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Hazard Identification, Risk Assessment, and Control Design for Digital Design & Prototyping Laboratory at a University in West Java

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ABSTRAK

Latar Belakang : *Digital & Design Prototyping Laboratory* di sebuah Universitas di Jawa Barat (Universitas X) memiliki berbagai potensi bahaya akibat penggunaan komputer, printer 3D, *workstation* elektronik, serta peralatan bersama. Kondisi ini memerlukan penilaian risiko yang sistematis untuk memastikan keselamatan pengguna dan kepatuhan terhadap standar K3. Penelitian ini bertujuan untuk mengidentifikasi potensi bahaya di Laboratorium Digital & *Design Prototyping*, menilai tingkat kemungkinan dan keparahan risiko melalui penilaian risiko, serta merumuskan rekomendasi pengendalian risiko yang sesuai. Kajian ini berfokus pada risiko fisik, kimia, dan ergonomi yang terkait dengan aktivitas prototyping guna meningkatkan keselamatan laboratorium

Metode: Penelitian ini menggunakan metode *Hazard Identification, Risk Assessment, and Control* (HIRAC) mengacu pada ISO 45001:2018 dan SMK3. Sebanyak 10 aktivitas laboratorium dianalisis berdasarkan parameter *likelihood* dan *severity* menggunakan matriks risiko 4×4. Data dikumpulkan melalui observasi langsung, dokumentasi yang berpotensi tidak aman, data rekaman kecelakaan kerja dan wawancara informal dengan asisten laboratorium.

Hasil: Penilaian awal menunjukkan beberapa aktivitas berada pada tingkat risiko sedang hingga tinggi, dengan nilai risiko tertinggi 12, yaitu pada bahaya tersandung akibat kabel longgar, sengatan listrik dari komputer, serta paparan biologis melalui perangkat komputer bersama. Aktivitas lain menunjukkan nilai risiko 8–9, seperti penyimpanan barang di lantai, kepadatan ruang, tumpahan makanan/minuman, dan risiko ergonomi. Setelah penerapan kontrol tambahan seperti pengelolaan kabel, peningkatan *housekeeping*, pengaturan kapasitas ruang, prosedur higienitas, dan perbaikan ergonomi, nilai risiko seluruh aktivitas menurun ke rentang 3–8. Penurunan signifikan terlihat pada risiko sengatan listrik (12 → 4), tumpahan (9 → 3), dan ergonomi (8 → 4). Secara keseluruhan, nilai risiko rata-rata turun dari 9,4 menjadi 4,6, menunjukkan reduksi risiko sebesar 51%.

Kesimpulan: Penerapan kontrol berbasis hierarki berpotensi menurunkan tingkat risiko pada aktivitas yang diidentifikasi. Dengan syarat bahwa rencana kontrol yang direkomendasikan dapat dijalani dengan konsisten.

Kata Kunci: Identifikasi Bahaya; Keselamatan Laboratorium; Keselamatan dan Kesehatan Kerja; Penilaian Risiko; Pengendalian Risiko

ABSTRACT

Background: *The Digital & Design Prototyping Laboratory at a University in West Java (University X) faces various potential hazards due to the use of computers, 3D printers, electronic workstations, and shared equipment. This situation requires a systematic risk assessment to ensure user safety and compliance with OHS standards. This study aims to identify potential hazards in the Digital & Design Prototyping Laboratory, assess the likelihood and severity of the risks through a risk assessment, and formulate appropriate risk control recommendations. This study focuses on the physical, chemical, and ergonomic risks associated with prototyping activities to improve laboratory safety.*

Methods: *This study used the Hazard Identification, Risk Assessment, and Control (HIRAC) method, referring to ISO 45001:2018 and SMK3. Ten laboratory activities were analyzed based on likelihood and severity parameters using a 4x4 risk matrix. Data were collected through direct observation, potentially unsafe documentation, work accident records, and informal interviews with laboratory assistants.*

Result: *Initial assessments indicated several activities were at moderate to high risk levels, with the highest risk scores of 12, including tripping hazards from loose cables, electrical shock from computers, and biological exposure through shared computer equipment. Other activities had risk scores of 8–9, including floor storage, crowded spaces, food/drink spills, and ergonomic risks. After implementing additional controls such as cable management, improved housekeeping, space management, hygiene procedures, and ergonomic improvements, the risk scores for all activities decreased to the 3–8 range. Significant decreases were seen in electrical shock (12 → 4), spills (9 → 3), and ergonomics (8 → 4). Overall, the average risk score decreased from 9.4 to 4.6, representing a 51% risk reduction..*

Conclusion: *Implementing a hierarchy-based control system has the potential to reduce the level of risk in identified activities, provided the recommended control plan can be consistently implemented.*

Keywords: ***Hazard Identification; HIRAC; Laboratory Safety; Risk Assessment; Risk Control; Occupational Health and Safety***

INTRODUCTION

A hazard is defined as a source or situation with the potential to cause injury or ill health, damage to property, environmental damage, or a combination of these [1]. In university settings, hazards are prevalent in practical learning spaces, such as laboratories, hall, classroom, etc. In Indonesia, the management of occupational safety and health (OSH) is a legal mandate, primarily governed [2] concerning Occupational Safety. This foundational regulation emphasizes the employer's obligation to ensure the safety of every person in the workplace, a definition that extends to academic environments such as university laboratories. This obligation is further reinforced [3] concerning Manpower, which explicitly states that every worker has the right to protection of their safety and health . In addition, according to the law and regulation of LAM Teknik Number 1 of 2025 [4], section on Facilities, Infrastructure, Occupational Health and Safety, and Environment (HSE), which explains that UPPS (Study Program Management Unit) must implement a comprehensive occupational health, safety, and environment (K3L) system to create a safe, comfortable, healthy, and environmentally-friendly campus environment. This University has begun to conduct HIRAC at a lab facility [5]. However, similar procedures have not been applied at Fablab

The Design Engineering Laboratory, operating within the Fabrication Laboratory (FabLab) at a University in West Java (University X), represents a workplace with high-risk complexity. As a facility supporting prototyping and product development using advanced equipment such as 3D printers, CNC machines, and electronics workstations, this laboratory presents a multitude of potential hazards that require serious management. Several laboratory accidents reported in Indonesian higher education institutions highlight the potential risks associated with inadequate safety management in academic laboratories. Previous incidents have included short electrical circuits leading to equipment damage, fires caused by improper use of laboratory machinery, and injuries resulting from insufficient safety procedures during prototyping activities. These cases demonstrate that laboratories within academic environments remain vulnerable to occupational hazards, underscoring the urgency of implementing a systematic occupational health and safety management approach. The implementation of Government Regulation (PP) No. 50 of 2012 concerning the Occupational Safety and Health Management System (SMK3) concerning the Occupational Safety and Health Management System (SMK3) is particularly relevant in this context, as it requires employers to implement a comprehensive K3 management system covering K3 policy formulation, planning, implementation, monitoring and evaluation, and continuous improvement to ensure safe and healthy working conditions [6,7].

The aim of this study is to comprehensively identify potential hazards present in the Digital & Design Prototyping Laboratory environment, conduct a thorough risk assessment to evaluate the likelihood and severity of these hazards, and develop informed recommendations for effective risk control measures. The study seeks to enhance safety protocols by systematically analyzing the types of risks associated with prototyping processes, including physical, chemical, and ergonomic risks, and propose practical interventions to mitigate these risks.

METHOD

2.1 Study Design and Setting

This study utilized the Hazard Identification, Risk Assessment, and Control (HIRAC) method to systematically evaluate potential hazards in the Design

Engineering Laboratory. The approach was developed based on the standards of ISO 45001:2018 Occupational Health and Safety Management System and the Indonesian Occupational Health and Safety Management System (SMK3). The method provides a structured process to identify, assess, and control hazards that may pose risks to laboratory users.

Data collection was carried out through direct observation 17th September 2025 at laboratory conditions and informal interviews with the laboratory assistant and students to obtain information regarding routine activities, potential hazards, and existing safety measures. The observation focused on identifying unsafe conditions such as improper equipment placement, inadequate housekeeping, or unsafe behaviors that could increase risk levels. Hazard identification conducted on September 10, 2025, within the campus area has revealed several specific risks present in this laboratory.

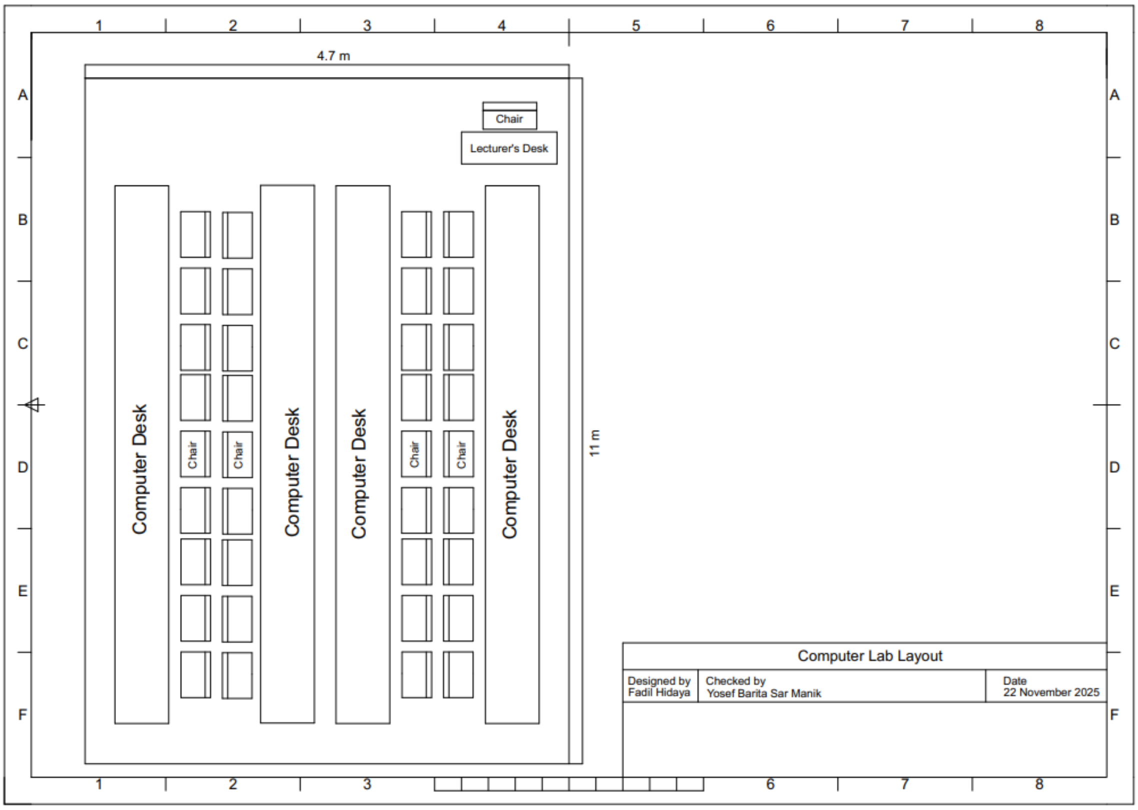

Figure 1. Digital Design & Prototyping Laboratory Layout

The Digital Design & Prototyping Laboratory at University X is designed to support teaching and learning activities related to computer-based design and prototyping. The laboratory room has approximate dimensions of 4.7 meters in width and 11 meters in length, with a linear layout to optimize space utilization and user circulation. The room layout consists of multiple student workstations arranged along the right and left sides of the laboratory, with the workstations facing the side walls. Each workstation is equipped with a desktop computer, a keyboard, and a mouse to support practical activities.

At the front area of the room, a lecturer's workstation is provided along with a presentation screen used as the main instructional media. Supporting facilities include ergonomic chairs, electrical power supply, network connections, adequate lighting, and a clear central circulation path to ensure user safety and comfort. Based on the number of available workstations and the seating arrangement, the laboratory has a maximum capacity of approximately 25 users, including students and the lecturer. This layout and facility arrangement are used as a reference in the Hazard Identification, Risk Assessment, and Control (HIRAC) study to evaluate potential risks related to ergonomics, electrical safety, fire hazards, and emergency evacuation routes.

2.2 Hazard identification

The HIRAC process involved three main stages: hazard identification, risk assessment, and risk control. In the identification phase, all potential hazards were recorded and classified according to their characteristics, which included physical, electrical, ergonomic, fire, radiation, and biological hazards. Each identified hazard was analyzed based on its source, potential cause, and the possible consequences to laboratory users.

2.3 Risk Assessment

The subsequent risk assessment phase employed a semi-quantitative risk to determine the risk level of each hazard. Two parameters likelihood and severity were rated on a scale of one to four, representing the probability of occurrence and the seriousness of the resulting consequence. The overall risk value was calculated by multiplying likelihood and severity ($R = L \times S$), and the final risk levels were categorized into low (1–4), moderate (5–8), high (9–12), and extreme (>12). This scoring system allowed the prioritization of hazards requiring immediate corrective action [7]

Table 1. Risk Likelihood Category
Source: (Igor et al. 2023)

Likelihood	
No	Description
1	Highly unlikely to occur during the lifetime of an operation/project
2	Event that may occur during the lifetime of an operation/project
3	Event that may occur (<once per year)
4	Recurring event during the lifetime of the operation/project or >once per year.

Table 2. Risk Severity Category
Source: (Igor et al. 2023)

Severity	
No	Description
1	Minors refers to a consequence that has low impact and is not significant to safety, health, or operations.
2	Moderate consequences, rated as 2, are generally significant but reversible
3	A significant consequence, with a rating of 3, is intended to cover incidents with the potential to cause one or more fatalities or permanently disabling injuries, or isolated cases of fatal or debilitating disease. These incidents are unacceptable; the rating of 3 does not diminish this.
4	A Catastrophic consequence, with a rating of 4, is intended to cover outcomes with a large number of fatalities. These might include: 1. A mass casualty event (slope failure with the potential to engulf multiple people, destruction of a personnel transport vehicle, underground fire, and similar) 2. A gas release capable of engulfing multiple people (chlorine or H2S release near an occupied building) 3. a widespread exposure to a substance that could later cause a cluster of cases of cancer or other debilitating disease.

Table 3. PTFI's 4x4 Risk Assessment Matrix
Source: (Igor et al. 2023)

FCX 4x4 RISK ASSESSMENT MATRIX				**Consequence**
4	8	12	16	Catastrophic (4)
3*	6*			Significant (3)
3	6	9	12	
2	4	6	8	Moderate (2)
1	2	3	4	Minor (1)

Following the risk assessment, control measures were determined based on the hierarchy of control, which prioritizes preventive strategies in the following order: elimination, substitution, engineering controls, administrative controls, and the use of personal protective equipment (PPE). Recommended actions included providing shelves for personal belongings, ensuring electrical safety through cable

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organization, and minimizing biological risks by disinfecting shared devices and promoting hand hygiene. All findings were summarized in a hazard observation sheet that documented activities, types of hazards, risk scores, and proposed control measures. The analysis indicated that several hazards, such as tripping risks, electrical exposure, ergonomic strain, and infection from shared devices, were classified in the moderate to high-risk category with values ranging from 8 to 12. These results highlight the need for enhanced safety awareness, improved spatial organization, and consistent application of risk control strategies to minimize occupational hazards in the Digital Design & Prototyping Laboratory.

RESULT

The hazard identification conducted in the Digital & Design Prototyping Laboratory revealed that the workspace still contains several risk-prone activities that may affect the safety and health of laboratory users. Based on direct observations and informal interviews, ten main activities were identified as sources of potential hazards, covering physical, electrical, ergonomic, fire, radiation, and biological risks. One of the most frequent issues observed was the presence of tripping hazards, mainly caused by loose cables and personal items placed on the floor. These conditions often generate moderate to high risk levels due to the limited space and the high movement of students within the laboratory. Additionally, prolonged computer use in improper sitting positions contributes to ergonomic risks, such as muscle strain and poor posture, which were commonly reported by users. The highest risk value was found in the category of biological exposure, particularly through the shared use of computer mice and keyboards. These devices can become a medium for transferring bacteria or viruses among users, resulting in a high-risk score due to frequent exposure and significant potential health impacts. Equipment-related hazards were also identified, especially involving 3D printer overheating. Although fire extinguishers (APAR) are available in the laboratory, the absence of a more robust temperature-monitoring mechanism means the risk remains at a low to moderate level and still requires engineering improvements. Overall, the risk assessment results show that most hazards fall within the moderate category, with several reaching high, notably those related to cable mismanagement, items stored on the floor, and the shared use of electronic devices. These findings emphasize the need for better workspace organization, stronger user compliance, and additional engineering controls to reduce hazards directly at their source.

Hazard Identification

Presents the results of hazard identification for various activities conducted in laboratory and classroom environments. Each activity is analyzed based on the type of hazard, existing control measures, potential hazards, and possible consequences. The findings indicate that the use of computers in the laboratory may lead to tripping hazards caused by improperly managed cables, as well as the risk of electric shock due to damaged electrical components. Crowded classroom conditions may hinder evacuation during emergencies, while bringing food or drinks into the laboratory can result in spills that may trigger short circuits. The operation of 3D printers is also associated with fire hazards caused by overheating. In addition, static activities such as prolonged sitting in front of a computer pose ergonomic risks, including muscle pain and poor posture. Storing personal belongings on the floor further contributes to tripping hazards. Overall, these identified hazards highlight the need for more effective control measures to minimize risks and enhance safety within educational settings.

Table 4. Hazard Identification

Activity	Types of Hazard	Current Control	Hazard Potential	Hazard Consequences
Using computers in lab	Falling Impact	Organize cables, use covers, incidental inspection	Loose cable under the desk	Fall
Using Computers in Lab	Electrical	Organize cables, use covers, incidental inspection	Possible electric shock	Death
Sitting in crowded classroom	Physical	Keep walkaways clear, limit occupancy	Overcrowded space, narrow aisles	Difficult evacuation during emergency
Bringing food/drinks into lab	Physical	Prohibit food/drinks, provide storage area outside	Spillage near computer	Short circuit
3D printer overheating	Fire Hazard	Availability of fire extinguishers (APAR) in accessible locations	Fire ignition due to overheating of the 3D printer’s nozzle	Burn injury from direct contact with overheated printer components
Sitting in front of a computer	Ergonomic	Take regular breaks, stretch regularly, stay hydrated	Muscle pain	Poor posture
Storing personal item on the floor	Falling Impact	Provide bag racks/shelves	Obstructed Pathways	Tripping

Activity	Types of Hazard	Current Control	Hazard Potential	Hazard Consequences
Exposure to non-ionizing radiation from prolonged use of laptops and 3D printers (e.g., electromagnetic waves, UV light from some 3D printers)	Radiation	Adjust screen, optimize lighting	Screen glare	Eye strain
Walking in lab with bags on the floor	Falling Impact	Keep walkways clear, provide shelves for bags, and secure cables.	Bags or cables left on the floor create tripping hazards.	Sprains
Shared computer mouse/keyboar d	Bloodborne Pathogens	Regular disinfection, encourage hand washing/sanitize r use.	Bacteria/viruses spread via shared devices.	Risk of infection/illness.

Risk Assessment

Presents the results of the risk assessment conducted for various activities within the laboratory and classroom environments. The assessment evaluates each activity based on its likelihood, average likelihood, severity, and maximum severity to generate a final risk value. The findings show that several activities fall within the medium to high-risk categories. For example, using computers in the laboratory is categorized as a high-risk activity due to the combination of moderate likelihood and high maximum severity, resulting in a risk value of 12. Crowded classroom conditions, as well as prolonged sitting in front of a computer, also demonstrate elevated risk values, primarily due to the increased likelihood of occurrence. Activities such as bringing food or drinks into the lab, storing personal items on the floor, and walking in the lab with obstructions present medium to high risk due to their potential to cause spills, tripping, or short circuits. Meanwhile, activities related to 3D printer use including overheating and exposure to non-ionizing radiation show lower but still significant risk values that require appropriate control measures. Overall, the risk assessment highlights the need for strengthened safety interventions, particularly for activities identified with higher risk values, to ensure a safer and more controlled learning environment (Table 5).

Table 5. Risk Assessment

Activity	Likelihood	Average Likelihood	Severity	Maximum Severity	Risk Value
Using computers in lab (tripping hazard from loose cables)	3	2	1	4	12
Using Computers in Lab (electrical shock)	1		4		
Sitting in crowded classroom	4	4	2	2	8
Bringing food/drinks into lab	3	3	3	3	9
3D printer overheating	2	2	2	2	4
Sitting in front of a computer	4	4	2	2	8
Storing personal item on the floor	4	4	2	2	8
Exposure to non-ionizing radiation from prolonged use of laptops and 3D printers (e.g., electromagnetic waves, UV light from some 3D printers)	4	4	1	1	4
Walking in lab with bags on the floor	4	4	2	2	8

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Activity	Likelihood	Average Likelihood	Severity	Maximum Severity	Risk Value
Shared computer mouse/keyboard	3	3	4	4	12

High and Extreme Risk Control

out the results from evaluating risks for lab activities in the high or extreme categories. Each one gets looked at for its hazard potential. We consider the current control measures too. Then there is the existing risk value. The table points out better or extra controls. It also figures out the new risk value once those get put in place. The data makes it clear that a few activities carry higher risks. Things like using computers with loose cables come to mind. Handling electrical equipment fits in there as well. These risks mostly stem from tripping hazards. Poor cable management plays a part. Potential electric shock adds to the trouble. Current controls do help cut down the dangers. Examples include incidental cable inspections. Routine checks count too. Still, they do not bring risks down to a low enough level.

The suggested controls look to lower the chances of or severity of incidents even more. Installing cable organizers stands out as one option. Adding warning signs helps. Conducting regular electrical testing rounds it out. Once these measures take effect the new risk values show a real drop in hazards. This proves that tougher safety steps work well. In the end Table 6 drives home the need for better engineering and administrative controls. Safer lab practices depend on them. They help prevent injuries from slips, trips, falls and electrical issues.

Table 6 summarizes the activities identified as having high initial risk levels prior to the implementation of additional control measures. These activities exhibited initial risk values ranging from 8 to 12, indicating a combination of relatively high likelihood of occurrence and potentially severe consequences. Major hazards identified include tripping caused by loose cables or personal items on the floor, electrical shock from damaged wiring or equipment, limited evacuation capability due to overcrowded rooms, spill-induced short circuits, overheating of 3D printers, and biological exposure associated with shared computer devices. The table also demonstrates that existing control measures were insufficient to adequately reduce these risks to acceptable levels. Consequently, a series of enhanced control strategies were proposed. These include engineering controls—such as installing cable organizers, implementing temperature monitoring systems, improving ventilation, and providing ergonomic furniture—as well as administrative controls, including stricter “No food or drink” policies, capacity adjustments, clearer evacuation routes, routine inspections, and strengthened hygiene protocols for shared equipment.

Following the implementation of these additional controls, all previously high-risk activities showed a significant reduction in their risk values, transitioning into moderate or low categories. This improvement highlights the effectiveness of systematic hazard control measures in mitigating risks within the laboratory environment. Overall, Table 6 reinforces the importance of comprehensive hazard identification and the application of hierarchical control strategies to enhance occupational health and safety performance.

Table 6. High & Extreme Risk Control

No	Activity	Hazard Potential	Current Control	Current Risk Value	Proposed Control	New Likelihood	New Severity	New Risk Value
1	Using computers in lab (tripping hazard from loose cables)	Falling / Tripping due to loose cables	Organizing cables incidental inspection	12	- Install cable organizers and protective covers - Implement routine inspection schedule - Add warning signage -Provide mandatory housekeeping checklist	2	4	8
2	Using computers in lab (electrical shock)	Electric shock from faulty wiring or devices	Cable inspection, incidental Monitoring	12	- Routine electrical testing and tagging - RCD (Residual Current Device) installation - Replace damaged cables immediately - No unauthorized repair	1	4	4
3	Sitting in crowded classroom	Difficult evacuation during emergency	Limit occupancy, keep walkways clear	8	- Reduce student capacity according to room layout - - Create clear evacuation route - Install directional signage - Conduct evacuation drill	2	2	4
4	Bringing food / drink into lab	Spill causing short circuit	Food / drink prohibition, Storage outside	9	- Enforce Strict “No food / no drink” rule - Place clear warning signs - Provide sealed storage cabinet	1	3	3

No	Activity	Hazard Potential	Current Control	Current Risk Value	Proposed Control	New Likelihood	New Severity	New Risk Value
					- Provide spill kit near computer area			
5	Sitting in front of a computer (ergonomic hazard)	Muscle pain, poor posture	Regular breaks, hydration	8	- Provide ergonomic chairs and adjustable desk -Implement mandatory micro-breaks - Posture guideline posters Stretching schedule	2	2	4
6	Storing personal items on the floor	Tripping hazard	Provide bag / shelves	8	- Install additional lockers / racks - Implement strict “No items on floor” rule - Conduct routine checks by lab assistant	2	2	4
7	Using laptops and 3D printers	Exposure to non-ionizing radiation from prolonged use	Incidental inspection	8	- Limit screen exposure time (rest every 60-90 min) - Increase distance from device (minimum 40-50 cm) - Use protective Shielding or filtered screens -Ensure proper ventilation around 3D printers - Provide training regarding safe radiation exposure - Rotate usage schedule to reduce prolonged exposure	1	3	3

No	Activity	Hazard Potential	Current Control	Current Risk Value	Proposed Control	New Likelihood	New Severity	New Risk Value
8	Walking in lab with bags on the floor	Tripping due to obstructed pathway	Incidental inspection	8	- Pathway marking and floor zoning - Provide centralized bag storage area - Enforce pathway clearance policy	2	2	4
9	Shared computer mouse / keyboard	Infection / contamination	Incidental cleaning	12	- Mandatory disinfecting wipe before / after use - Provide personal keyboard covers - Hand hygiene protocol - Weekly deep cleaning	2	4	8
	Average			9.4	Average			4.6

DISCUSSION

The findings of this study indicate that the Digital & Design Prototyping Laboratory still presents several conditions that align with known categories of workplace hazards commonly documented in engineering learning environments. The presence of cluttered pathways mainly caused by unmanaged cables and personal belongings corresponds with fundamental safety theory, which states that poor housekeeping significantly increases the likelihood of slip, trip, and fall incident [8]. This alignment reinforces previous literature emphasizing that orderly spatial organization is a foundational element of risk prevention, particularly in areas with high user mobility such as design laboratories [9]. Thus, this study strengthens the theoretical understanding that administrative controls and structured workspace management are essential for maintaining safe learning conditions.

Although no specific ergonomic assessment was conducted, prolonged computer use in suboptimal sitting postures may potentially contribute to musculoskeletal strain, as supported by existing literature [10]. Prior studies highlight that academic laboratories often lack adaptive furniture, resulting in postural fatigue among students during extended work sessions [11]. Therefore, the patterns observed in this study further validate established ergonomic theory, demonstrating that workstation design directly influences user comfort and long-term health outcomes.

A notable finding relates to biological exposure through shared computer devices. This hazard is well supported by earlier research showing that frequently touched surfaces, particularly shared input devices can act as reservoirs for microbial transmission if not sanitized regularly [12]. Studies conducted in educational environments similarly report elevated microbial loads on keyboards and mice when hygiene protocols are inconsistently applied [13]. The consistency between these findings and existing literature underscores the importance of implementing routine disinfection measures and promoting proper hand hygiene among laboratory users.

The risk of fire associated with overheating prototyping equipment, especially 3D printers, is another area that mirrors established knowledge. Prior studies identify thermal hazards from 3D printing operations as a potential ignition source if left unattended or improperly ventilated [14]. However, unlike some literature that categorizes this hazard as high-risk due to potentially severe outcomes [15], this study found the risk level to be lower. This distinction appears to stem from the presence of fire extinguishers and routine monitoring within the laboratory. This divergence suggests a context-specific nuance: operational discipline and consistent oversight can substantially reduce the actual risk level. Consequently, this may be considered a unique contribution of the study, demonstrating that hazard severity can differ from theoretical predictions depending on environmental controls and user behavior.

Electrical hazards associated with cable mismanagement also align with prior theories, which emphasize the importance of proper cable routing to prevent accidental exposure to electrical faults or short circuits [16]. Literature widely supports the notion that even low-voltage systems can pose risks when cables are tangled or compressed under furniture [17]. Thus, the study reaffirms the relevance of engineering controls and routine inspections to maintain electrical safety in laboratory settings.

Another important aspect revealed in this study is the role of user behavior in contributing to hazards. Actions such as bringing food or drinks into the workspace or placing bags in walking paths demonstrate unsafe practices that can indirectly elevate risk levels. This observation is consistent with behavioral safety theory, which identifies unsafe acts as predominant contributors to incidents in educational laboratories [18]. By aligning with these findings, the study reinforces the argument that establishing a strong safety culture is just as crucial as improving physical infrastructure.

Despite its contributions, this study has several limitations. The data collection period was relatively short, which may not fully capture variations in laboratory usage throughout the academic cycle. The assessment relied largely on observational data and informal interviews, introducing the possibility of subjective interpretation. Additionally, environmental parameters such as lighting intensity, noise level, and ventilation quality were not measured quantitatively, limiting the analysis of physical conditions that may influence hazard levels. Future research would benefit from longitudinal observation and the incorporation of quantitative environmental assessments to provide a more comprehensive understanding of laboratory risks

Overall, the discussion situates the findings within existing theory and relevant studies. The identified controls should be regarded as recommended risk control measures, and it is strongly suggested that these recommendations be implemented by the institution to potentially reduce the identified laboratory hazards.

CONCLUSION

This study identified that several activities in the Digital & Design Prototyping Laboratory initially had moderate to high risk levels, with values ranging from 8 to 12. The highest initial risks were found in tripping hazards, electrical shock, and biological exposure through shared computer devices (each RV = 12). After applying additional controls based on the hierarchy of controls, all activities showed a measurable reduction in risk. Key improvements include a decrease in electrical shock risk from 12 to 4, food/drink spill hazards from 9 to 3, ergonomic risks from 8 to 4, and biological contamination from 12 to 8. Overall, the average risk value decreased from 9.4 to 4.6, indicating that the implemented controls effectively reduced laboratory hazards to acceptable levels. Overall, the average risk value decreased from 9.4 to 4.6 based on the proposed control scenarios, indicating a potential reduction in laboratory hazards to acceptable levels. These findings suggest that the HIRAC approach may contribute to lowering risk severity and improving operational safety when the recommended controls are implemented.

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