyond student-level instruction, the broader biosafety literature highlights that incident prevention depends on institutional systems-clear reporting pathways, visible SOPs, safety culture, and aligned policies-alongside high-quality skills training [10], [12], [29]. Recent studies and evaluations of biosafety education interventions, safety culture, and organizational Biorisk management support integrating simulation-based emergency response, competency checks, and structured Biorisk management programs to reduce real-world exposures and injuries during training and early practice [10], [12], [15], [17], [24], [28].

This multi-university survey shows that veterinary students in the Visayas generally hold favorable biosafety perceptions and have strong knowledge of core principles and routine laboratory practices [10], [11], [23]. Still, their integrated competence remains predominantly moderate, with clear weaknesses in biosafety infrastructure awareness and emergency preparedness [25], [32], [36]. Because moderate and fragmented knowledge may not reliably translate into safe behavior during real exposures [7], [8], [33], veterinary programs should implement progressive, competency-based biosafety instruction with hands-on skills training, simulations, and clear institutional systems (incident reporting, health surveillance, and engineering controls) before clinical rotations [10]–[12], [24]. Targeted investments in accessible biosafety resources and regular competency assessments can strengthen student readiness and reduce preventable biological risks in training and future practice [10]–[12], [29].

4. CONCLUSION

Veterinary students are expected to develop integrated, practice-ready biosafety competence before they are consistently exposed to biological hazards during laboratory work and clinical training. The study revealed that while students showed a strong grasp of core biosafety principles and routine laboratory practices, their overall knowledge level remained largely moderate. Notable weaknesses were observed in emergency preparedness and institutional/infrastructure awareness. These gaps could hinder safe performance during real incidents, including spills, sharps injuries, and exposure responses. These findings highlight the need for veterinary programs to implement competency-based, scaffolded biosafety instruction that should be reinforced before clinical rotations. This can be implemented through hands-on training and simulation-based drills, supported by clear institutional systems. The results provide a foundation for developing standardized biosafety modules and minimum competency assessments across institutions. Further studies should evaluate the effectiveness of targeted interventions using longitudinal designs, skills-based assessments and institutional audits of biosafety resources and policy visibility to determine which strategies most effectively enhance both knowledge, competence and safety behaviors.

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This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest.

INFORMED CONSENT

Informed consent was obtained from all participants before data collection. Participation was voluntary, and respondents were assured of anonymity and confidentiality throughout the study.

ETHICAL APPROVAL

This study was reviewed and approved by the Local Research Ethics Committee. The research was conducted in accordance with established ethical standards for human participants.

DATA AVAILABILITY

The datasets created and analyzed during this study are not publicly available due to confidentiality and ethical restrictions. However, they can be obtained from the corresponding author upon reasonable request.

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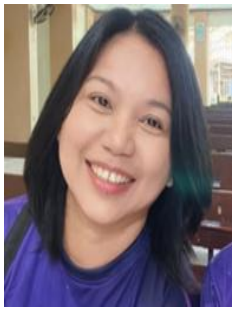
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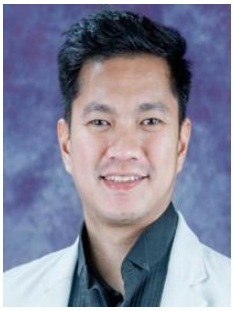
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