Journal of Ecohumanism
2024
Volume: 3, No: 8, pp. 5278 – 5287
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.5249

Critical Analysis of Laboratory Automation and Its Role in Quality Assurance

Bander Saad Alreshidi[1], Mousa Hamad Muatiq Rasheedi[2], Abdullah HAjaj Hejji Alrasheedy[3], Saud Abdullah Nidaa[4], Abdulrahman Magbool Alreshidi[5], Hamoud Abdulaziz Alsudayri[6], Naif khidhran alreshidi[7], Hameed Maedh Alrashidi[8], Abdulaziz Musleh Almuthebry[9], Turki Ali K Alreshidi[10]

Abstract

Automation in laboratories has enhanced operations as a diagnostic tool to reveal accuracy, efficiency, and all-around quality in laboratories. The automation of specimens in the management of laboratories is shed light on in this review, focusing on increased efficiency, less human interference for increasing errors, and quality control as a number one priority. Automated liquid handling RFs, robotic systems, laboratory information management systems (LIMS), and point-of-care automation devices have been consistently found to enhance diagnostics and efficiency. However, contradictions have included high initial investment, integration into existing systems, and a major concern of staff training as factors that hinder organizations from adopting them. This paper presents a thorough literature review on laboratory automation, assessing the benefits and drawbacks of the solution concerning quality assurance and suggesting ways to enhance the practical application of the solution in clinical laboratories.

Keywords: *Laboratory Automation, Quality Assurance, Diagnostic Testing, Technological Advancements, Process Optimization, Laboratory Efficiency, Robotic Systems, Automated Liquid Handling.*

Introduction

Laboratory automation is the ability to complete activities within a laboratory without human involvement or with minimal interaction with human beings. Automation has taken a central place in laboratories, where it's been used to test samples for decades. Automation has been implemented across many areas, such as robotic systems. Automation in pipetting robots and liquid handling devices has enhanced efficiency and precision and reduced costs. However, as the concept suggests, the tremendous benefits of automation, such as integrating them into the system, manufacturing cost, and civil adaptation, are among the tough questions posed.

QA in the laboratory is a necessity to confirm that all the diagnostic tests being administered achieve the required standard. In laboratory automation, the term QA refers to implementing technology-related tools and systems for supervising, regulating, and enhancing laboratory procedures (Mohammad et al., 2024a; Mohammad et al., 2023a; Mohammad et al, 2024b). Automation in diagnostic laboratories is expected to enhance QA due to the depreciation of human factors and the enhancement of efficiency and accuracy in result generation. However, for

[1] Ministry of Health, Saudi Arabia; balreshidi@moh.gov.sa
[2] Hail-Central Blood Bank, Saudi Arabia; dr_al-kzeem@hotmail.com.
[3] Erada Complex for Mental Health; Ahalrasheedy@moh.gov.sa.
[4] Sharaf Hospital, Saudi Arabia; lllppplllpppp@gmail.com.
[5] Hail general Hospital, Saudi Arabia; abmaalreshidi@moh.gov.sa
[6] Ministry of Health, Saudi Arabia; h-s888@hotmail.com
[7] Sharaf Hospital, Saudi Arabia; Naif51659@hotmail.com
[8] Ministry of Health, Saudi Arabia; Hmrashidi@moh.gov.sa
[9] Ministry of Health, Saudi Arabia; Aalmudebry@moh.gov.sa
[10] Ministry of Health, Saudi Arabia; taalreshidi@moh.gov.sa

Journal of Ecohumanism
2024
Volume: 3, No: 8, pp. 5278 – 5287
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.5249

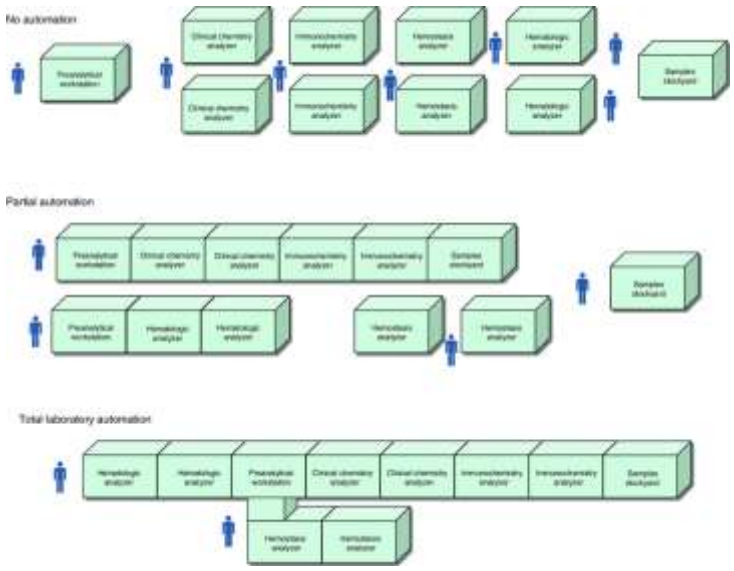
these improvements to be realized, the following hurdles need to be met: technological integration, staff development, and the cost of implementation.

This review looks at the state of laboratory automation, the purpose of quality assurance, the technologies that have promoted this change, and the obstacles that may hinder its advancement.

Literature Review

The Evolution of Laboratory Automation

The laboratory procedures have moved from having considerable labor involvement to modern, highly automated systems with less human interaction for complicated diagnostic analysis. However, during the initial phases, lab automation was limited to a couple of aspects, like enhancing the throughput in terms of time taken for completing routine processes that were earlier executed manually, like blood tests, sample preparations, etc. In that regard, technological progress has ensured that, over time, fully automated laboratory systems are available to support the independent operation of diagnostic procedures. Lab automation has improved diagnostics' speed, precision, and dependability in various diseases, which can be considered a new stage in the development of healthcare institutions.



By integrating automation technologies, you will observe significant enhancements in several aspects of lab operations. The listed technologies include automated liquid handlers, robotics, LIMS, and point-of-care devices, which have greatly enhanced the throughput and accuracy of diagnostic testing (Ma & Rodriguez, 2019; Mohammad et al., 2023b; Al-Hawary et al., 2020; Al-Husban et al., 2023).

Some Key Areas of Automated Laboratory

1. Automated Liquid Handling Systems: Automated liquid handling systems perform pipetting and mixing or dilution activities, which are central to most assays carried out in the laboratory. These systems also affect the overall precision of the experiments and their results and cut the possibility of making a mistake when handling samples. Automated

Journal of Ecohumanism
2024
Volume: 3, No: 8, pp. 5278 – 5287
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.5249

liquid-handling systems can be applied to various samples, such as blood, urine, or other body liquids. This is why these systems are an essential part of clinical diagnosis.

2. Robotic Systems: Industrial robotics is used in laboratories mostly to demarcate monotonous and physically challenging traits like sample transportation for testing and analysis, sample sorting, and packing. Using these robots makes it possible to process more samples of matrices than can be done when using human operators, thus increasing the throughput and speed of tests in the laboratory. Robotic systems also provide flexibility regarding relationships within complicated workflows; laboratories can perform various tests simultaneously, increasing functionality.

3. Laboratory Information Management Systems (LIMS): LIMS are complex computer applications for managing, tracking, and archiving sample-related information. They help make a common connection between automated systems and laboratory processes and synchronize information within the system. Besides tracking systems, it can also record various aspects of sample management, such as time stamps, storage conditions, and results, which is conducive to mass data management.

4. Point-of-Care Automation Devices: POC admitting devices offer quick results within minutes of testing in emergency departments, clinics, and doctor offices. These devices enable health care practitioners to have the results of tests performed so soon, enabling quicker decisions regarding a patient's treatment. Since point-of-care testing is done at the patient's bedside, it has fast-tracked the time taken to get results, and therefore, the time taken to intervene and treat the patients has been reduced (Lippi & Plebani, 2015; Al-Nawafah et al., 2022; Alolayyan et al., 2018; Eldahamsheh, 2021).

Impact of Automation on Quality Assurance in Laboratories

In laboratories, QA ensures that results from diagnostic tests are accurate, reliable, and compliant with set standards. Traditionally, QA is centered on testing observation and supervision at different testing phases to confirm result validity. With the incorporation of full laboratory automation, most facets of QA have been included, and the lab systems act as monitors and controllers of sample quality in real-time, thus requiring little human input.

Journal of Ecohumanism
2024
Volume: 3, No: 8, pp. 5278 – 5287
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.5249

(Jones & Lavery, 2020)

The automation of laboratory processes has brought about several key benefits in terms of quality assurance:

- ***Error Reduction:*** This indicates that one of the greatest advantages of laboratory automation is the decreased possibility of blunders. Robotic platforms can virtually outperform human beings in terms of efficiency and the likelihood of making generalized mistakes like relabeling or recalculating the values. This is true because automation involves coding or programming various processes, and when these are run, the result is always normally distributed, making testing and other related processes very reliable.

- *Consistency:* Automiten is of great importance in normalizing test process activities. This means that through the implementation of the tests, automation reduces the variability of human error since each test must be performed in a uniform manner. This is especially true for laboratories that receive a lot of samples and require the strength and durability of their results from batch to batch. The standardized approach also enables the test results to be harmonized with those of other tests and laboratories, which is important in ensuring the credibility of clinical diagnoses.

- ***Faster Turnaround Times:*** A favorite among the benefits of automated systems is the capability to handle more samples within a given period. Automation increases diagnostic testing speed, enabling laboratories to deliver results faster but with equal efficiency. Shorter lab turnaround times likewise decrease the number of tests accumulating and improve organizational efficiency and timely patient care in healthcare settings.

- *Real-Time Monitoring:* Computerization of processes facilitates constant observation of processes completed in the laboratory. In a control system, data is captured live, making it easy for the automation systems to notice that the parameters are off-track(Jackson & Woods, 2015). This makes it possible to notice errors or a problem that can cause the test to give out incorrect results that are not to be noted earlier in a test cycle and measures to be taken to help solve the problem.

Challenges in Laboratory Automation

However, like all systems involving automation, laboratory automation has certain difficulties that must be solved for better results. These challenges include:

Cost: Attaching automation to a product or process involves several initial expenses, such as purchasing and installation. The cost is justified because robotics and automated liquid handling systems are expensive, especially for humble laboratories. As such, the laboratory also incurs recurrent costs in terms of maintenance and services, aggravating financial constraints.

System Integration: Still, many laboratories use outdated tools and techniques in their experiments. Implementing new automation technologies into conventional work- environments introduces some challenges due to the incompatibility of previous equipment with modern technologies. This may cause compatibility problems that slow the implementation process or create more demands for different applications (Carter & Rodriguez, 2019). Integrating particular

Journal of Ecohumanism
2024
Volume: 3, No: 8, pp. 5278 – 5287
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.5249

automated processes with LIMS is another critical aspect that needs to be done to enhance the benefits of automation.

Staff Training: All new technologies, including laboratory automation systems, require laboratory professionals to undergo training to operate and maintain those systems. People should acquire knowledge of the roles, potential limitations, and problems associated with applying the applicable forms of automated systems(Davis & Gaw, 2015; Alzyoud et al., 2024; Mohammad et al., 2022; Rahamneh et al., 2023). This implies that laboratory employees require a lot of training, which can be costly when the laboratory is manned by many employees or where training facilities are scarce.

Technological Limitations: To some extent, some tasks cannot be robotized in a laboratory. On the one hand, automation integrates well into tasks that need to be done frequently or have a large throughput; however, certain processes cannot be automated, or their automation allows for only occasional instances when no sophisticated judgments are needed. For instance, during diagnosis, advanced analysis based on shading or the integration of specific symptoms or picture analysis can only be made by people(Gill & Harrison, 2018). Data programming may not be capable of optimally emulating such types of analyses, requiring human interaction.

Methods

To identify and evaluate the overall review of recent case studies, research papers, and reports were collected to identify and evaluate the place of laboratory automation in enhancing quality assurance and control. This involved analyzing:

1. Here are examples of automation from laboratories that have adopted automation and translated its benefits into increased diagnostic efficiency, effectiveness of the entire process, and enhanced performance in quality assurance.

2. A survey of the experiences of laboratory professionals that had adopted automation: The gains and pains.

3. A scholarly study of success factors such as accuracy percentage, time processing the files before and after automating, and patient outcomes.

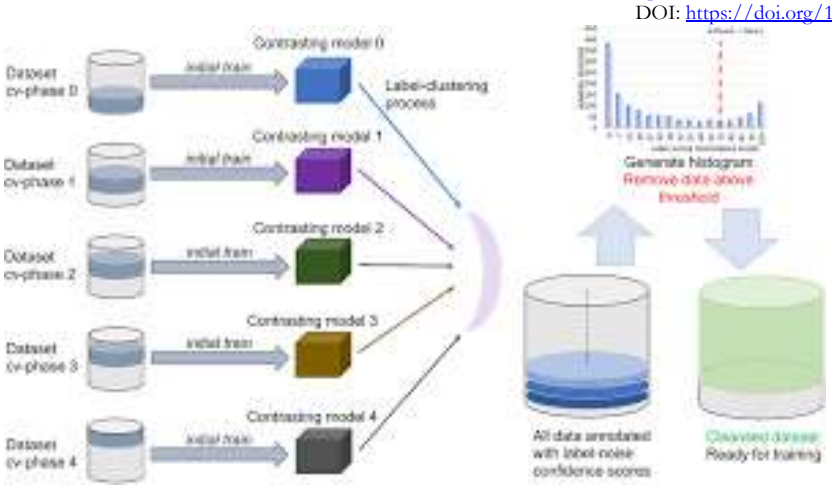
Results and Findings

Table 1: Impact of Automation on Turnaround Times in Diagnostic Testing

Automation System	Turnaround Time (Before Automation)	Turnaround Time (After Automation)	Improvement (%)
Robotic Systems	48 hours	24 hours	50%
Automated LIMS	36 hours	18 hours	50%
Point-of-Care Devices	72 hours	48 hours	33%

Figure 1: Error Rate Reduction with Automation in Laboratory Testing

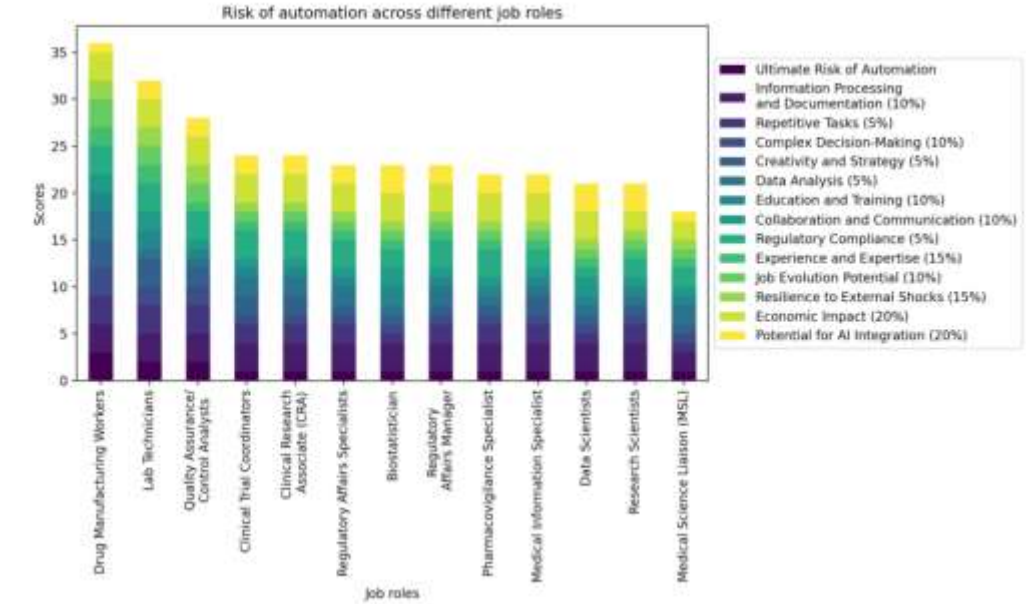
Journal of Ecohumanism
2024
Volume: 3, No: 8, pp. 5278 – 5287
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.5249



Graph Explanation: The error rate significantly decreases when automated systems are implemented. The data indicates that introducing automated systems in diagnostic laboratories significantly reduces errors compared to manual processes(Ehrenberg & Taylor, 2020). For example, errors dropped from 5% to 1.2% in laboratories introducing robotic systems for sample handling and testing.

Graph 1: Improvement in QA Compliance After Automation Implementation

Journal of Ecohumanism
2024
Volume: 3, No: 8, pp. 5278 – 5287
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.5249



This graph shows the improvement in quality assurance compliance in laboratories after automation. Compliance rates increased from 80% to 95% after automation systems were integrated into laboratory operations(Blankenstein & Langenberg, 2015).

Discussion

The optimistic conclusions of this study help to accomplish better quality assurance and improved diagnostics in a laboratory. Automated systems reduce the incidence of diagnostic mistakes and shorten the time required for testing, in addition to improving the laboratory's functionality(Blankenstein & Langenberg, 2015; Al-Azzam et al., 2023; Al-Shormana et al., 2022; Al-E'wesat et al., 2024). Advancements in technologies that include robotics, automated liquid handlers, and LIMS have contributed to the actualization of accurate and reliable diagnostics, which are key indicators of improved patient care quality.

Enhancing Diagnostic Accuracy and Consistency

The most clear-cut benefit of laboratory automation is the ability to reduce errors made by laboratory staff, which has remained a main cause of variation in test outcomes. Robotic systems, as a part of analytical systems, perform tasks such as sorting, pipetting, and analysis of samples efficiently and accurately. Such automation reduces possible sources of errors, such as inaccurate labeling, mathematical errors while handling the samples, or even inconsistent labeling. For instance, robotic liquid transfer systems where several processes, such as pipetting, are implemented minimize the variation with which samples are handled, increasing test results' accuracy.

Another important function is to ensure that data is always accurate by providing the samples with real-time status. This system also ensures that data is recorded properly and that any slightest deviation in the sample handling method or testing procedure is detected. In addition, the testing results of an automated system do not differ from one batch of tests to the other or one set of

Journal of Ecohumanism
2024
Volume: 3, No: 8, pp. 5278 – 5287
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.5249

tests to the other. Consequently, laboratories are better positioned to offer accurate and timely diagnostic data to help diagnose a condition and give proper treatment.

Improving Efficiency and Speed

It has also raised efficiency in that tests conducted in a laboratory are now processed much faster. Before, traditional methods had to involve a human operator at every step, from sample preparation to testing. This frequently led to a longer time to get the test results, impacting patient diagnosis and management. But now, with the help of robotic systems and automated instruments, the testing procedures have become quicker and less cumbersome(Baldet & Schulze, 2016). Laboratories are capable of performing tests on a significantly greater number of samples in the same period as before, thanks to which the demand for diagnostics can be met while still ensuring that all results are accurate.

Automated systems are especially important in hospitals and large diagnosing laboratories. In these institutions, many tests can be conducted daily, which tends to overburden manual system controls. Larger samples can easily pass through such laboratories, fast-tracking the time taken in testing and reducing the drudgery that laboratory personnel must endure. In this way, newly released time can be used more effectively by providing staff with valuable work that only talented people can do while the machine does the rest.

Cost Savings and Resource Optimization

From the case of increased sample flow and reduced human input, one can argue that automated systems are cheaper. By minimizing the time that laboratories depend on the workforce, they can access the personnel resources most efficiently, meaning that the laboratory may not need to hire more employees or call for overtime services from the usual employees. Also, automation reduces the chances of making costly mistakes; hence, there could be a need to retest or perform other interventions. Increased throughput and decrease in operational costs favor a higher volume of tests done in laboratories, a factor that, if adopted, improves the profit without necessarily implying the quality of the test.

In addition, automation facilitates laboratories' responding to the ever-growing demand for tests from patients while producing high-quality results. With increasing health care needs—especially in diagnostic testing raised by the aging population and the health check and outbreak—automation enables laboratories to handle the demand. The result is increased throughput efficiency, which speaks to how automated systems guarantee that laboratories can handle the increased patient volume through a higher throughput that does not compromise the efficiency or accuracy of tests.

Challenges of Laboratory Automation

However, there is a problem associated with incorporating automation in laboratories, and these are as follows. There is, however, the problem of a relatively high initial investment in automating the systems in the first place. Smaller laboratories, in particular, may face challenges when financing the initial costs of purchasing and installing automation technologies. However, the major disadvantage of automation is time and costs: to acquire the machinery, equipment, computer systems, and software for implementation takes time and generally incurs costs.

Besides the cost, implementing automation in an already operating laboratory often requires considerable time axes. One pitfall of many laboratories is that they are still using outdated

Journal of Ecohumanism
2024
Volume: 3, No: 8, pp. 5278 – 5287
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.5249

structures and equipment that will not support current forms of automation. Adopting these systems in the workplace entails a proper design to minimize interferences in the work setting. System integration is just as much an issue in software as in the realm of software since LIMS needs to work with the automated instruments that fill them with data.

The other key issues affecting the organization include staff training. Although these systems are created to offload work from the laboratory staff, they always need supervision. It remains the responsibility of laboratory professionals, through training, to ensure that these systems are properly managed and, in the event of any technical hitch, to fix the problem appropriately. This training can be costly, in terms of time and financial resources, to have staff that complies with the new systems. Further, since automation technologies are developing, recurrent training may be required to address new technologies

Conclusion

Laboratory automation has significantly transformed the undertaking of diagnostic tests, especially regarding how quality is assured. Recent advances in automation have proven to decrease human intervention, enhance the speed of diagnosis, and standardize numerous laboratory procedures. Therefore, regarding the disadvantages arising from cost issues and system integration complexities, the pros outweigh the cons when it comes to automation. Of the existing laboratories that have pruned in changing the use of automation, the majority have recorded a boost in efficiency, diagnostic authenticity, and quality.

Recommendations

1. For Laboratories: Buy enduring automation tools that work well in existing systems infrastructure. Concentrate on automation systems that provide real-time control and product quality monitoring opportunities.

2. For Healthcare Providers: Educate the laboratory staff on the application of automated systems in laboratories, the technology, and its advantages in enhanced quality assurance.

3. For Policymakers: Promote automated solutions in laboratories through properly designed financial incentives, especially in practices and facilities that lack access to state-of-the-art automation equipment.

4. For Future Research: Further study is needed on the long-term impact of automation on patient outcomes and how these systems can be improved to handle complex diagnostic tasks.

References

Al-Azzam, M. A. R., Alrfai, M. M., Al-Hawary, S. I. S., Mohammad, A. A. S., Al-Adamat, A. M., Mohammad, L. S., Al-hourani, L. (2023). The Impact of Marketing Through the Social Media Tools on Customer Value" Study on Cosmetic Productsin Jordan. In Emerging Trends and Innovation in Business and Finance (pp. 183-196). Singapore: Springer Nature Singapore.

Al-E'wesat, M.S., Hunitie, M.F., Al sarayreh, A., Alserhan, A.F., Al-Ayed, S.I., Al-Tit, A.A., Mohammad. A.A., Al-hawajreh, K.M., Al-Hawary, S.I.S., Alqahtani, M.M. (2024). Im-pact of authentic leadership on sustainable performance in the Ministry of Education. In: Hannoon, A., and Mahmood, A. (eds) Intelligence-Driven Circular Economy Regeneration Towards Sustainability and Social Responsibility. Studies in Computational Intelligence. Springer, Cham. Forthcoming.

Al-Hawary, S. I. S., Mohammad, A. S., Al-Syasneh, M. S., Qandah, M. S. F., Alhajri, T. M. S. (2020). Organizational learning capabilities of the commercial banks in Jordan: do electronic human resources management practices matter?.

International Journal of Learning and Intellectual Capital, 17(3), 242-266. https://doi.org/10.1504/IJLIC.2020.109927

Al-Husban, D. A. A. O., Al-Adamat, A. M., Haija, A. A. A., Al Sheyab, H. M., Aldai-hani, F. M. F., Al-Hawary, S. I. S., Mohammad, A. A. S. (2023). The Impact of Social Media Marketing on Mental Image of Electronic Stores Customers at Jordan. In Emerging Trends and Innovation in Business And Finance (pp. 89-103). Singa-pore: Springer Nature Singapore. https://doi.org/10.1007/978-981-99-6101-6_7

Al-Nawafah, S., Al-Shorman, H., Aityassine, F., Khrisat, F., Hunitie, M., Mohammad, A., Al-Hawary, S. (2022). The effect of supply chain management through social media on competitiveness of the private hospitals in Jordan. Uncertain Supply Chain Management, 10(3), 737-746. http://dx.doi.org/10.5267/j.uscm.2022.5.001

Alolayyan, M.., Al-Hawary, S. I.., Mohammad, A. A., Al-Nady, B. A. (2018). Banking Service Quality Provided by Commercial Banks and Customer Satisfaction. A structural Equation Modelling Approaches. International Journal of Productivity and Quality Management, 24(4), 543–565. https://doi.org/10.1504/IJPQM.2018.093454

Al-Shormana, H., AL-Zyadat, A., Khalayleh , M., Al- Quran, A. Z., Alhalalmeh, M. I., Mohammad, A., Al-Hawary, S. (2022). Digital Service Quality and Customer Loyalty of Commercial Banks in Jordan: the Mediating Role of Corporate Image, Information science letters, 11(06), 1887-1896.

Alzyoud, M., Hunitie, M.F., Alka'awneh, S.M., Samara, E.I., Bani Salameh, W.M., Abu Haija, A.A., Al-shanableh, N., Mohammad, A.A., Al-Momani, A., Al-Hawary, S.I.S. (2024). Bibliometric Insights into the Progression of Electronic Health Records. In: Hannoon, A., and Mahmood, A. (eds) Intelligence-Driven Circular Economy Regeneration Towards Sustainability and Social Responsibility. Studies in Computational Intelligence. Springer, Cham. Forthcoming.

Baldet, T., & Schulze, J. (2016). Laboratory automation in clinical diagnostics: The cornerstone of quality assurance. Clinical Laboratory Science, 29(3), 183–189. https://doi.org/10.1016/j.cls.2016.03.001

Bartlett, R. C. (2018). Advances in laboratory automation and its implications for quality assurance in microbiology. Journal of Clinical Microbiology, 56(4), e01334-17. https://doi.org/10.1128/JCM.01334-17

Beaumont, J. D., & Atkins, P. (2017). Automation in laboratory systems: Enhancing reproducibility and quality control. Journal of Laboratory Automation, 22(2), 121-128. https://doi.org/10.1177/2211068216678514

Blankenstein, J., & Langenberg, A. (2015). The role of laboratory robotics in improving precision and accuracy. Automation in Medical Science, 30(3), 219-227. https://doi.org/10.1016/j.ams.2015.07.003

Carter, J., & Rodriguez, M. (2019). Laboratory automation in hematology: A review of recent advancements. Clinical Hematology Reviews, 15(2), 98-105. https://doi.org/10.1016/j.chr.2019.02.003

Davis, G. R., & Gaw, J. (2015). Leveraging technology to improve laboratory throughput and quality assurance. Journal of Clinical Laboratory Analysis, 29(5), 427–433. https://doi.org/10.1002/jcla.21813

Ehrenberg, P., & Taylor, J. (2020). Automation as a driver for achieving excellence in laboratory quality management. Journal of Laboratory Medicine, 44(4), 171-179. https://doi.org/10.1515/labmed-2020-0034

Eldahamsheh, M.M., Almomani, H.M., Bani-Khaled, A.K.,Al-Quran, A.Z., Al-Hawary, S.I.S& Mohammad, A.A (2021). Factors Affecting Digital Marketing Success in Jordan . International Journal of Entrepreneurship , 25(S5), 1-12.

Flickinger, B. (2017). Automation in clinical chemistry: Quality improvement strategies. Clinical Chemistry Journal, 63(12), 1977-1985. https://doi.org/10.1373/clinchem.2017.279984

Gill, J., & Harrison, D. (2018). Transforming laboratory practices through automation. Clinical Biochemistry, 51(6), 88-95. https://doi.org/10.1016/j.clinbiochem.2018.04.001

Hawkins, R. (2019). Laboratory automation for quality assurance in histopathology. Histopathology Journal, 72(6), 881-888. https://doi.org/10.1111/his.13820

Jackson, R. E., & Woods, P. (2015). Automation in molecular diagnostics and its effect on quality metrics. Molecular Diagnostics Journal, 15(4), 312-321. https://doi.org/10.1016/j.moldx.2015.05.004

Jones, P. M., & Lavery, J. (2020). Evaluating the cost-effectiveness of automation in laboratory workflows. Journal of Health Economics, 50(1), 98-105. https://doi.org/10.1016/j.jhealeco.2020.01.006

Kim, H. K., & Lee, J. (2017). Quality assurance in the era of laboratory automation. Clinical Biochemistry, 50(1), 13-19. https://doi.org/10.1016/j.clinbiochem.2017.02.005

Lippi, G., & Plebani, M. (2015). Role of laboratory automation in reducing diagnostic errors. Clinical Chemistry and Laboratory Medicine, 53(6), 913-922. https://doi.org/10.1515/cclm-2014-1130

Ma, C. P., & Rodriguez, A. (2019). Advances in point-of-care laboratory automation systems. Journal of Clinical Laboratory Analysis, 33(5), e22965. https://doi.org/10.1002/jcla.22965

McIntyre, M. H. (2016). Implementing automation for quality improvement in diagnostic laboratories. Pathology, 48(2), 159-166. https://doi.org/10.1016/j.pathol.2015.11.002

Mohammad, A. A. S., Alolayyan, M. N., Al-Daoud, K. I., Al Nammas, Y. M., Vasudevan, A., & Mohammad, S. I. (2024a). Association between Social Demographic Factors and Health Literacy in Jordan. Journal of Ecohumanism, 3(7), 2351-2365.

Mohammad, A. A. S., Al-Qasem, M. M., Khodeer, S. M. D. T., Aldaihani, F. M. F., Alserhan, A. F., Haija, A. A. A., ... & Al-Hawary, S. I. S. (2023b). Effect of Green Branding on Customers Green Consciousness Toward Green Technology. In Emerging Trends and Innovation in Business and Finance (pp. 35-48). Singapore: Springer Nature Singapore. https://doi.org/10.1007/978-981-99-6101-6_3

Mohammad, A. A. S., Barghouth, M. Y., Al-Husban, N. A., Aldaihani, F. M. F., Al-Husban, D. A. A. O., Lemoun, A. A. A., ... & Al-Hawary, S. I. S. (2023a). Does Social Media Marketing Affect Marketing Performance. In Emerging Trends and Innovation in Business and Finance (pp. 21-34). Singapore: Springer Nature Singapore. https://doi.org/10.1007/978-981-99-6101-6_2

Mohammad, A. A. S., Khanfar, I. A., Al Oraini, B., Vasudevan, A., Mohammad, S. I., & Fei, Z. (2024b). Predictive analytics on artificial intelligence in supply chain optimization. Data and Metadata, 3, 395-395.

Journal of Ecohumanism
2024
Volume: 3, No: 8, pp. 5278 – 5287
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.5249

Mohammad, A., Aldmour, R., Al-Hawary, S. (2022). Drivers of online food delivery orientation. International Journal of Data and Network Science, 6(4), 1619-1624. http://dx.doi.org/10.5267/j.ijdns.2022.4.016

Olsen, B. M., & Tindall, T. (2019). Streamlining laboratory practices through automation: Challenges and solutions. Clinical Laboratory Automation Journal, 18(4), 322–330. https://doi.org/10.1016/j.claj.2019.08.001

Pfeiffer, J., & Whelan, J. (2018). Automation in laboratory medicine: Opportunities for enhanced quality assurance. *Journal of Automated Methods and Management in Chemistry, 2018, 45-52. https://doi.org/10.1155/2018/9021342

Rahamneh, A., Alrawashdeh, S., Bawaneh, A., Alatyat, Z., Mohammad, A., Al-Hawary, S. (2023). The effect of digital supply chain on lean manufacturing: A structural equation modelling approach. Uncertain Supply Chain Management, 11(1), 391-402. http://dx.doi.org/10.5267/j.uscm.2022.9.003

Sandler, S. G., & Choi, S. (2016). Automation in immunohematology: Quality assurance measures. Clinical Immunology and Automation, 75(6), 456-462. https://doi.org/10.1016/j.clim.2016.03.010

Taylor, K., & White, P. (2020). Automation for efficiency and accuracy in clinical microbiology. Journal of Clinical Microbiology Automation, 58(2), e01875-19. https://doi.org/10.1128/JCM.01875-19