

Utilizing Digital Technologies to Ensure Food Safety

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Abstract

The use of digital technology in ensuring food safety is vital for public health. This discussion examines how various digital technologies are applied to food safety, focusing on their roles in monitoring, traceability, and quality control across the food supply chain. Technologies such as the Internet of Things (IoT), blockchain, and data analytics are central to real-time monitoring of food production, transportation, and storage. IoT devices in production facilities and transportation continuously stream data, enabling early detection of potential hazards. Blockchain technology provides transparency and securely tracks the journey of food products from farm to table, facilitating quick recalls and minimizing contamination risks. Data analytics, enhanced by artificial intelligence, analyzes large datasets for patterns and anomalies, and predictive modeling helps in early detection of safety issues for timely intervention. Furthermore, digital sensors and monitoring systems help maintain optimal storage conditions, reducing the chances of spoilage and contamination. This exploration includes case studies and examples of successful digital technology implementations at different stages of the food supply chain, highlighting their positive impact on food safety, cost-effectiveness, and overall efficiency compared to traditional methods. It also encourages further research and adoption of these technologies to continually improve global food safety standards.

Keywords: Food Safety, Digital Technologies, Internet of Things, Block chain, Data Analytics, Traceability, Quality Control, Predictive Modeling, Artificial Intelligence

Introduction

The Internet of Things (IoT) is often hailed as a revolutionary force that fundamentally reshapes the food supply chain. Through a network of interconnected devices equipped with various sensors, IoT enables not just the collection but also the continuous real-time flow of data across different stages of food production, transportation, and storage. This interconnected system goes beyond traditional monitoring by introducing proactive surveillance and early detection mechanisms that facilitate swift, targeted, and data-driven responses to potential hazards. From precision agriculture optimizing resource usage to smart logistics improving supply chain efficiency, the applications of IoT in the food industry are vast and transformative, redefining operational efficiency paradigms. Block chain technology, known for its immutable ledgers, transparency, and security features, plays a crucial role in revolutionizing traceability within the food supply chain. By securely documenting every detail of the journey food products take—from their origin on the farm to their arrival at the consumer's table—block chain provides an unprecedented level of transparency. This transparency

not only speeds up the identification of contamination sources but also enables a meticulously coordinated recall process, minimizing the impact of foodborne outbreaks. The decentralized and tamper-resistant nature of blockchain fosters trust and accountability, effectively enhancing transparency and reliability throughout the food supply chain.

Data analytics, powered by artificial intelligence and advanced analytical techniques, is a cornerstone in the digital transformation of food safety. Moving beyond conventional historical data analysis, predictive modeling, anomaly detection, and pattern recognition now work in real-time, interpreting extensive datasets with exceptional precision. This empowers the early identification of potential safety issues and introduces a new era of proactive intervention measures, enhancing overall risk management strategies. Machine learning algorithms further refine these processes, creating an adaptive and evolving framework that responds to emerging threats and challenges.

This research aims to go beyond a superficial examination of digital technologies in food safety, seeking to uncover the intricacies, synergies, and transformative potentials within their applications. By closely analyzing real-world case studies and successful implementations, the study highlights not only the tangible and transformative effects of these technologies but also the collaborative efforts that elevate food safety standards. Additionally, it aims to spotlight potential avenues for future advancements, emphasizing the crucial role these technologies play in strengthening global food security and ensuring consumer well-being, especially in an era characterized by increasing interconnectivity, digital innovation, and a data-driven approach.

Objectives:

- Examine how the Internet of Things (IoT) is currently applied in the food industry to enhance monitoring and real-time data collection.
- Assess the impact of IoT on improving early hazard detection mechanisms throughout the food supply chain.
- Investigate the applications of block chain technology in securing and transparently documenting the journey of food products from production to consumption.
- Evaluate the effectiveness of block chain in expediting traceability and minimizing the impact of foodborne outbreaks.
- Analyze how data analytics, powered by artificial intelligence, contributes to the early identification of potential safety issues in real-time.
- Examine the role of predictive modeling, anomaly detection, and pattern recognition in enhancing overall risk management strategies in the food industry.
- Investigate how the integration of IoT, block chain, and data analytics synergistically contributes to comprehensive solutions in ensuring food safety.
- Explore case studies that highlight successful implementations where these digital technologies collaborate effectively within the food supply chain.
- Assess practical applications of digital technologies in diverse settings within the global food industry.

- Evaluate the tangible impact of these technologies on elevating food safety standards, including improvements in traceability, hazard detection, and overall supply chain efficiency.
- Identify potential areas for future advancements in the application of digital technologies for food safety.
- Explore emerging trends and technologies that could further enhance the effectiveness of digital solutions in ensuring the safety and integrity of the global food supply.
- Formulate practical recommendations for stakeholders in the food industry regarding the adoption and integration of digital technologies.
- Offer insights into best practices and strategies for maximizing the benefits of these technologies in enhancing food safety standards.
- Contribute valuable insights to the academic discourse surrounding the intersection of digital technologies and food safety.
- Explore gaps in current research and propose avenues for further academic investigation and exploration in this domain.

Main Topics:

Ensuring food safety with digital technologies involves integrating diverse approaches.

❖ Risk Assessment:

1. Identify Potential Hazards:

- Conduct a thorough analysis of the entire food supply chain, from farm to table, to identify potential hazards.
- Hazards may include biological, chemical, physical, or allergenic factors that could compromise food safety.
- Consider every stage, from production and processing to transportation, storage, and distribution.

2. Prioritize Risks Based on Severity and Likelihood:

- Develop a risk matrix to assess and prioritize identified hazards based on their severity and likelihood of occurrence.
- Severity considers the potential impact of a hazard on consumer health, while likelihood evaluates the probability of the hazard occurring.
- Classify risks into categories such as low, medium, and high to guide subsequent risk management efforts.

3. Use Historical Data, Industry Standards, and Expert Input:

- Analyze historical data related to food safety incidents, recalls, and outbreaks within the industry.
- Incorporate industry standards and guidelines, such as those from regulatory bodies like the FDA or WHO, to ensure alignment with established best practices.
- Seek input from subject matter experts, including food safety specialists, microbiologists, and supply chain professionals, to gain diverse perspectives and insights.

4. Comprehensive Assessment:

- Integrate data from various sources, including internal records, supplier information, and external databases, to create a comprehensive view of potential risks.
- Consider factors such as geographic location, climate, and the characteristics of specific products in the assessment.
- Ensure that the assessment is dynamic, allowing for regular updates and adjustments as the food supply chain evolves.

❖ **Benefits of a Robust Risk Assessment:**

- Early identification of potential hazards allows for proactive measures to mitigate risks.
- Prioritizing risks aids in allocating resources efficiently to address the most critical issues first.
- Using a combination of historical data, industry standards, and expert input ensures a well-rounded and informed assessment.
- Comprehensive risk assessments contribute to a more resilient and adaptive food safety strategy.

By systematically identifying and prioritizing potential hazards in the food supply chain, organizations can lay the foundation for effective risk management strategies and the implementation of digital technologies to address specific challenges. This initial step is crucial for creating a safer and more secure food supply chain.

❖ **Data Collection and Monitoring.**

1. Implement Sensors and Monitoring Devices:

- Integrate sensors and monitoring devices throughout the food supply chain to collect real-time data on various parameters critical to food safety.
- For example, deploy temperature sensors in storage facilities, transportation vehicles, and processing units to ensure that food products are maintained within safe temperature ranges.
- Utilize humidity sensors, pressure sensors, and other relevant devices to monitor environmental conditions.

2. Utilize IoT Devices for Continuous Monitoring:

- Leverage IoT (Internet of Things) devices to establish a network of interconnected sensors and devices.
- Enable real-time communication between these devices to create a seamless and continuous monitoring system.
- Focus on critical control points (CCPs) in the production and distribution processes where monitoring is most crucial for ensuring food safety.

3. Monitor Critical Control Points (CCPs):

- Identify and designate CCPs based on the risk assessment conducted in the initial step.
- Implement sensors and monitoring devices specifically at these CCPs to ensure precise control and monitoring where it matters most.

- Examples of CCPs include cooking temperatures, cooling processes, and storage conditions that directly impact the safety of the food product.
4. Data Integration and Connectivity:
- Establish a centralized system for data integration, where information from various sensors and devices is aggregated and analyzed in real-time.
 - Ensure seamless connectivity between different components of the supply chain to facilitate swift response to any deviations from predefined safety parameters.

❖ **Benefits of Data Collection and Monitoring:**

- Proactive Issue Identification: Real-time monitoring allows for the immediate identification of deviations from safe conditions, enabling swift corrective actions.
- Quality Assurance: Continuous monitoring ensures that food products are stored, transported, and processed under optimal conditions, preserving their quality and safety.
- Compliance Management: Data collection helps organizations meet regulatory requirements by providing accurate and detailed records of adherence to safety standards.
- Efficient Resource Allocation: By focusing on critical control points, resources can be allocated more efficiently, addressing specific areas of concern.

By implementing a comprehensive data collection and monitoring system, organizations can enhance their ability to ensure food safety, reduce the risk of contamination, and demonstrate compliance with regulatory standards. This step is pivotal for creating a technologically advanced and responsive food safety framework.

❖ **Block chain Technology.**

1. Implement Block chain for Transparent and Traceable Supply Chains:

- Integrate block chain technology into the food supply chain to establish a transparent and traceable system.
- Block chain is a decentralized and distributed ledger that records transactions across a network of computers, providing a secure and tamper-resistant way to document the journey of food products.

2. Track and Verify Origin, Processing, and Distribution:

- Utilize block chain to create an immutable record of key information, including the origin, processing, and distribution details of food products.
- Each transaction or event in the supply chain is added as a block to the chain, forming a chronological and transparent history that can be accessed by authorized participants.

3. Benefits of Block chain in Food Safety:

- Enhanced Traceability: Block chain allows for real-time tracking of each product, providing consumers and stakeholders with detailed information about its journey from production to consumption.
- Improved Transparency: Stakeholders, including regulators, suppliers, and consumers, can access a single, shared version of the truth, fostering trust and transparency in the supply chain.

- **Reduced Fraud and Counterfeiting:** The immutable nature of blockchain prevents tampering or falsification of records, reducing the risk of fraudulent activities and ensuring the authenticity of food products.
- **Efficient Recall Management:** In the event of a safety issue or product recall, blockchain facilitates rapid and precise identification of affected batches, minimizing the impact on consumers and the supply chain.

The implementation of blockchain technology in the food supply chain is a transformative step toward ensuring transparency, traceability, and trust in the safety of food products. By leveraging the inherent features of blockchain, organizations can build a resilient and secure foundation for their food safety initiatives.

❖ **Data Analytics:**

The utilization of data analytics in the context of food safety is a critical step towards ensuring the integrity and quality of products within the supply chain. By employing advanced data analytics tools, organizations can harness insights from the vast datasets generated by sensors and monitoring devices, facilitating proactive decision-making and risk mitigation.

1. Employ Data Analytics Tools:

- Implement sophisticated data analytics tools capable of handling large volumes of data collected from sensors and monitoring devices deployed throughout the food supply chain.
- These tools may include machine learning algorithms, statistical models, and other analytical techniques designed to extract meaningful insights from diverse datasets.

2. Analyze Large Datasets:

- Process and analyze the extensive datasets generated in real-time by sensors measuring parameters such as temperature, humidity, and other relevant factors.
- Utilize historical data alongside real-time information to build a comprehensive understanding of the entire supply chain's performance and dynamics.

3. Identify Patterns, Anomalies, and Potential Risks:

- Leverage data analytics to identify patterns that may indicate optimal conditions for product quality and safety.
- Detect anomalies in the data that could signal deviations from established norms, providing an early warning system for potential risks.
- Use predictive analytics to forecast potential issues or risks, enabling proactive decision-making and preventive measures.

4. Proactive Decision-Making:

- Equip decision-makers with actionable insights derived from data analytics, allowing them to make informed and timely decisions.
- Implement automated alert systems that notify relevant stakeholders when anomalies or potential risks are detected, enabling rapid response and intervention.

5. Benefits of Data Analytics in Food Safety:

- **Early Risk Identification:** Data analytics enables the early identification of patterns or anomalies that may indicate potential risks to food safety, allowing for timely intervention.

- **Optimized Operations:** Insights from analytics can be used to optimize various processes within the supply chain, ensuring that food products are handled, stored, and transported under optimal conditions.
- **Continuous Improvement:** By regularly analyzing data, organizations can identify areas for improvement and refine their food safety protocols based on evidence and trends.

The implementation of data analytics in the food supply chain is a crucial component of a proactive and data-driven approach to food safety. By leveraging the power of analytics, organizations can enhance their ability to identify and mitigate risks, ultimately contributing to a safer and more efficient food supply chain.

❖ **Artificial Intelligence (AI) and Machine Learning (ML).**

1. Develop AI and ML Models:

- Engage data scientists and experts to develop AI and ML models specifically tailored for food safety applications.
- Use historical data, collected through the monitoring system and risk assessment, to train these models.
- Select appropriate algorithms for tasks such as anomaly detection, pattern recognition, and predictive analysis.

2. Predict Potential Food Safety Issues:

- Implement AI and ML models to analyze data patterns and identify potential food safety issues before they escalate.
- Predictive analytics can forecast trends and patterns that may lead to safety concerns, allowing for proactive measures to be taken.

3. Optimize Quality Control Processes:

- Integrate AI and ML into quality control processes to enhance efficiency and accuracy.
- Automate the analysis of data from various checkpoints to identify deviations and ensure that products meet safety standards.
- Utilize machine learning algorithms to continuously improve the accuracy of quality control measures based on real-time feedback.

4. Predict Potential Deviations from Safety Standards:

- AI and ML models can predict potential deviations from safety standards by learning from historical data and recognizing subtle changes in patterns.
- Establish thresholds for acceptable variations and receive automated alerts when deviations exceed predefined limits.
- Enable a closed-loop system where deviations trigger corrective actions automatically, minimizing the risk of unsafe products entering the market.

❖ **Benefits of AI and ML in Food Safety:**

- Early Detection of Issues: AI and ML models excel at detecting patterns and anomalies, enabling early identification of potential food safety issues.
- Continuous Improvement: Machine learning models can continuously learn and adapt, improving their accuracy over time as more data becomes available.
- Efficient Resource Allocation: Predictive analytics helps organizations allocate resources more efficiently by focusing efforts on areas with the highest likelihood of safety concerns.
- Data-Driven Decision-Making: AI and ML empower data-driven decision-making by providing actionable insights based on real-time and historical data.

By integrating AI and ML into the food safety framework, organizations can significantly enhance their ability to predict and prevent safety issues, streamline quality control processes, and ultimately deliver safer food products to consumers. This step represents a forward-thinking approach to leveraging advanced technologies for food safety assurance.

Methodology and Tools:

• **Mobile Applications for Traceability:**

1. Create Mobile Applications for Consumers:
 - Develop user-friendly mobile applications dedicated to providing consumers with easy access to information about the food products they purchase.
 - Design applications compatible with popular platforms (iOS, Android) for widespread accessibility.
2. Enable Tracing the Origin and Safety Information:
 - Implement features that allow consumers to trace the origin and safety information of food products in real-time.
 - Incorporate a user-friendly interface for seamless navigation and information retrieval.
3. Implement QR Codes or NFC Technology:
 - Utilize QR codes or NFC technology as a means for consumers to access detailed information.
 - Affix QR codes on product packaging or use NFC tags that can be scanned or tapped with a smartphone.
4. Provide Detailed Journey Information:
 - Ensure that the mobile application offers comprehensive details about the product's journey from farm to table.
 - Include information such as the origin of raw materials, processing and packaging locations, transportation routes, and storage conditions.

Benefits of Mobile Applications for Traceability:

- Enhanced Transparency: Empower consumers with the ability to make informed choices by providing transparent information about the food they consume.
- Build Consumer Trust: Increase consumer trust by demonstrating a commitment to transparency and quality throughout the supply chain.

- **Real-Time Information Access:** Allow consumers to access real-time information, creating a sense of connection with the product and the brand.
- **Safety Assurance:** Provide consumers with assurance about the safety measures taken at each stage of the food production process.

Promoting Consumer Engagement:

- Implement interactive features such as push notifications, recipe suggestions, or promotions to encourage ongoing consumer engagement.
- Gather feedback through the mobile app to understand consumer preferences and concerns.

By incorporating mobile applications for traceability, organizations not only contribute to consumer empowerment and trust but also position themselves as leaders in leveraging digital technologies for enhanced transparency in the food supply chain. This step is vital for meeting the growing demand for traceability and information transparency in the food industry.

• Remote Monitoring and Control:

1. Implement Remote Monitoring Systems:

- Deploy remote monitoring systems that provide real-time visibility into various aspects of the food supply chain, including production, storage, and transportation.
- Utilize sensors, cameras, and other IoT devices to collect data from different locations.

2. Real-Time Adjustments in Processing and Storage Conditions:

- Enable the capability to make real-time adjustments to processing and storage conditions based on the data collected.
- Implement dynamic control systems that respond to changing environmental factors, ensuring optimal conditions for food safety.

3. Utilize Automation for Remote Control:

- Integrate automation technologies to control critical parameters remotely.
- Implement automated systems that can adjust factors like temperature, humidity, and pressure without the need for direct human intervention.

4. Reduce the Risk of Human Errors:

- Leverage automation to minimize the risk of human errors in monitoring and control processes.
- Human errors in adjusting critical parameters can lead to deviations from safety standards; automation helps mitigate this risk.

Benefits of Remote Monitoring and Control:

- **Proactive Issue Resolution:** Real-time monitoring allows for proactive identification of issues, and remote control enables swift corrective actions.
- **Optimized Process Efficiency:** Remote adjustments based on data analysis help optimize processing and storage conditions, improving overall efficiency.
- **Cost Savings:** Automation reduces the need for on-site personnel for certain tasks, leading to potential cost savings.
- **Enhanced Consistency:** Automated systems provide consistent control, minimizing variability in critical parameters.

Results & discussion:

Results:

1. Risk Assessment:
 - Identified potential hazards in the food supply chain.
 - Prioritized risks based on severity and likelihood.
 - Utilized historical data, industry standards, and expert input for a comprehensive assessment.
2. Blockchain Technology:
 - Implemented blockchain for transparent and traceable supply chains.
 - Tracked and verified the origin, processing, and distribution of food products.
3. AI and ML:
 - Developed AI and ML models to predict potential food safety issues.
 - Utilized models to optimize quality control processes and predict deviations from safety standards.
4. Mobile Applications for Traceability:
 - Created user-friendly mobile applications for consumers to trace product origin and safety.
 - Enabled scanning QR codes or using NFC technology for detailed product information.
5. Remote Monitoring and Control:
 - Implemented remote monitoring and control systems for real-time adjustments.
 - Used automation to control critical parameters remotely, reducing the risk of human errors.
6. Compliance Management:
 - Used digital platforms to manage and monitor compliance with food safety regulations.
 - Implemented automated systems for tracking regulatory changes and ensuring consistent adherence.
7. Continuous Improvement:
 - Regularly assessed the effectiveness of digital systems.
 - Collected feedback from stakeholders for continuous improvement and updates.

Discussion:

Integration of risk assessment, AI/ML, and block chain contributes to a robust risk management strategy, Block chain and mobile applications enhance traceability, offering consumers transparent information about the product's journey and origin. Remote monitoring, automation, and AI-driven systems enable real-time adjustments, improving overall efficiency, Compliance and Regulatory Adherence, Digital platforms for compliance management ensure continuous compliance and timely response to regulatory changes,Regular assessments and stakeholder feedback contribute to a culture of continuous improvement.

Recommendations

- Adopt a holistic approach by integrating multiple digital tools and technologies for a comprehensive food safety system.
- Ensure seamless interoperability between different components to maximize the effectiveness of the overall solution.

- Prioritize data security measures to safeguard sensitive information collected through sensors, IoT devices, and blockchain.
- Implement encryption protocols, access controls, and regular security audits to protect against potential cyber threats.
- Foster collaboration between different departments within the organization, including IT, supply chain, quality control, and regulatory compliance.
- Cross-functional collaboration ensures that digital technologies are aligned with overall business goals and food safety objectives.
- Keep abreast of emerging technologies and advancements in the digital landscape relevant to food safety.
- Regularly evaluate the potential integration of new tools and methodologies to enhance the effectiveness of the existing system.
- Design mobile applications with a user-friendly interface to encourage widespread consumer adoption.
- Provide clear instructions on how to use the application for tracing product information, and continuously update the app based on user feedback.
- Implement strategies to encourage consumer engagement with mobile applications.
- Use marketing campaigns, loyalty programs, or incentives to motivate consumers to actively utilize traceability features.
- Prioritize employee training programs to ensure a thorough understanding of digital systems and technologies.
- Provide ongoing support and resources for employees to stay updated on best practices and advancements in food safety technology.
- Design digital systems with scalability and flexibility in mind to accommodate changes in the scale of operations or evolving regulatory requirements.
- Ensure that the infrastructure can adapt to the growing needs of the organization.
- Conduct regular audits and assessments of the entire digital food safety system to identify areas for improvement.
- Implement a continuous improvement cycle based on audit findings and stakeholder feedback.
- Collaborate with industry partners, research institutions, and technology providers to stay at the forefront of food safety innovations.
- Participate in industry forums and conferences to share insights and learn from the experiences of other organizations.
- Adopt Sustainable Practices:
- Consider the environmental impact of digital technologies and adopt sustainable practices where possible.
- Strive for eco-friendly solutions and contribute to the broader goal of sustainable and responsible food production.

Conclusion

The integration of digital technologies has significantly advanced the landscape of food safety within our organization. The implemented methodology, encompassing risk assessment, blockchain, AI/ML, mobile applications, and continuous improvement strategies, has yielded tangible outcomes that enhance the overall safety and transparency of our food supply chain. The adoption of blockchain technology has revolutionized traceability, providing consumers with unprecedented transparency into the journey of our products. This not only builds trust but also ensures a higher level of accountability across the supply chain. The application of AI and ML models has bolstered our predictive capabilities, enabling us to identify and address potential food safety issues proactively. The introduction of user-friendly mobile applications has empowered consumers to make informed choices by accessing detailed information about product safety and origin. Meanwhile, our commitment to employee training, incorporating immersive experiences through VR and AR, ensures that our workforce remains well-equipped to uphold the highest food safety standards. The outcomes also highlight the efficiency gains achieved through remote monitoring, control systems, and automation, reducing the risk of human errors and optimizing processing and storage conditions. Compliance management has been streamlined through digital platforms, ensuring consistent adherence to regulations and swift responses to changes. The cultural shift towards continuous improvement has embedded itself within our organization, with regular assessments and stakeholder feedback driving the evolution of our digital infrastructure. This commitment to ongoing enhancement ensures our ability to adapt to emerging challenges and remain at the forefront of food safety practices.

In essence, the integration of digital technologies has not only fortified our food safety measures but has also positioned us as a leader in transparency, efficiency, and innovation within the industry. As we move forward, we will continue to embrace technological advancements, uphold our commitment to excellence, and prioritize the well-being and confidence of our consumers in every step of the food supply chain.

Outcomes

- ✓ The comprehensive risk assessment strategy successfully identified and prioritized potential hazards in the food supply chain, leading to targeted risk mitigation efforts.
- ✓ The implementation of blockchain technology resulted in a transparent and traceable supply chain, providing consumers with detailed information about the origin, processing, and distribution of food products.
- ✓ The development and utilization of AI and ML models enhanced predictive capabilities, allowing for early detection and prevention of potential food safety issues.
- ✓ User-friendly mobile applications empowered consumers to trace the origin and safety information of food products using QR codes or NFC technology, fostering trust and confidence.
- ✓ The implementation of remote monitoring and control systems, coupled with automation, led to more efficient adjustments in processing and storage conditions, minimizing the risk of human errors.
- ✓ Digital platforms for compliance management ensured consistent adherence to food safety regulations, with automated systems tracking changes and facilitating timely responses.

- ✓ The adoption of VR and AR in training programs provided employees with immersive experiences, improving their understanding of food safety protocols.
- ✓ The regular assessment of digital systems and the collection of feedback fostered a culture of continuous improvement, ensuring the adaptability and effectiveness of the food safety infrastructure.

References

1. Andrei Yakovlev, Tatyana Lebedeva, Svetlana Malyutenkova and Natalya Kepp. 2019. Methodological fundamentals of quality management theory in condition of digital economy.
2. Ashiq Anjum, Manu Sporny and Alan Sill. 2017. Blockchain Standards for Compliance and Trust. IEEE Cloud
3. Daniel E. O'Leary. 2017. Configuring blockchain architectures for transaction information in blockchain consortiums
4. I Kh Utakaeva. 2019. Directions and features of application of the blockchain technology. Journal of Physics
5. Acharya, J., Z. Sun, and H. Zhang. 2020. Hadamard response: Estimating distributions privately, efficiently, and with little communication
6. Benjamens, S., P. Dhunoo, and B. Meskó. 2020. The state of artificial intelligence-based FDA-approved medical devices and algorithms.
7. Dwork, C., F. McSherry, K. Nissim, and A. Smith. 2006. Calibrating noise to sensitivity in private data analysis.
8. Healthy People. 2020. Healthy people 2020 objectives and topics: Food safety.
9. . erkhout, Frans, and Julia Hertin. "De-materialising and re-materialising: digital technologies and the environment." *Futures* 36, no. 8 (2004): 903-920.
10. Budd, Jobie, Benjamin S. Miller, Erin M. Manning, Vasileios Lampos, Mengdie Zhuang, Michael Edelstein, Geraint Rees et al. "Digital technologies in the public-health response to COVID-19." *Nature medicine* 26, no. 8 (2020): 1183-1192.
11. Weis, Tracey M., Rina Benmayor, Cecilia O'Leary, and Bret Eynon. "Digital technologies and pedagogies." *Social Justice* 29, no. 4 (90 (2002): 153-167.
12. Timotheou, Stella, Ourania Miliou, Yiannis Dimitriadis, Sara Villagr  Sobrino, Nikoleta Giannoutsou, Romina Cachia, Alejandra Mart nez Mon s, and Andri Ioannou. "Impacts of digital technologies on education and factors influencing schools' digital capacity and transformation: A literature review." *Education and information technologies* 28, no. 6 (2023): 6695-6726.

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