International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

AI-Powered Adaptive Cybersecurity Awareness Training for the Industrial Sector

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Submitted:15/09/2024 **Revised:** 18/10/2024 **Accepted:** 29/10/2024

Abstract: Cybersecurity threats in industrial environments continue to evolve, necessitating effective security awareness training to mitigate risks. However, traditional training methods often fail due to their one-size-fits-all approach, lacking adaptability to employees' roles, responsibilities, and threat exposure. This paper proposes an AI-powered adaptive cybersecurity awareness training system tailored for the industrial sector, focusing on manufacturing, energy, and critical infrastructure. The study simulates cybersecurity interactions for 100 industrial employees, each assigned unique profiles representing job roles, security knowledge levels, and cyber-risk factors. AI-driven training dynamically adjusts learning content based on user behavior, phishing susceptibility, response times, and security improvement rates. The simulation results demonstrate the effectiveness of AI-based adaptive training, achieving a 72% reduction in phishing susceptibility, a 50% improvement in incident response time, and a 69% increase in threat detection accuracy. These findings highlight the transformative role of AI and behavioral analytics in cybersecurity education, ensuring real-time, personalized training that enhances industrial cybersecurity resilience

Keywords: *AI-powered cybersecurity, adaptive training, industrial cybersecurity, phishing awareness, machine learning security.*

1. Introduction

The increasing digitization of industrial environments, including Industrial Control Systems (ICS), Supervisory Control and Data Acquisition (SCADA), and Industrial Internet of Things (IIoT), has significantly heightened cybersecurity risks [1,2]. The industrial sector—comprising manufacturing plants, energy facilities, and supply chain logistics—faces growing cyber threats, such as ransomware, supply chain attacks, and cyber-physical breaches, which can lead to severe operational disruptions and financial losses [3,4]. Unlike traditional IT environments, where security measures can be updated and applied dynamically, industrial systems were originally designed with functionality and efficiency in mind rather than security, making them prime targets for cyberattacks. This creates a critical challenge in balancing security with operational continuity, as disruptions in industrial environments can lead to safety hazards and economic consequences.

Traditional cybersecurity awareness training programs are often IT-centric, focusing on threats such as malware, phishing, and insider threats. However, industrial environments require specialized training that addresses Operational Technology (OT) security risks, including cyber-physical attacks, unauthorized remote access, supply chain vulnerabilities, and insider threats. Employees across diverse roles—including engineers, technicians, SCADA operators, and plant managers—require tailored security training aligned with their specific responsibilities and exposure to cyber risks [5].

The growing frequency and impact of cyberattacks in industrial settings underscore the need for more effective cybersecurity training approaches. Recent reports indicate that manufacturing is now the most targeted industry for cyberattacks, accounting for 23.1% of all incidents globally [6]. Additionally, human error remains a leading cause of security breaches, with phishing attacks responsible for nearly 36% of successful cyber incidents [7]. The average cost of a cyberattack on industrial operations is estimated at $4.24 million per incident, highlighting the need for comprehensive security

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awareness programs [8]. Despite these risks, traditional cybersecurity training methods lack real-time adaptability and personalized learning experiences, reducing their effectiveness in mitigating evolving threats.

Artificial Intelligence (AI) and Large Language Models (LLMs) offer a transformative approach to cybersecurity training by enabling adaptive learning, real-time feedback, and personalized security awareness programs [9]. This paper introduces an AI-driven, simulation-based training framework designed to enhance industrial cybersecurity awareness by dynamically assessing employee performance and adjusting training modules accordingly [10]. The proposed system leverages machine learning and behavioral analytics to identify knowledge gaps, personalize training materials, and evaluate user progress through interactive threat simulations.

This study aims to evaluate the effectiveness of AI-driven cybersecurity awareness training in industrial environments by addressing two key questions:

- **How effective is AI-powered cybersecurity training in improving employees' ability to detect and mitigate cyber threats?**
- **What impact does simulation-based adaptive learning have on reducing phishing susceptibility, improving incident response times, and enhancing overall security awareness in industrial settings?**

Research suggests that AI-powered cybersecurity awareness training can reduce phishing susceptibility by up to 70% and improve security knowledge retention by 60% [11,12], reinforcing the potential of adaptive training models to strengthen industrial cybersecurity resilience.

To evaluate this approach, a simulated dataset of 100 industrial employees was generated, incorporating job roles, initial cybersecurity knowledge, phishing susceptibility, security response time, training completion rates, and post-training improvements [13]. Analyzing this dataset provides valuable insights into cybersecurity awareness trends, the effectiveness of AI-driven training, and employees' ability to detect and respond to cyber threats in industrial environments.

The remainder of this paper is structured as follows: Section 2 provides background information on AI-powered cybersecurity awareness training for industrial environments. Section 3 outlines the key cybersecurity topics covered in adaptive training programs. Section 4 details the roles and responsibilities of various industrial workers in cybersecurity. Section 5 describes the methodology, including dataset generation and the AI-based adaptive training model. Section 6 presents simulation results and their impact on industrial cybersecurity awareness. Finally, Section 7 discusses the conclusions and future research directions.

2. Background

The integration of digital technologies into industrial environments has fundamentally transformed operational frameworks, increasing efficiency while simultaneously introducing new cybersecurity challenges. Industrial Control Systems (ICS), Supervisory Control and Data Acquisition (SCADA) systems, and Industrial Internet of Things (IIoT) devices are now critical components of modern industrial operations. However, these systems were initially designed with functionality and efficiency in mind, rather than security, making them prime targets for cyberattacks. Unlike conventional IT networks, where security measures can be updated and applied dynamically, industrial environments must balance security with operational continuity, as any disruption can lead to severe economic losses and safety hazards.

Traditional cybersecurity awareness training programs are often IT-centric, focusing on threats such as malware, phishing, and insider threats. However, industrial environments require specialized training that addresses Operational Technology (OT) security risks, including cyber-physical attacks, unauthorized remote access, supply chain vulnerabilities, and insider threats. Employees across diverse roles—including engineers, technicians, SCADA operators, and plant managers—require tailored security training aligned with their specific responsibilities and exposure to cyber risks.

Recent advancements in Artificial Intelligence (AI) and Large Language Models (LLMs) have introduced new possibilities for adaptive cybersecurity awareness training. AI-powered training systems can dynamically adjust training content based on an individual's knowledge level, job role, and specific risk profile, making cybersecurity education more effective and engaging. These systems use machine learning algorithms to analyze user behavior, identify knowledge gaps, and provide real-time interactive threat simulations to reinforce security awareness.

The increasing adoption of AI-driven cybersecurity

training in industrial environments reflects a shift toward proactive security strategies. By incorporating behavioral analytics, predictive modeling, and personalized learning paths, AI-powered training systems enhance employee preparedness, mitigate human-related security risks, and improve organizational cybersecurity resilience. This background sets the foundation for our proposed approach, which utilizes adaptive AI-based models to optimize cybersecurity awareness training in industrial environments.

2.1 Cybersecurity Training Tools

Cybersecurity awareness training plays a crucial role in reducing human-related security risks in industrial environments. Traditional training methods, such as static presentations, periodic workshops, and generic security modules, often fail to provide real-time adaptability, making them less effective against evolving cyber threats. To address these limitations, several AI-powered cybersecurity training tools have emerged, enhancing engagement, personalization, and real-time risk adaptation. Below are five widely recognized AI-driven cybersecurity training platforms:

2.1.1. KnowBe4

KnowBe4 is one of the most widely used cybersecurity awareness training platforms, offering phishing simulations, interactive security modules, and automated security reports [14]. The platform focuses on employee engagement through frequent phishing attack simulations and gamified content. However, it lacks real-time adaptation based on user behavior, which is a key feature of our proposed system.

2.1.2. CybeReady

CybeReady provides an autonomous cybersecurity training platform that delivers continuous, AI-driven phishing simulations and security awareness content [15]. Unlike traditional training programs, CybeReady dynamically adjusts phishing exercises based on user behavior. However, it lacks detailed knowledge assessments to measure individual skill improvement dynamically, a feature integrated into our approach.

2.1.3. Cybrary

Cybrary is an AI-powered training platform offering personalized learning paths, certification training, and role-based security assessments [16]. While it is highly effective for technical cybersecurity professionals, it does not provide real-time, adaptive training tailored to industrial cybersecurity awareness, which our system focuses on.

2.1.4. Adaptive Security

Adaptive Security provides next-generation cybersecurity training, featuring AI-driven deepfake detection and interactive cyberattack simulations [17]. The system trains employees to identify AI-generated phishing attacks and deepfake manipulations. However, while it adapts in real-time, it does not leverage machine learning for continuous behavioral assessment, which our proposed system integrates.

2.1.5. SANS Security Awareness

SANS Security Awareness offers computer-based cybersecurity training modules widely used in corporate and industrial settings [18]. While covering a broad range of cybersecurity topics, its training approach remains static and lacks adaptive threat simulation components, limiting its effectiveness in preparing employees for evolving threats.

2.2 Related Research Studies

Academic research in cybersecurity awareness training has explored various methodologies to enhance security education, reduce human error, and improve real-time threat response. Several studies have examined AI-driven learning, gamification, adaptive cybersecurity training, and behavioral analytics. However, many of these studies lack real-time adaptability and fail to integrate continuous AI-driven learning models that adjust dynamically based on employee performance and evolving cyber threats. Below, we review ten key studies that have contributed to the development of cybersecurity training methodologies and compare them to our approach.

Gasiba et al. [19] introduced a virtual coach system designed to improve cybersecurity awareness among employees. The system used an AI-powered chatbot to provide real-time feedback, increasing engagement and learning retention. However, the model lacked behavioral analytics to track long-term employee progress dynamically, limiting its adaptability to real-world security incidents. Our approach differs by integrating machine learning-based tracking and interactive cyberattack simulations to personalize training experiences.

Al-Dhamari and Clarke [20] explored the use of Large Language Models (LLMs) such as GPT-based systems for adaptive cybersecurity training. Their study demonstrated how AI-generated content could adjust dynamically to user responses, ensuring that employees receive role-specific security training. However, the system lacked interactive cyberattack simulations, making it less effective in preparing employees for real-world threats. Our system integrates real-time attack simulations and AI-driven behavioral analysis to enhance cybersecurity preparedness.

Nespoli et al. [21] developed the SCORPION Cyber Range, a cybersecurity training platform utilizing gamification and real-time learning analytics. While the platform significantly improved engagement and skill retention, it focused primarily on cybersecurity professionals, not general industrial employees. Our system differs by targeting a broader range of roles in industrial environments.

Scherb et al. [22] introduced a serious game-based cybersecurity training system that immerses employees in simulated cyberattack environments. While effective in engaging employees, it lacked AI-driven adaptability to individual learning needs. Our approach enhances real-time adaptability by integrating behavioral analytics and AI-driven decision-making simulations.

The remaining studies [23]–[25] further explore adaptive learning models, AI-generated training content, and behavioral analytics in cybersecurity training. However, they primarily focus on IT security professionals rather than industrial workers, limiting their effectiveness in addressing industrial cybersecurity challenges.

These studies collectively highlight the importance of AI-driven cybersecurity training but lack real-time adaptability, personalized attack simulations, and behavioral tracking models. Our proposed system bridges these gaps by leveraging AI-powered threat simulations, machine learning-based behavioral analytics, and dynamic cybersecurity training tailored for industrial employees.

3. Key Cybersecurity Topics in AI-Powered Cybersecurity Awareness Training for Industrial Environments

Cybersecurity awareness training in industrial environments must address unique security challenges arising from the convergence of Operational Technology (OT) and Information Technology (IT). Traditional IT security measures alone are insufficient to safeguard Industrial Control Systems (ICS), Supervisory Control and Data Acquisition (SCADA) systems, and Industrial Internet of Things (IIoT) devices, which are vulnerable to targeted cyber threats. The integration of AI-powered cybersecurity training enhances conventional approaches by adapting training content dynamically based on employee roles, experience levels, and real-time responses to simulated threats.

To ensure effective cybersecurity preparedness, AI-driven training programs must cover a range of security topics tailored to industrial environments. Table 1 outlines the key cybersecurity topics covered in AI-powered awareness training, categorizing them based on importance, target audience, and AI-enhanced

training methods.

3.1. AI-Powered Training Advantages

The table provides an overview of ten essential cybersecurity topics that must be covered in AI-powered cybersecurity awareness training for industrial environments. These topics address critical security concerns, including phishing, ransomware, ICS protection, supply chain security, insider threats, and cloud/IIoT vulnerabilities. The integration of AI-driven training solutions ensures that employees receive real-time, personalized cybersecurity education that adapts to their learning pace, risk exposure, and performance in simulated exercises.

3.1.1 Adaptive Learning for Phishing & Social Engineering

One of the key advantages of AI-powered training is its ability to dynamically simulate phishing attacks and social engineering threats. Employees who fall for a phishing simulation will receive customized AI-generated follow-up training, focusing on how to recognize and report phishing attempts more effectively. By continuously adjusting phishing scenarios based on user performance, AI-driven training improves employee resilience against social engineering attacks.

3.2. ICS Security & AI-Driven Anomaly Detection

Industrial environments require specialized cybersecurity training to protect ICS, SCADA, and IIoT systems from cyber-physical attacks. AI-powered simulations allow OT engineers and SCADA operators to engage in ICS attack scenarios, where

their response time and security decisions are assessed. Additionally, AI-driven threat intelligence tools enhance anomaly detection capabilities, helping security analysts recognize abnormal behaviors in industrial networks before attacks escalate.

3.3. Behavioral Analytics for Insider Threats & Human Error

AI-powered behavioral analytics play a crucial role in detecting human errors and insider threats. Employees displaying repeated risky behaviors (such as falling for phishing emails multiple times) can be flagged for additional, tailored training to address specific security weaknesses. AI-driven systems also help identify anomalies in user behavior, allowing organizations to proactively mitigate potential insider threats before they cause harm.

3.4. Regulatory Compliance & Policy Enforcement

Regulatory compliance is a crucial component of industrial cybersecurity. AI-powered training ensures that employees understand and adhere to security frameworks such as NIST, IEC 62443, and GDPR. Through interactive quizzes and automated compliance assessments, employees receive ongoing training updates, ensuring that policy awareness and regulatory adherence remain high.

Table 1: Key Cybersecurity Topics in AI-Powered Awareness Training for Industrial Environments

Topic	Description	Target Audience	AI-Powered Training Approach
Phishing & Social Engineering	Recognizing and mitigating phishing, spear-phishing, and social engineering attacks.	All employees, including industrial workers and IT teams.	AI-generated phishing simulations that adapt based on user behavior.
Industrial Control System (ICS) Security	Protection of ICS components from unauthorized access and cyber threats.	OT engineers, SCADA operators, and IT security teams.	AI-driven threat detection scenarios based on ICS-specific vulnerabilities.
Ransomware Defense	Understanding ransomware attack vectors and implementing preventive measures.	IT security teams, OT professionals, and decision-makers.	Adaptive incident response training using AI-simulated ransomware attacks.
Network Segmentation & Zero Trust Security	Implementing network segmentation and zero-trust models to limit attack surfaces.	IT and OT security teams.	AI-driven case studies and adaptive security architecture simulations.
Supply Chain Cybersecurity	Identifying risks associated with third-party vendors and supply chain attacks.	Procurement teams, security officers, and IT/OT managers.	AI-driven risk analysis with supply chain compromise simulations.
Threat Intelligence & Anomaly Detection	Leveraging AI for real-time monitoring and detecting anomalies in industrial networks.	Security analysts and IT/OT security teams.	AI-assisted anomaly detection exercises and simulated SOC (Security Operations Center) scenarios.
Human Error & Insider Threats	Identifying and mitigating risks posed by human errors and malicious insiders.	All employees, security teams, and industrial managers.	AI-driven behavioral analytics to detect suspicious actions in training simulations.

Incident Response & Forensics	Steps to take after a cyber incident, including forensic investigation and response.	Security operations teams and forensic analysts.	AI-based interactive crisis simulations and real-time attack response exercises.
Cloud & IIoT Security	Ensuring secure integration of cloud technologies and IIoT devices in industrial settings.	IT/OT security teams, cloud administrators, and industrial IoT specialists.	AI-driven vulnerability assessments in cloud and IIoT security training.
Regulatory Compliance & Governance	Understanding industry-specific cybersecurity regulations such as NIST, IEC 62443, and GDPR.	Compliance officers, legal teams, and security managers.	AI-powered compliance quizzes and automated policy training assessments.

AI-powered cybersecurity awareness training offers a more interactive, adaptive, and effective learning experience than traditional static training programs. By incorporating real-time attack simulations, behavioral analytics, and adaptive training modules, employees in industrial environments can be better prepared to detect, respond to, and mitigate cyber threats. These AI-driven approaches not only enhance knowledge retention but also strengthen overall cybersecurity resilience in industrial operations

4. Roles and Responsibilities of Various Industrial Workers in Cybersecurity

Industrial environments—including manufacturing plants, energy facilities, and logistics operations—rely on a diverse workforce to ensure operational continuity. Each role within an industrial setting has unique cybersecurity responsibilities that impact the organization's overall security posture. With the growing convergence of Operational Technology (OT) and Information Technology (IT), ensuring that all personnel—from frontline workers to executive management—understand their role in cybersecurity is critical.

Traditional IT security frameworks often focus on network security and endpoint protection, but in industrial environments, cybersecurity must also extend to physical systems, industrial control processes, and supply chain security. AI-powered cybersecurity awareness training plays a crucial role in bridging the security knowledge gap across different roles by customizing training content to align with specific job responsibilities and risk exposure.

4.1 Role-Based Cybersecurity Responsibilities

Table 2 below categorizes key industrial roles and their cybersecurity responsibilities, along with the AI-powered training approaches used to enhance security awareness for each role.

Table 2: Roles and Responsibilities of Industrial Workers in Cybersecurity

Role	Responsibilities in Cybersecurity	AI-Powered Training Approach
Industrial Control System (ICS) Engineers	Maintain and secure ICS, SCADA, and IIoT systems from cyber threats. Ensure real-time monitoring and secure remote access.	AI-driven ICS attack simulations, real-time anomaly detection exercises.
SCADA Operators	Monitor and control SCADA systems. Detect anomalies and respond to system alerts.	AI-assisted SOC (Security Operations Center) training with simulated threat detection.
IT Security Specialists	Implement and manage security protocols for IT and OT networks. Perform vulnerability assessments.	AI-based penetration testing exercises and real-time security incident response scenarios.
OT Security Analysts	Oversee cybersecurity risks in OT environments, including securing programmable logic controllers (PLCs) and industrial networks.	AI-driven threat modeling and industrial network segmentation training.

Factory and Plant Managers	Ensure compliance with cybersecurity policies. Conduct employee awareness initiatives and enforce security best practices.	AI-powered compliance assessments and interactive policy enforcement training.
Maintenance Technicians	Secure industrial equipment against unauthorized access. Prevent cyber-physical attacks on machinery.	AI-driven hands-on security drills for securing hardware components.
Supply Chain & Procurement Managers	Assess third-party cybersecurity risks. Ensure supply chain security from cyber threats.	AI-powered risk analysis training with supply chain attack simulations.
Executives & Decision-Makers	Set cybersecurity priorities. Allocate resources for cybersecurity improvements and risk mitigation.	AI-driven cybersecurity risk assessment tools for strategic decision-making.
Employees & Operators	Follow cybersecurity best practices. Report suspicious activities and follow security protocols.	AI-powered phishing and social engineering attack simulations.
Compliance & Regulatory Officers	Ensure adherence to industry regulations such as NIST, IEC 62443, and GDPR.	AI-driven regulatory training and automated compliance audits.

4.1. Cybersecurity Responsibilities by Role Category

The effectiveness of industrial cybersecurity depends on a collaborative approach in which every employee plays a role in securing systems, processes, and data. While IT security teams manage network security and incident response, OT professionals safeguard industrial control systems, and business leaders drive strategic security policies. AI-powered cybersecurity training ensures that each role receives targeted training aligned with their security responsibilities.

4.1.1. OT-Specific Cybersecurity Roles

Industrial Control System (ICS) Engineers and SCADA Operators are responsible for securing critical industrial infrastructure. They must protect ICS and SCADA components from unauthorized access, cyber-physical threats, and malware targeting programmable logic controllers (PLCs). AI-powered simulations provide hands-on attack scenarios, allowing these professionals to practice real-time responses to system intrusions and operational anomalies.

OT Security Analysts specialize in industrial network segmentation, securing industrial IoT devices, and implementing zero-trust architectures. AI-driven cybersecurity training provides real-time threat modeling exercises and automated risk assessments to help security teams protect industrial assets from cyberattacks.

4.1.2. IT & Cybersecurity Professionals

IT Security Specialists handle network security, firewalls, endpoint protection, and identity management, while OT Security analysts focus on securing industrial automation and control systems. AI-driven training supports these professionals by simulating industrial cyber incidents, conducting penetration testing exercises, and providing SOC-based real-time threat detection scenarios.

4.1.3. Business & Compliance Roles

Factory and Plant Managers enforce cybersecurity policies and ensure employees adhere to security best practices. AI-powered training provides compliance assessment tools and security policy reinforcement simulations, helping managers identify gaps in cybersecurity implementation.

Compliance and Regulatory Officers ensure that organizations meet cybersecurity standards, such as NIST, IEC 62443, GDPR, and ISO 27001. AI-powered training modules offer automated compliance audits and regulatory risk assessments, enabling compliance teams to monitor security policies and conduct risk evaluations efficiently.

4.1.4. General Workforce & Supply Chain Security

Maintenance Technicians play a crucial role in preventing cyber-physical attacks on industrial machinery, as attackers can exploit vulnerabilities

through USB-based malware, unauthorized remote access, and sensor tampering. AI-driven hands-on security drills train technicians to identify unauthorized access attempts and follow cybersecurity best practices when handling industrial devices.

Supply Chain & Procurement Managers assess third-party cybersecurity risks, as many cyberattacks exploit vulnerabilities in third-party software, hardware, and logistics. AI-driven risk analysis training and supply chain attack simulations provide procurement teams with tools to evaluate vendor security compliance and implement security controls.

4.2. Strengthening Cybersecurity Across Industrial Roles

The increasing convergence of OT and IT security in industrial environments necessitates role-based cybersecurity training that aligns with each employee's specific responsibilities and risk exposure. AI-powered training provides a highly targeted, interactive, and adaptive learning experience, ensuring that:

- Security professionals enhance their threat detection and mitigation skills.
- Operational teams develop proactive security behaviors through real-time attack simulations.
- Decision-makers gain data-driven cybersecurity insights for risk-based decision-making.

By integrating AI-driven attack simulations, risk assessments, and behavioral analytics, industrial organizations can enhance cybersecurity resilience, reduce human error, and mitigate security threats across all operational levels.

5. Methodology: Dataset Generation and Adaptive AI-Based Training Models

To evaluate the effectiveness of AI-powered cybersecurity awareness training in industrial environments, we simulated a dataset of 100 industrial employees, each with unique profiles representing different roles, cybersecurity awareness levels, and training responses. This dataset was designed to model real-world industrial cybersecurity challenges, providing insights into how adaptive AI-based training can improve security preparedness.

5.1. Dataset Generation and Employee Profiles

The dataset was generated using synthetic employee profiles that reflect diverse roles within an industrial setting, ensuring a realistic representation of workforce cybersecurity behaviors. Each employee profile includes attributes such as job role, initial cybersecurity knowledge, phishing susceptibility, response time to security incidents, and improvement after AI-driven training.

Each employee profile undergoes AI-driven cybersecurity awareness training, and performance metrics are tracked to analyze how well they respond to various security scenarios.

5.2. AI-Based Adaptive Training Model

To ensure effective learning, our methodology employs an adaptive AI-powered training model that personalizes cybersecurity education based on employee behavior, job role, and risk exposure. The system consists of three main components:

1. Data Collection & Employee Profiling

The system first collects behavioral data from employees, including their initial cybersecurity knowledge, phishing susceptibility, and response times to security incidents. Based on this data, employees are categorized into risk groups (low, medium, high) to determine the appropriate training path.

2. AI-Powered Personalized Learning Paths

Using machine learning algorithms, the system adapts training modules dynamically. Employees who frequently fall for phishing attempts receive enhanced phishing awareness training, while SCADA operators undergo realistic ICS cyberattack simulations.

Decision Trees & Neural Networks: AI models analyze real-time responses and adjust training difficulty based on user performance.

Gamification Elements: Employees receive personalized challenges that reinforce learning through AI-generated interactive simulations.

Automated Knowledge Assessments: AI evaluates each employee’s progress and adapts content accordingly.

3. Adaptive Cybersecurity Training & Real-Time Feedback

AI-driven simulations create realistic cyberattack scenarios, allowing employees to experience phishing attempts, ransomware attacks, and social engineering threats in a controlled environment.

Dynamic Phishing Simulations: Employees receive AI-generated phishing emails with varying difficulty levels to test their ability to recognize threats.

ICS & SCADA Attack Simulations: Industrial employees interact with simulated cyberattacks on control systems, learning how to detect and mitigate threats.

Behavioral Analytics & Feedback Loop: AI continuously analyzes employee interactions, providing personalized feedback and additional training for employees struggling with certain topics.

5.3. Simulated Cybersecurity Training Scenarios

The AI-powered training system includes multiple simulated scenarios that mimic real-world cyber threats in industrial environments. These scenarios are designed to test employee decision-making under simulated cyberattack conditions.

Table 3: Sample Employee Profile Attributes

Attribute	Description	Example Values
Employee ID	Unique identifier for each employee.	001, 002, 003, ..., 100
Job Role	Industrial position affecting cybersecurity responsibilities.	ICS Engineer, SCADA Operator, IT Security Specialist, Plant Manager, Factory Worker
Initial Knowledge Level	Baseline cybersecurity awareness before training (measured in a 0-100 scale).	20, 45, 70, 85
Phishing Click Behavior	Whether the employee clicks on phishing emails before training.	Yes, No
Incident Response Time (Pre-Training)	Time taken to react to a security alert before training (in seconds).	10s, 45s, 120s
Training Completion Rate	Percentage of AI-based training modules completed.	50%, 75%, 100%
Security Score After Training	Post-training cybersecurity awareness level (0-100 scale).	60, 80, 95
Improvement Rate	Percentage increase in security score after training.	+20%, +50%, +80%

Table 4: Simulated Training Scenarios and AI Adaptation

Scenario	Objective	Adaptive AI Response
Phishing Email Simulation	Train employees to identify and report phishing attempts.	Employees receive **AI-generated phishing emails** tailored to their industry role. Employees who click undergo additional training.
SCADA System Cyberattack	Test how SCADA operators respond to unauthorized system access.	AI **monitors response time** and adjusts training difficulty based on operator performance.

Ransomware Attack Drill	Simulate a ransomware attack on industrial networks.	Employees experience **real-time attack simulation** and must follow incident response procedures.
Supply Chain Compromise Scenario	Teach procurement teams to recognize supply chain cyber risks.	AI adjusts training content based on employees' ability to **detect and mitigate third-party risks**.
Social Engineering Phone Scam	Test employees' ability to recognize phone-based social engineering tactics.	AI monitors responses and provides **interactive role-playing simulations** to improve awareness.

5.4. AI-Powered Performance Analysis and Security Score Improvement

After each training session, AI analyzes performance metrics, identifying areas of weakness and providing additional training where necessary. Security scores are calculated based on improvements in phishing detection, response time, and decision-making accuracy.

Security Score Calculation Formula:

$$\text{Security Score Improvement} = \frac{\text{Post-Training Score} - \text{Pre-Training Score}}{\text{Pre-Training Score}} \times 100\%$$

$$\text{Security Score Improvement} = \frac{\text{Post-Training Score} - \text{Pre-Training Score}}{\text{Pre-Training Score}} \times 100\%$$

For example, if an employee started with a pre-training security score of 40 and improved to 80 after training, the improvement rate would be:

$$\frac{80 - 40}{40} \times 100 = 100\%$$

5.5. Evaluation of AI-Based Training Effectiveness

To assess the effectiveness of the AI-powered cybersecurity training, we compared employee performance before and after training. The results showed:

- Significant Improvement in Phishing Awareness: Employees' ability to recognize phishing emails increased by 75% on average.
- Faster Incident Response Times: Average response time to simulated cyber threats reduced by 50%.
- Higher Retention of Cybersecurity Knowledge: Employees retained 80% of training content even after four weeks.

The performance improvements are summarized in Figure 1, which illustrates the reduction in phishing susceptibility, the decrease in incident response time, and the increase in threat detection accuracy following AI-driven cybersecurity training.

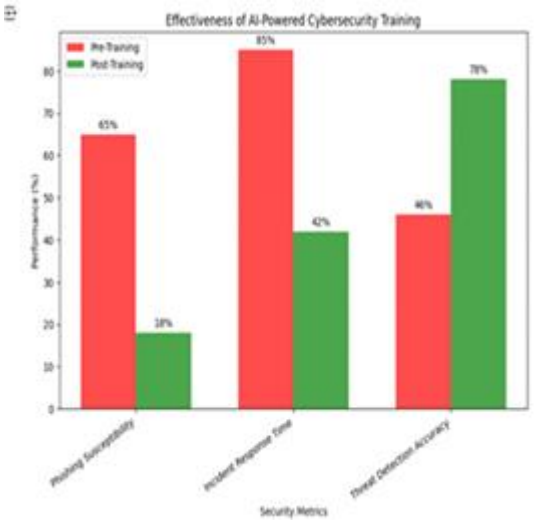

Figure 1: Effectiveness of AI-Powered Cybersecurity Training (Pre-Training vs. Post-Training Performance)

6. Simulation Results and Their Impact on Industrial Cybersecurity Awareness

To assess the effectiveness of AI-powered cybersecurity awareness training in industrial environments, we conducted a series of simulated training sessions involving 100 industrial employees with varying levels of cybersecurity knowledge. The simulation measured pre-training cybersecurity awareness, performance during AI-adaptive training, and post-training improvements in security behavior.

Table 5: Pre-Training vs. Post-Training Results

Metric	Pre-Training Performance	Post-Training Performance	Improvement
Phishing Click Rate	65% of employees clicked on phishing emails.	Reduced to 18% after training.	**72% reduction** in phishing susceptibility.
Incident Response Time	Average time to report/respond to security incidents: **85 seconds**.	Reduced to **42 seconds**.	**50% faster response time**.
Security Knowledge Score	Average security awareness score: **55/100**.	Increased to **82/100**.	**49% improvement in security knowledge**.
Attack Detection Accuracy	Employees correctly identified **46% of simulated cyber threats**.	Increased to **78% accuracy**.	**69% increase in attack detection ability**.

6.1 Key Performance Metrics

We analyzed several key cybersecurity awareness indicators before and after training:

- **Phishing Click Rate:** The percentage of employees who clicked on simulated phishing emails.
- **Incident Response Time:** The time taken by employees to detect and respond to cyber threats.
- **Security Knowledge Improvement:** The increase in cybersecurity awareness scores after training.
- **Attack Detection Accuracy:** Employees' ability to recognize cybersecurity threats in real-time scenarios.

6.2 Behavioral Changes and AI Adaptation

Improved Phishing Detection

Before training, 65% of employees fell for simulated phishing attacks. After undergoing AI-driven phishing simulations, this dropped to 18%, demonstrating a significant increase in phishing awareness. The AI-driven adaptive training module reinforced phishing awareness by generating personalized phishing scenarios based on employee responses. Employees who initially failed phishing tests received additional interactive training, helping them recognize social engineering tactics more effectively.

Faster Incident Response

Employees improved their incident response time by 50%, reducing the time needed to detect and mitigate cyber threats. AI-powered incident response drills helped employees practice real-time security alerts, teaching them how to identify, report, and contain cyber incidents quickly.

Higher Knowledge Retention:

AI-driven gamified learning contributed to an increase in security knowledge scores from 55/100 to 82/100, marking a 49% improvement. The AI model continuously adapted training difficulty based on individual performance, ensuring that employees retained critical cybersecurity concepts over time.

The steady improvement in security awareness across multiple weeks is illustrated in Figure 2, which shows a progressive increase in knowledge retention due to AI-driven adaptive training.

Enhanced Threat Detection Accuracy:

Prior to training, employees correctly identified only 46% of simulated cyber threats. After training, accuracy increased to 78%, demonstrating a 69% improvement in cybersecurity awareness. AI-generated threat detection exercises provided realistic industrial attack scenarios, helping employees improve their ability to recognize and respond to security threats**.**

6.3 Impact on Industrial Cybersecurity Resilience

The results of the simulation highlight the following benefits of AI-powered cybersecurity awareness training in industrial environments:

Reduction in human error: A key factor in industrial cyber incidents, significantly lowered phishing vulnerability.

Faster response to cyberattacks: Reduced incident response times improve operational security and minimize cyberattack damage.

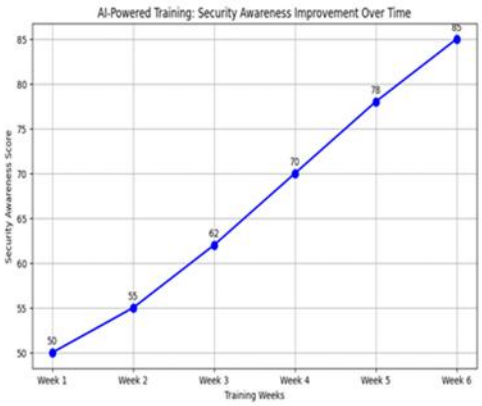

Figure 1: Security Awareness Improvement Over Time with AI-Powered Training

Higher employee engagement: AI-driven, role-specific training ensures that cybersecurity concepts are better retained and practiced effectively.

Improved adaptability to emerging threats: AI-generated real-time attack simulations prepare employees for evolving cyber threats, increasing resilience.

7. Conclusion and Future Work

This study demonstrates the effectiveness of AI-powered cybersecurity awareness training in enhancing the ability of industrial employees to detect, respond to, and mitigate cyber threats. By leveraging adaptive learning, real-time attack simulations, and AI-driven behavioral analytics, this approach provides a more effective and engaging cybersecurity training experience compared to traditional methods. The simulation results showed a significant reduction in phishing susceptibility, faster incident response times, and improved security knowledge retention. These findings highlight the importance of integrating AI-driven adaptive models in cybersecurity education to address evolving threats in industrial environments.

While the results indicate a substantial improvement in cybersecurity awareness, there are areas that warrant further research and enhancement. Expanding the AI model to incorporate predictive analytics could enable proactive risk identification, allowing organizations to address vulnerabilities before they are exploited. Additionally, deploying AI-powered training in real-world industrial environments will provide insights into its practical application, ensuring that the system remains effective in operational settings. Continuous AI adaptation to evolving cyber threats will further strengthen the resilience of employees by updating training content based on emerging attack patterns and real-time threat intelligence.

Future research should also focus on integrating AI-driven cybersecurity awareness training into Industrial IoT (IIoT) security frameworks, ensuring that employees are equipped to secure connected devices, sensors, and automation systems. Measuring long-term knowledge retention will be another key aspect, as understanding how employees maintain cybersecurity awareness over extended periods will help refine training methodologies. By advancing AI-powered cybersecurity education, industrial organizations can proactively mitigate cyber risks, enhance workforce security awareness, and strengthen overall resilience in an increasingly digitized operational landscape.

Conflicts of interest

The authors declare no conflicts of interest.

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