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E-waste in Information Systems Research

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Abstract

Technological advances in the Information Systems (IS) Science field require technical infrastructure, that is based on hardware and software. While different calculation models, as well as life cycle models, try their best to describe and explain the lifespan and costs of technology, the scope, nature and impacts of electronic waste (E-waste) have remained an understudied field within Information Systems Science. The majority of the studies on E-waste are mainly focused on the area of environmental sciences but very few studies are conducted within the contents of the IS field, although, major sources of E-waste are generated in this field. This study gap is basically concentrated within the scope of this research. The scope of this paper is therefore to investigate the role, characteristics and present status of E-waste research in the field of IS as well as the possible management of E-waste with respect to reducing, reusing and recycling as much as possible. This study also suggested future research on E-waste within the context of the IS field.

Keywords: E-waste; Information Systems Science; Academic Discipline; Research.

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1. Introduction

Usually, the goal in adopting information technology is to enhance and improve performance and productivity. The cost effectiveness as well as gained benefits have been widely studied in Information Systems Science research, but the darker side of technology has not gained similar interest. Most of the literature concerning digital transformation is focused on positive impacts of the digitalization, but there is also a dark side of digitalization including potential negative impacts on companies [1], [2], unethical use of technology [3], problems with well-being at work [4] as well as carbon footprint and energy consumption [5].

Due to rapid technological development and advancement in global electronics industries, the amount of obsolete electronic equipment has increased in the world's waste stream [6]. This has stimulated a continuous cycle of consumption of electronic equipment and disposal. According to research conducted by the ITU [7], a record 53.6 million metric tonnes (Mt) of E-waste was reported to have been produced globally in 2019, an increase of 9.2 Mt over the previous five years. This amount is growing E-waste making it one of the fastest-rising waste streams globally.

Due to domestic production and the import of electrical and electronic equipment that is outdated or used as E-waste is a problem for the majority of both developed and developing countries [8]. It was stated that there is an uncertainty of how to handle or dispose of such E-waste [9]. The majority of the nations lack effective systems for collecting, classifying, storing, and disposal of E-waste, as well as for putting hazardous waste-related laws into effect [10].

The goal of this paper is to stir discussion within the Information systems Science community about the role, characteristics, and present status of E-waste research in this field. Authors question the present status quo, where E-waste research is practically non-existent within IS research and make suggestions for new research openings within Information Systems Science on E-waste. The research problem in this study is therefore to find out what is the status of E-waste research in IS studies. This can be further clarified into two research questions such as:

1. How much and in what areas is E-waste studied?
2. What is the situation and role of E-waste studies in top tier IS journals?

While circular economy and recycling have become mainstream trends in Western economies, electronic waste has been mostly studied in environmental studies or waste management. Even though computer manufacturers strive to produce eco-friendly computers and IT managers do their best to run ICT services as green as possible and have their own solutions for dealing with old and obsolete information technology, the E-waste management seems to remain excessively understudied field within Information Systems Science.

2. Electronic Waste, Recycling and Waste Management

2.1. The Concept of E-waste

Electronic waste has been around since the introduction of electronic devices. Gartner [11] defines E-waste as a generic term that covers all electronic equipment that has reached its end-of-life. According to this definition, E-waste covers both valuable and dangerous materials, where the latter requires special care in recycling.

The Global E-waste Statistics Partnership [12] goes a bit further in its definition by stating that E-waste refers to "all items of electrical and electronic equipment (EEE) and its parts that have been discarded by its owner as waste without the intent of re-use". According to them, different names for E-waste are used, such as "WEEE (Waste Electrical and Electronic Equipment)", "electronic waste" or "e-scrap", depending on the region in question.

Electronic waste covers many different products, and The Global E-waste Statistics Partnership [12] divides these in six different categories of waste, and all these have different lifetime profiles: (1) "Temperature exchange equipment", (2) "Screens, monitors", (3) "Lamps", (4) "Large equipment", (5) "Small equipment", and (6) "Small IT and telecommunication equipment". It is worth noting that according to them, all these different types of waste behave differently regarding quantity, monetary value, or health and environmental issues.

2.2. Recycling, Circular Economy and Waste management

While waste and waste management has been studied extensively in the field of engineering, especially in environmental engineering and civil engineering, these topics are relatively non-existent in the IT related journals. When considering IS management, the whole lifespan of the IT infrastructure should be considered.

As the procedures for managing the enormous E-waste stream are not well defined, they are recycled inefficiently, and their undesired components are dumped in local landfills or other inefficient ways [13]. The absence of legislation intended to create an action or recovery mechanism and the general public's ignorance of the toxicity of E-waste are the main reasons influencing this tendency. The growth of global economies and the eradication of public awareness can be fueled by an effective management system for formal E-waste recycling. To overcome such calamity, it is increasingly important for governments to pass e-waste-specific legislation and create integrated E-waste management frameworks in order to increase the rate of collection, reuse, recycling, and recovery of E-wastes and reduce disposal.

Nowadays, there is an increasing concern among environmentalists and other interested parties on the production, recovery, recycling, and reuse of electronic products. To adopt such remedial approaches of E-waste, consumers can play a crucial part in the life cycle of electronic products through comprehending their E-waste disposal habits, as well as considering the factors that may or may not motivate them to adopt environmentally friendly practices [14], [15].

In the case of the electronics industry, the focus on the circular economy is critical, which deals with the function of life-cycle analysis. The shift to a circular economy also deals with carbon-neutral and sustainability in electrical gadget production. This circularity can be enhanced by promoting eco-design and design for recyclability of electronic products. In this way, there are significant opportunities for recovering valuable components and essential materials from E-waste. All of these initiatives might be combined with existing business opportunities in companies [16]. It is estimated that adopting the circular economy strategy has the potential to cut the use of new materials by 32% within 15 years and by 53% by 2050 [17].

The management of E-waste through the circular economy principle can overcome the disadvantages related to the existing cradle-to-grave economy. In the case of electronics products, this circularity can be achieved through the material design and development of the product's features considering environmental awareness and the use of materials re-cycled from E-waste for new gadgets. Managing E-waste also protects human health from harmful diseases that need to follow certain treatments [18].

3. Method, Research Problem and Used Approach

In this study, the main method is an experimental literature review. According to definition by Rowe [19, p. 243], “a literature review synthesizes past knowledge on a topic or domain of interest, identifies important biases and knowledge gaps in the literature and proposes corresponding future research directions”. Edmondson and Mcmanus [20, p. 1155] noted already a decade earlier, that previous studies provide “An aid in identifying unanswered questions, unexplored areas, relevant constructs, and areas of low agreement”.

The goal of this study is to emphasize the need for lacking E-waste studies within IS research. Authors argue that this is an integral part of IT management and should be included in future research recommendations. The material selection for this study was made using SCOPUS database and SJR-ranking.

4. Research

Our experimental literature review was conducted in two phases, where first present situation regarding research on electronic waste was studied and then the focus was put on publications focused on E-waste primarily on IT and IS fields. The research was done in the following phases on March 2nd, 2023:

1. *Searching e-waste studies from the Scopus* database [21] during the years 1994-2023 with the basic search using the following search string: ”(TITLE-ABS-KEY (*"e-waste"*) OR TITLE-ABS-KEY(*waste*) AND SRCTITLE (*information*) OR SRCTITLE (internet) OR SRCTITLE (data) OR SRCTITLE (computer) OR SRCTITLE (computing)”. Result: 3876 documents
2. *Limiting the time period* to the years 2004-2023. Result: 2894 documents

3. *Collecting proper journals* from the Scimago Journal & Country Ranking from the journals in the field of Information systems and management, which were highly ranked (Q1 level) in the year 2021 and limiting the results from the earlier phases to the selected journals. Result: 31 documents.
4. *Choosing the best journals (most highly ranked)* according to the quality of journals for deeper analysis. Result: 2 documents. The literature review is seen in the Figure 1.

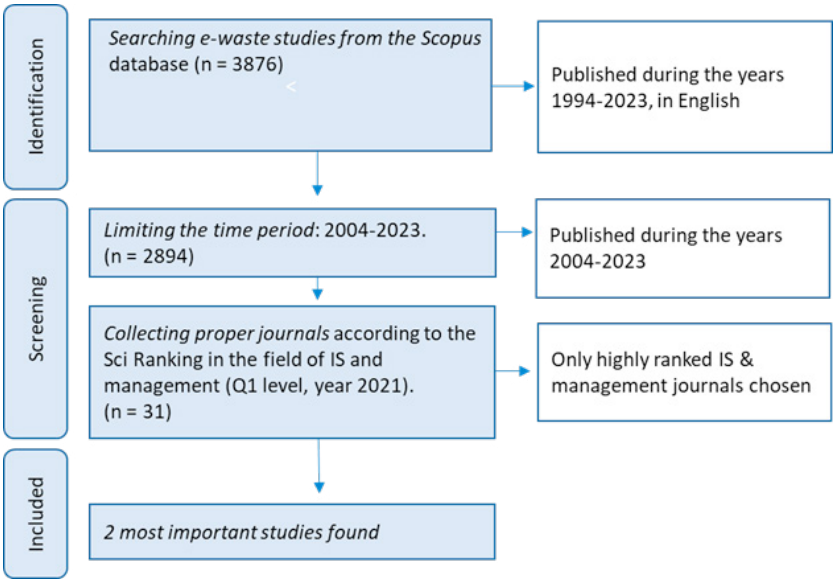

Fig. 1. Literature review process.

The approach used on literature review in this research is very similar to the traditional PRISMA (see for instance Madhavan et al. [22]).

4.1. General E-waste Studies

When finding out what kind of research has been published regarding E-waste between the years 1994-2023 using the Scopus database [21], it was seen that published articles related to electronic waste started to appear no sooner than 2003, and since then the number has been steadily increasing. A great majority of articles were published under environmental sciences, while followed by engineering and chemistry. The rest of the articles were scattered under different subject areas, while IT, MIS, or Information systems were missing.

Journals, where focus was on environmental studies, formed a majority of journals publishing E-waste related articles between the years 2004-2023, while engineering, chemistry and energy followed with remarkably smaller numbers. Rest of the journals publishing E-waste related articles were scattered under different subject areas, and surprisingly journals related to IT, MIS, or IS were practically absent.

4.2. E-waste in Information Systems Studies

Following stage in our study started by collecting proper journals based on journal ranking, and for this Scimago Journal & Country Ranking was used. Used criteria was “Information Systems and Management” from year 2021, and then the journals were further narrowed to cover only Q1 journals [23]. As a result, total of 31 journals were selected for the analysis based on their SJR-ranking. The list of these is journals is presented in table 1.

Table 1. Selected Q1 journals from SJR-ranking for analysis [21].

Accounting, Organizations and Society	Information Sciences	Journal of Management Information Systems
Big Data and Society	Information Systems Research	Journal of Responsible Innovation
Big Data Research	International Journal of Accounting Information Systems	Journal of Strategic Information Systems
Critical Perspectives on Accounting	International Journal of Information Management	Journal of the Association for Information Science and Technology
Decision Sciences	International Journal of Management Science and Engineering Management	Knowledge-Based Systems
Decision Support Systems	International Journal of Systems Science: Operations and Logistics	Management Accounting Research
Enterprise Information Systems	Journal of Big Data	MIS Quarterly: Management Information Systems
European Journal of Information Systems	Journal of Engineering and Technology Management - JET-M	Omega
European Journal of Operational Research	Journal of Industrial Information Integration	Quality Technology and Quantitative Management
IEEE Internet of Things Journal	Journal of Information Systems	
IEEE Transactions on Services Computing		
Information and Management		

In the following part of the article selection, article topics and abstracts were studied and as a summary two articles were found. The first article was published in Enterprise Information Systems by Wang and Wang [24] and it has been cited 61 times. It was a case study related to e-waste and one assumption of the study was, that the amount of e-waste is increasing, but the waste can be seen as an important area of manufacturing and remanufacturing. There should be better recycling and utilization of electronic devices.

The second article was published in the International Journal of Information Management by Dwivedi et al. [25] and this was cited 76 times. They argued, that increasing digitalization is increasing the problem of e-waste even if it is used for mitigation of climate change. Because there is no clear policy on e-waste management, the world produces about 50 million tonnes of e-waste, with only 20% of it being dealt with sustainably. The majority of technology and IS related research is focused the other subjects than e-waste, like impact of technology on behaviors, changed working practices, impact on people and communities, role of data, technology and IS governance, etc.

Table 2. E-waste articles.

Article	Key results	Challenges	Opportunities (examples)
Wang and Wang (2017): A cloud-based production system for information and service integration: an internet of things case study on waste electronics,"	Manufacturing Cloud is extended to remanufacturing processes. As a neutral WEEE (Waste Electrical and Electronic Equipment) management platform, WRCloud breaks the boundaries between different EEE stakeholders and provides a shared service and information pool to support the component recovery from individual level to international level.	Collection, recycling and recovery of EEE in Europe should be improved. In the USA only 29,2 % of WEEE was properly recovered. In the developing countries like China, India and Brazil recovery percentage is even lower.	recycling and utilization of EEE
Dwivedi et al (2022). Climate change and COP26: Are digital technologies and information management part of the problem or the solution? An editorial reflection and call to action,"	technology in many forms is an important when mitigating the impacts of climate change, but technology is also part of the problem because of the e-waste. The responsible digitalization and elimination of e-waste are important.	Big amount of e-waste, not so successful recycling, short life span of products.	Using transdisciplinary approaches to solve e-waste problems, increasing the awareness of global warming issues, responsibility

4.3. Results

Based on the results of this study, following questions could be asked. While IT field produces a great amount of electronic waste, why has this part of the IT manager's responsibilities been so understudied? What is the best way to approach this problem, or is there any reason why this should not be studied within IS? Is this something IS scholars should include in their future research agenda?

First research question was: How much and in what areas E-waste is studied? It seems that it is mostly covered by environment and engineering related disciplines. The second research question was: What is the situation and role of E-waste studies in top tier IS journals? Based on the findings, it seems that this is practically non-existent. Reasons for this might vary, but the fact is that IT field is located in the very center of this problem domain in the role of producer of E-waste. Many decisions IT managers make will greatly influence the amount of produced E-waste, so why is this not studied within IS?

From the literature survey, it is clearly noticed that there is a lack of awareness of dealing with E-waste in information systems sciences. This limitation can be overcome in several ways. For instance, it is necessary to offer proper education and training to the producers as well as workers involved in electronic product design and development to make them aware to follow the entire product life cycle [15], [26]. Additionally, state-of-the-art technology such as blockchain can be deployed to monitor and manage the e-products from production to retirement [27]. Moreover, the interfacing of the Internet of Things (IoT), blockchain and smart contracts ensure tracking and managing E-waste with the creation of e-products and ending with their disposal as E-waste and recycling into basic materials [28].

5. Discussion

Debate over the maturity of IS discipline has been going on for a long time. Since the introduction of the results of the ACM Task Force on the core computer science [29], the field of Information Technology has been evolving and expanding. According to Computing Curricula 2020 [30, pp. 27–28], "*IS addresses the ongoing and innovative use of computing technologies to enable human activities to achieve their goals in ways that are better, faster, cheaper, less painful, cleaner, or more effective.*" In the same computing curricula [30], the proposed draft of the Information Systems Competencies does not directly refer to lifecycle thinking of the whole IS system, nor on applying sustainable development within IS. However, it does refer to IT management and development practices for "*optimized use of information systems and plan for a long term IS viability*" [30, p. 115], but this is does not seem to be the same thing.

While being a part of the whole, IT infrastructure is an essential part of contemporary IT/IS systems. Information Systems require technological infrastructure in order to operate efficiently and the management of IS/IT functions should cover the whole lifecycle of IT artefacts. Although Information Systems Science can be considered as applied science due to its strong connection to practice, the main foundation for teaching is strongly based on academic research. Those willing to excel in the IS field will most likely study IS as an academic discipline. Students will gain latest knowledge and theories from the academic field. In addition to substance, also the values and ethics are being transferred to students. If studying how to deal with all the more increasing problem of electronic waste efficiently from IT management perspective is simply missing from the research agenda, what sort of message does it provide to specialists of tomorrow?

On a global scale pollution is a problem that touches everyone in some way. The reasons for not studying this area in IS might be manifold. To claim that this is not an interesting area, or that it has nothing to do with Information Systems is simplifying the problem domain and short-sighted. It can be argued, that this sort of thinking removes IS from its context. The definitions of IS usually cover among other things IT infrastructure, organizations as well as people using the systems. While focus might be primarily on just technological issues, the remains (or outputs) of information systems in the form of electronic waste should be covered as well.

Literature about digitalization is mostly focused on positive impacts of the digitalization, and negative aspects are not given as much weight. From the conducted literature survey, it is noticed that the majority of the works on E-waste deal with the management of common solid wastes such as incineration, landfills, energy generation, etc. However, there are very limited amount of studies conducted considering fully the electronic items used in Information

Systems Science. In general, E-wastes are often mixed with ordinary solid wastes and processed using the same methods, although they vary substantially in terms of value, importance, and usability point of view.

This study is limited to studying E-waste related studies only in IS context, thus other related fields of study have not been included in this study. In addition, also the grey literature has been left out of the scope of this study. This study considers this gap in managing E-waste from the IS perspective, where E-waste can be separated from generic solid waste solely based on the nature of the components' design, value, and recycling possibilities. In this way, a substantial amount of E-waste can be reused, refabricated, and recycled as valuable resources. In future studies, managing the E-waste can be initiated from the very beginning of the life cycle of electronic products. In the case of life cycle analysis, the electronic component used under IS should be designed considering various factors in mind such as the degradable nature, the possibility of recycling/reusing, environmentally friendly materials use, carbon neutrality, etc. Moreover, future study can also be considered to study the percentage of E-waste from information systems compared to E-waste from electronic systems such as mobile phones in the spotlight. This strategy surely helps to promote both user and environment-friendly electronic products or components in the IS field.

References

[1] C. Buck, J. Clarke, R. Torres de Oliveira, K. C. Desouza, and P. Maroufkhani, "Digital transformation in asset-intensive organisations: The light and the dark side," *J. Innov. Knowl.*, vol. 8, no. 2, p. 100335, 2023, doi: 10.1016/j.jik.2023.100335.

[2] L. Yang, B. Huo, M. Tian, and Z. Han, *The impact of digitalization and inter-organizational technological activities on supplier opportunism: the moderating role of relational ties*, vol. 41, no. 7. 2021. doi: 10.1108/IJOPM-09-2020-0664.

[3] F. J. García-Peñalvo, "Avoiding the dark side of digital transformation in teaching. an institutional reference framework for eLearning in higher education," *Sustain.*, vol. 13, no. 4, pp. 1–17, 2021, doi: 10.3390/su13042023.

[4] U. Bamel, S. Kumar, W. M. Lim, N. Bamel, and N. Meyer, "Managing the dark side of digitalization in the future of work: A fuzzy TISM approach," *J. Innov. Knowl.*, vol. 7, no. 4, p. 100275, 2022, doi: 10.1016/j.jik.2022.100275.

[5] U. Lichtenthaler, "Digitainability : The Combined Effects of the," *Jim*, vol. 9, pp. 64–80, 2021, [Online]. Available: https://ijooes.fe.up.pt/index.php/jim/article/view/2183-0606_009-002_0006%0A

[6] C. K. Nduneseokwu, Y. Qu, and A. Appolloni, "Factors influencing consumers' intentions to participate in a formal e-waste collection system: A case study of Onitsha, Nigeria," *Sustain.*, vol. 9, no. 6, pp. 1–17, 2017, doi: 10.3390/su9060881.

[7] ITU, "Global E-waste Monitor 2020." [Online]. Available: https://www.itu.int/en/ITU-D/Environment/Pages/Spotlight/Global-Ewaste-Monitor-2020.aspx

[8] S. Vishwakarma *et al.*, "E-waste in Information and Communication Technology Sector: Existing scenario, management schemes and initiatives," *Environ. Technol. Innov.*, vol. 27, p. 102797, 2022, doi: 10.1016/j.eti.2022.102797.

[9] T. Andersen and L. L. Halse, "Product Lifecycle Information Flow in E-waste Handling: a Means to Increase Circularity?," *Circ. Econ. Sustain.*, no. 1, 2023, doi: 10.1007/s43615-023-00258-1.

[10] E. Ada, H. K. Ilter, M. Sagnak, and Y. Kazancoglu, "Smart technologies for collection and classification of electronic waste," *Int. J. Qual. Reliab. Manag.*, 2023, doi: 10.1108/IJQRM-08-2022-0259.

[11] Gartner, "Electronic Waste (e-Waste)," Gartner Glossary. Accessed: Jul. 03, 2023. [Online]. Available: https://www.gartner.com/en/information-technology/glossary/electronic-e-waste

[12] The Global E-waste Statistics Partnership, "What is e-waste." Accessed: Jul. 03, 2023. [Online]. Available: https://globalewaste.org/what-is-e-waste

[13] P. Thakur and S. Kumar, "Evaluation of e-waste status, management strategies, and legislations," *Int. J. Environ. Sci. Technol.*, vol. 19, no. 7, pp. 6957–6966, 2022, doi: 10.1007/s13762-021-03383-2.

[14] M. Aboelmaged, "E-waste recycling behaviour: An integration of recycling habits into the theory of planned behaviour," *J. Clean. Prod.*, vol. 278, p. 124182, 2021, doi: 10.1016/j.jclepro.2020.124182.

[15] S. Thukral, D. Shree, and S. Singhal, "Consumer behaviour towards storage, disposal and recycling of e-waste: systematic review and future research prospects," *Benchmarking*, vol. 30, no. 3, pp. 1021–1072, 2022, doi: 10.1108/BIJ-12-2021-0774.

[16] N. Pajunen and M. E. Holuszko, "Circular Economy in Electronics and the Future of e -Waste," in *Electronic Waste*, John Wiley & Sons,

Ltd, 2022, pp. 299–314. doi: https://doi.org/10.1002/9783527816392.ch13.

[17] M. Esposito, T. Tse, and K. Soufani, "Introducing a Circular Economy: New Thinking with New Managerial and Policy Implications," *Calif. Manage. Rev.*, vol. 60, no. 3, pp. 5–19, 2018, doi: 10.1177/0008125618764691.

[18] Ankit *et al.*, "Electronic waste and their leachates impact on human health and environment: Global ecological threat and management," *Environ. Technol. Innov.*, vol. 24, p. 102049, 2021, doi: 10.1016/j.eti.2021.102049.

[19] F. Rowe, "What literature review is not: Diversity, boundaries and recommendations," *Eur. J. Inf. Syst.*, vol. 23, no. 3, pp. 241–255, 2014, doi: 10.1057/ejis.2014.7.

[20] A. C. Edmondson and S. E. Mcmanus, "Methodological fit in management field research," *Acad. Manag. Rev.*, vol. 32, no. 4, pp. 1155–1179, 2007, doi: 10.5465/AMR.2007.26586086.

[21] Scopus (Elsevier), "Abstract & Citation Database." Accessed: Mar. 02, 2023. [Online]. Available: https://www.scopus.com/search/form.uri?display=basic#basic

[22] M. Madhavan, S. Wangtueai, M. A. Sharafuddin, and T. Chaichana, "The Precipitative Effects of Pandemic on Open Innovation of SMEs: A Scientometrics and Systematic Review of Industry 4.0 and Industry 5.0," *J. Open Innov. Technol. Mark. Complex.*, vol. 8, no. 3, 152, 2022, doi: 10.3390/joitmc8030152.

[23] SJR, "Scimago Journal & Country Rank," Journal rankings. Accessed: Mar. 02, 2023. [Online]. Available: https://www.scimagojr.com/journalrank.php?category=1802

[24] X. V. Wang and L. Wang, "A cloud-based production system for information and service integration: an internet of things case study on waste electronics," *Enterp. Inf. Syst.*, vol. 11, no. 7, pp. 952–968, 2017, doi: 10.1080/17517575.2016.1215539.

[25] Y. K. Dwivedi *et al.*, "Climate change and COP26: Are digital technologies and information management part of the problem or the solution? An editorial reflection and call to action," *Int. J. Inf. Manage.*, vol. 63, no. November 2021, 2022, doi: 10.1016/j.ijinfomgt.2021.102456.

[26] S. Gupta, "E-waste Management : Teaching how to Reduce , Reuse and Recycle For Sustainable Development- Need of Some Educational strategies," *J. Educ. Pract.*, vol. 2, no. 3, pp. 74–87, 2007, [Online]. Available: https://www.iiste.org/Journals/index.php/JEP/article/view/202/87

[27] S. Sahoo, A. Mukherjee, and R. Halder, "A unified blockchain-based platform for global e-waste management," *Int. J. Web Inf. Syst.*, vol. 17, no. 5, pp. 449–479, 2021, doi: 10.1108/IJWIS-03-2021-0024.

[28] V. Maphosa and M. Maphosa, "E-waste management in Sub-Saharan Africa: A systematic literature review," *Cogent Bus. Manag.*, vol. 7, no. 1, 2020, doi: 10.1080/23311975.2020.1814503.

[29] P. J. Denning *et al.*, "Computing as a discipline," *Computer (Long. Beach. Calif).*, vol. 22, no. 2, pp. 63–70, 1989, doi: 10.1109/2.19833.

[30] CC2020 Task Force, "Computing Curricula 2020: Paradigms for Global Computing Education," Association for Computing Machinery, New York, 2020. doi: 10.1145/3467967.