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The Role of Ishikawa Quality Control Tools in Scientific Research: A Review

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Abstract
Dr. Ishikawa stated that 95% of problems in the process can be solved using 7 quality control tools. This study aims to review the role of Ishikawa quality control tools in scientific research. A study was conducted on articles from Sciencedirect in 2023 using VOSviewer and article content. Most keywords that appear in VOSviewer are related to Industry 4.0 technology. Quality Control (QC) tools are applied to various types of research methods and company sectors, where a study uses 1-5 QC tools in a study. Most articles use experimental methods, and most studies fall within the trading sector. The most frequently used QC tools are histograms, flow charts and scatter diagrams. There has been no research that uses check sheets and cause and effect diagrams, research in the financial sector or research that combines experimental methods and case studies. The results of the study indicate that QC tools function as supporters in an article of scientific research, not as variables (main keywords) in an article of scientific research.

Keywords:
Ishikawa, Quality Control (QC) tools, Research Methods, Company Sectors, VOSviewer

1. Introduction

The research to be conducted discusses complex system analysis, focusing on the tools used to conduct the analysis. The selection of the right analysis tool in conducting research will support the achievement of accurate and reliable research results so that it can contribute to the development of science.

In the book “What is Quality Control” Dr. Ishikawa states that 95% of problems in the process can be solved by using 7 QC tools (Antony et al., 2021), (McDermott et al., 2022)(Nakkiew & Poolperm, 2016), (Muhammad, 2015). Problems in the production process will affect the sustainability of the company. In its application, 7 QC tools are integrated with various improvement methods including Lean and Six Sigma (McDermott et al., 2022). In the book "Introduction to Quality Control", Ishikawa states that if QC tools are used skillfully, then 95% of problems in the workplace will be resolved and only 5% need to use advanced statistics to solve them (Antony et al., 2021). QC tools consist of 7 tools, namely: Check Sheets, Histograms, Pareto Charts, Cause & Effect Diagrams, Control Charts, Scatter Diagrams, and Stratification (Antony et al., 2021), (Nakkiew & Poolperm, 2016), atau *flow chart* (Muhammad, 2015). It has not been clearly stated which QC tool is the most effective and whether it is the same for all sectors, both manufacturing and services.

7 Basic QC tools are a set of techniques or visual tools as an important tool in finding the root cause of quality problems and solving problems developed by Kaoru Ishikawa, which is a valuable tool for quality management and implementing process improvements. Ishikawa recommends using simple tools in solving problems (McDermott et al., 2022). 7 QC tools can be used by anyone to solve quality problems, even without statistical training. The benefits of 7 QC tools are to improve communication between operators and management, detection, prioritization of problems, organization of potential causes that result in problems. QC tools can be applied to any business process and are not limited to manufacturing processes (Antony et al., 2021).

7 QC tools consist of Flow Chart, Check Sheet, Pareto Chart, Histogram, Cause & Effect Diagram, Scatter Diagram, Control Chart. Flow Chart is used to show all process steps wisely, to identify problems and to control the process after deletion. Check sheet is a tool used to collect data and record which process occurs how many times, helps to categorize data. Pareto consists of a series of simple bars whose height indicates the impact of the problem. Data in a Pareto chart is arranged in descending order and displays variables in graphical form. Histogram is a graphical representation of numerical data used to show how often each distinct value in a set of data occurs. Histogram is used to determine the shape of a data set and works best when the amount of data is smaller. Cause and effect diagram is called a fishbone diagram because of its graphical structure, used to find the root cause of a problem, where all possible causes of the problem are considered and try to find out the reason for each reason that caused the problem. Scatter diagram is used for paired numerical data, to find out the relationship between two variables where the X-axis shows the independent variable and the Y-axis shows the dependent variable. The results of the cause and effect diagram are reinforced with a scatter diagram. Control charts are used to study process variations over time and check process stability with two control limits, namely minimum and maximum value limits (Muhammad, 2015).

Previous research conducted by (Antony et al., 2021), found that the most widely used QC tools in the manufacturing and service sectors were Pareto, Histogram and Cause and Effect Analysis, while the least used were Scatter diagram and Stratification. The main finding was that only 80% of quality problems with 7 QC tools, in contrast to Ishikawa's statement in his research in the 1970s and 1980s that 95% of process problems could be solved with 7 QC tools.

In this study, a review will be conducted on articles from Sciencedirect in 2023, which use one or more of the 7 QC tools. The review covers the types of QC tools and the company sectors that implement them. Classification of company sectors based on JASICA (Jakarta Stock Exchange Industrial Classification) (Widyaningdyah & Aryani, 2013). This study aims to review the role of Ishikawa QC tools in scientific research. Here are some research questions that will be answered:
RQ1: What are the most frequently used QC tools, top 3?
RQ2: What are the company sectors that implement QC tools?
RQ3: What types of research use QC tools?
RQ4: What are the benefits of QC tools in research?

2. Method

Literature review was conducted on articles from Sciencedirect, with the keywords "Check sheet" OR "Pareto chart" OR "Flow chart" OR "Cause and effect diagram" OR "Histogram" OR "Scatter diagram" OR "Control chart"), for the period 2023 (as of September 25, 2023), research articles, subject areas Engineering, open access & open archive. Analysis was conducted with VOSviewer and based on content (article content). For analysis with VOSviewer, 1000 articles were used and for content analysis, the top 100 articles (the most appropriate/relevant to the keywords) were used. Analysis with VOSviewer to see research trends, research gaps & research novelty. Detailed analysis of the content of each article to gain an overview of previous research reviewed to answer research questions and obtain research objectives. The flowchart of the research method can be seen in Figure 1.

3. Results and Discussion

3.1 Results

Figure 2 show mapping results of 1000 articles with VOSviewer full counting for keywords with a minimum occurrence limit of 5 times. None of the QC tools appear as keywords, but other keywords appear in the articles that use QC tools. It can be interpreted that QC tools function as support in an article, not as variables (main keywords) in an article. The majority of keywords that appear in VOSviewer are related to Industry 4.0 technology (figure 2). If checked in the author section for all occurrences, 9 clusters or groups of authors are obtained which are marked with circle colors (figure 3), the same color indicates cluster similarities.

Figure 1
Research method flowchart

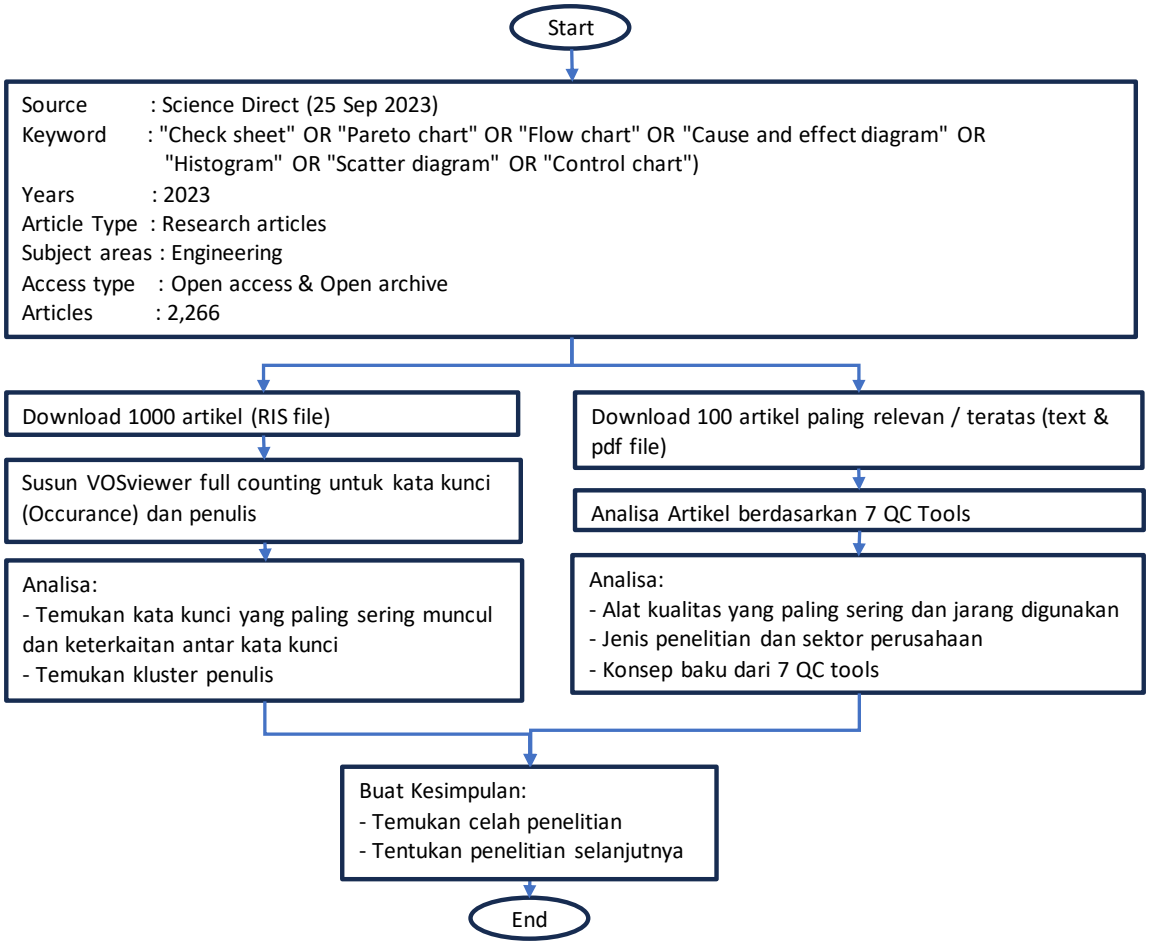


Figure 2
VOSviewer full counting for keywords (minimum 5 occurrences)

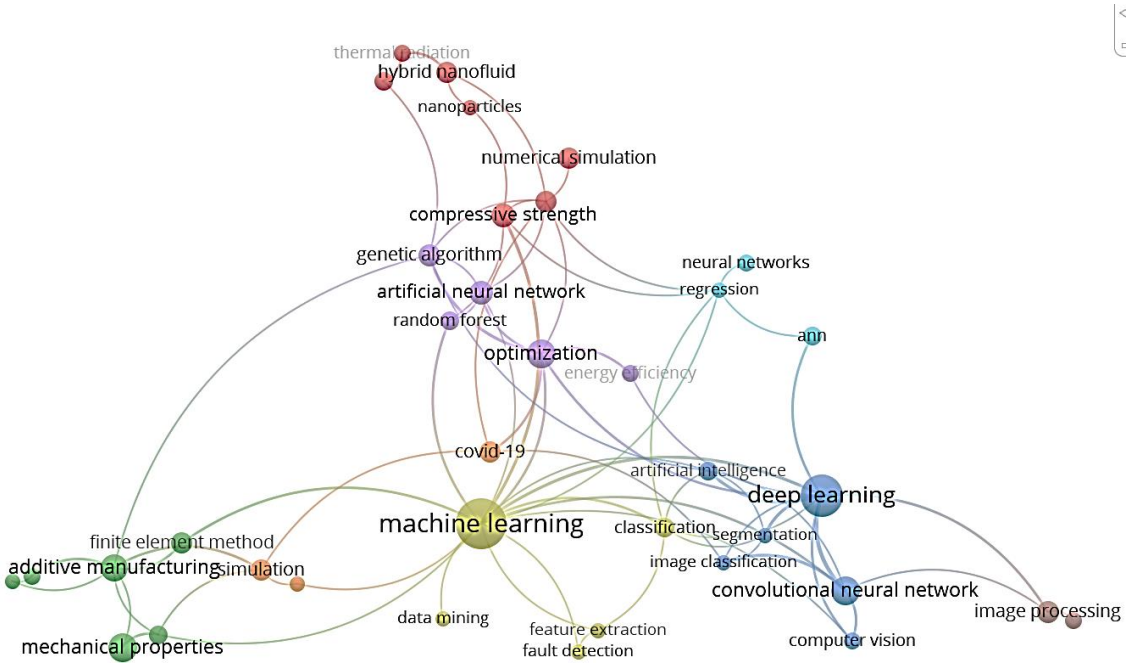
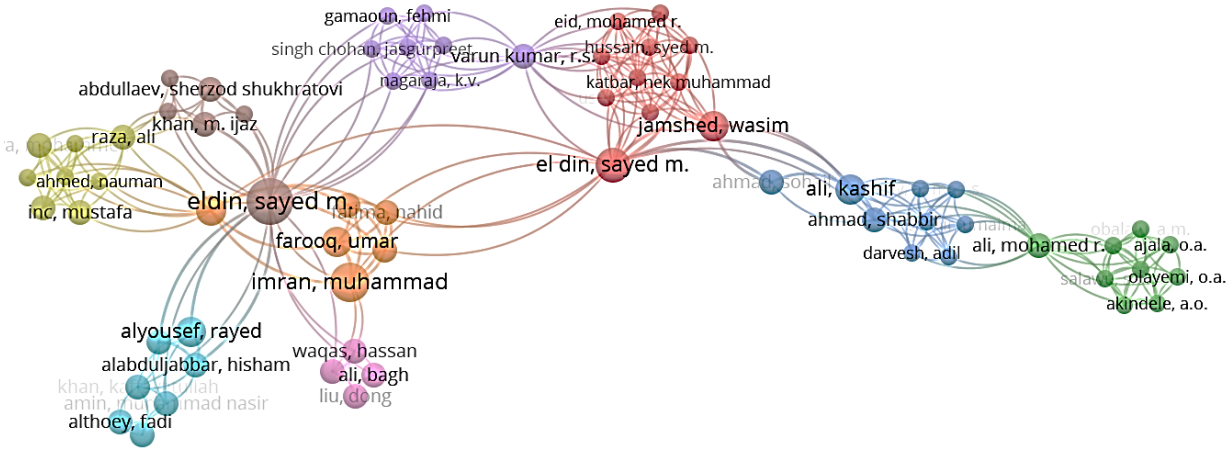


Figure 3
VOSviewer full counting for authors (all appearances)



3.2 Discussion

Based on 100 articles reviewed, total article that published by author for each country show on table 1. The authors of the 100 articles come from 28 countries. China is the country with the most productive researchers compared to other countries.

Table 1
Researcher categories based on country of origin

Ranking	Country	Articles	Total Articles
1	China	32	32
2	India	20	20
3	UK	7	7
4	Saudi Arabia	6	6
5	Italy, Malaysia, Pakistan, Spain, Sweden	3	15
6	Thailand	2	2
7	Brazil, Chile, Colombia, Egypt, France, Greece, Iran, Ireland, Japan, Kazakhstan, Nigeria, Norway, Portugal, Taiwan, The Netherlands, Uganda, United Arab Emirates, USA	1	18
Total			100

RQ1: What are the most frequently used QC tools, top 3?

The most frequently used QC tools are Histogram (68 articles), Flow Chart (59 articles) and Scatter diagram (37 articles). While Pareto chart and control chart are each used in 19 articles (table 2). Histograms are most often used to show the distribution of research data. Histograms are graphs (Muhammad, 2015) that are easy to read visually. Flow charts are often used to show research stages, process stages (Muhammad, 2015) or program algorithms in scientific research.

QC tools that are rarely used or never used in writing articles are Check sheet and Cause and effect diagram (table 2). Check sheets are not found in scientific articles because the function of check sheets is for data collection (Muhammad, 2015) in the field and will not be displayed in scientific articles that are limited in number of pages. The results of observations in the field recorded in the form of check sheets will be reported in a histogram. Cause and effect diagrams are used in research to find the cause of a problem and then find a solution to the problem (Muhammad, 2015).

The number of QC tools used in a study varies from 1-5 tools, 27 articles were found using 1 tool, 53 articles using 2 tools, 12 articles using 3 tools, 7 articles using 4 tools and only 1 article using 5 tools (table 2). Flow charts and histograms are often used together in a research article. Scatter diagrams are used in conjunction with other QC tools.

Table 2.
Matrix of QC tools and business sectors

No	Author (Year)	7 QC Tools	Business Sector
1	(Han & Li, 2023)	3	B (Coal Mining)
2	(Wong et al., 2023)	5	D (Machinery and heavy equipment)
3	(Ahmed et al., 2023)	2,3,6	D (Machinery and heavy equipment)
4	(Cox et al., 2023)	2	C (Metals and Similar)
5	(Gaidai et al., 2023)	3	D (Machinery and heavy equipment)
6	(Lai, 2023)	3,5	F (Property and Real Estate)
7	(Harikrishnan et al., 2023)	3,5	I (Health)
8	(Zhu et al., 2023)	5,7	I (Health)
9	(Zhou et al., 2023)	3	D (Machinery and heavy equipment)
10	(Moralidou et al., 2023)	3,5,6,7	I (Health)
11	(Cuesta Parra et al., 2023)	2	G (Non-Building Construction)
12	(Ben et al., 2023)	3,5	G (Non-Building Construction)
13	(Pei et al., 2023)	5,6	I (Computer and Device Services)
14	(Elshafei et al., 2023)	3,5,6,7	G (Energy)
15	(Chou et al., 2023)	3,5	I (Health)
16	(Contuzzi & Casalino, 2023)	2,6	C (Metals and Similar)
17	(Bevans et al., 2023)	7	G (Energy)
18	(Shaikh et al., 2023)	2,6,7	D (Textile and Garment)
19	(Shibu et al., 2023)	3,5,6,7	F (Building Construction)
20	(Zhang et al., 2023)	3	D (Electronics)
21	(X. Liu et al., 2023)	3	G (Transportation)
22	(Moses Obeti et al., 2023)	5	G (Infrastructure)
23	(Song et al., 2023)	3,5,6,7	G (Energy)
24	(Sabahno & Amiri, 2023)	7	E (Pharmacy)
25	(Ding et al., 2023)	3,5	I (Computer and Device Services)
26	(Gülçür et al., 2023)	5,6	D (Electronics)
27	(Manatura et al., 2023)	2	G (Energy)
28	(Z. Wang et al., 2023)	3,5	D (Machinery and heavy equipment)
29	(Atif et al., 2023)	5	I (Health)
30	(Junzhe et al., 2023)	3,5	G (Infrastructure)
31	(Talordphop et al., 2023)	7	D (Other Industries)
32	(Bai et al., 2023)	3,5	G (Infrastructure)
33	(Bhattarai et al., 2023)	5	I (Health)
34	(Chen et al., 2023)	5,6	I (Computer and Device Services)
35	(Kumar & Y, 2023)	3,5	I (Health)
36	(Yin et al., 2023)	3,5	G (Infrastructure)
37	(Henningsson et al., 2023)	5,6	I (Computer and Device Services)
38	(Gong et al., 2023)	3,5	D (Machinery and heavy equipment)
39	(P. Wang et al., 2023)	3,5,7	I (Computer and Device Services)
40	(Xie et al., 2023)	5,6	F (Building Construction)
41	(Mukhtarkhanov et al., 2023)	2	D (Electronics)
42	(Rahul et al., 2023)	3,5	A (Other agriculture)
43	(Zheng et al., 2023)	3,5	G (Energy)
44	(WANG et al., 2023)	3,5	D (Automotive and Components)
45	(Sharma, Sharma, Mishra, Noeiaghdam, et al., 2023)	3,5	B (Basic Industries and Other Chemicals)
46	(Rahmana Putra et al., 2023)	2,6	B (Basic Industries and Other Chemicals)
47	(M et al., 2023)	3,5,6,7	D (Machinery and Heavy Equipment)
48	(Bazoobandi et al., 2023)	2,6	G (Infrastructure)

49	(G. Liu et al., 2023)	5,6,7	A (Other agriculture)
50	(Li, Wu, et al., 2023)	3,5,6	I (Health)
51	(Khan et al., 2023)	2	D (Textile and Garment)
52	(Soria-Garcia et al., 2023)	3,5,6	I (Health)
53	(Hu et al., 2023)	7	I (Computer and Device Services)
54	(Alegria, 2023)	5	I (Computer and Device Services)
55	(Nazar et al., 2023)	3,5,6	C (Cement)
56	(K et al., 2023)	3,5	I (Health)
57	(Lv & Zhang, 2023)	3,5	A (Other agriculture)
58	(Salah et al., 2023)	2,3	E (Food and Beverage)
59	(das Vitorias do Nascimento et al., 2023)	2	G (Infrastructure)
60	(Vidakis et al., 2023)	2,3,6	D (Machinery and Heavy Equipment)
61	(Chaudhari et al., 2023)	3,5	I (Health)
62	(Li, Deng, et al., 2023)	3,5,6	G (Infrastructure)
63	(Al-Mansor et al., 2023)	5	I (Health)
64	(Malagi et al., 2023)	3,5,6	I (Health)
65	(Sunday et al., 2023)	3,6	G (Infrastructure)
66	(Do et al., 2023)	3,5	I (Health)
67	(Srinivas & Mosiganti, 2023)	3,5	I (Health)
68	(Nasim et al., 2023)	3,5,6,7	D (Machinery and Heavy Equipment)
69	(Yang & Xuan, 2023)	3,5	I (Computer and Device Services)
70	(Wu et al., 2023)	3,6	I (Health)
71	(Kodaira et al., 2023)	5,6	G (Transportation)
72	(Raza et al., 2023)	3,5	D (Machinery and Heavy Equipment)
73	(Mauro & Vassalos, 2023)	6	D (Machinery and Heavy Equipment)
74	(Sabir et al., 2023)	3,5,6	I (Health)
75	(Sesta et al., 2023)	5	D (Automotive and Components)
76	(Gou et al., 2023)	3,5	I (Computer and Device Services)
77	(Alshaeer et al., 2023)	2,3,5,6,7	F (Building Construction)
78	(Kaswan et al., 2023)	5,6	I (Health)
79	(Urmeneta et al., 2023)	3,7	G (Energy)
80	(Sardar et al., 2023)	3,5	I (Computer and Device Services)
81	(Lidmar et al., 2023)	5,6	G (Infrastructure)
82	(Alves et al., 2023)	5	D (Machinery and Heavy Equipment)
83	(Navarro et al., 2023)	5	F (Building Construction)
84	(Suo et al., 2023)	6,7	G (Energy)
85	(Chakraborty & Suri, 2023)	3,5	I (Computer and Device Services)
86	(Shi & Zhao, 2023)	3,5	G (Telecommunication)
87	(Ghareeb et al., 2023)	3,5,6	G (Infrastructure)
88	(Sarkar & Mandal, 2023)	3,5	I (Health)
89	(Hrishikesh Jaware et al., 2023)	3,5	I (Health)
90	(Sauceda et al., 2023)	2	D (Machinery and Heavy Equipment)
91	(Bechlenberg et al., 2023)	3,5	G (Energy)
92	(G & K, 2023)	3,5	I (Health)
93	(Nisar, Tabassum, et al., 2023)	3,5	I (Health)
94	(Mohtaram et al., 2023)	2,3	G (Energy)
95	(Costa et al., 2023)	2,6	I (Health)
96	(Sharma, Sharma, Mishra, & Fernandez-Gamiz, 2023)	3,5,6	G (Energy)
97	(Munir et al., 2023)	7	I (Computer and Device Services)
98	(Chaudhuri & Choudhury, 2023)	2,3	F (Building Construction)
99	(Rana et al., 2023)	2,5,6,7	G (Energy)
100	(Nisar, Sahar, et al., 2023)	5,6	I (Health)

Description: 1: Check sheet; 2: Pareto Chart; 3: Flow chart; 4: Cause and effect diagram; 5: Histogram; 6: Scatter diagram; 7: Control Chart; A: Agriculture; B: Mining; C. Basic and Chemical Industry; D: Miscellaneous Industry; E: Consumer Goods Industry; F: Property, Real Estate and Building Construction; G: Infrastructure, Utilities and Transportation; H: Finance; I: Trade.

RQ2: What are the company sectors that implement QC tools

Refers to JASICA clasification (Widyaningdyah & Aryani, 2013), the Company sectors that implement QC tools include 3 (agriculture), 3 (consideration sector), 3 (basic and chemical industry), 21 (various industries), 2 (consumer goods industry), 6 (property, real estate and construction), 26 (infrastructure, utilities and transportation), 36 (trade). No research was found in the financial sector that uses QC tools. Detailed data is shown in table 2.

RQ3: What types of research use QC tools?

QC tools are applied to 4 types of basic research methods and 5 types of combination methods. Experimental research is the type of research that mostly uses QC tools, followed by models, simulations and case studies (table 3). There has been no research that combines experimental and case study methods.

Table 3.
Types of research methods - summary

Research Method	Code	Article	ME	MK	SE	SM	SK	Total	%
Experiment	E	48	6		5			59	59%
Model	M	18	6	1		2		27	27%
Simulation	S	7			5	2	2	16	16%
Case Study	K	11		1			2	14	14%
Total		84	6	1	5	2	2	100	

Description: ME= Model and Experiment; MK= Model and Case Study; SE= Simulation and Experiment; SM= Simulation and Model; SK=Simulation and Case Study.

RQ4: What are the benefits of QC tools in research?

Of the 100 articles, 19 quality concepts were detected that applied QC tools, where the majority were based on histograms (17 concepts), while the scatter diagram and control chart concepts were only 1 concept each (table 4). QC tools are a standard method that will support the smooth running of scientific research and ensure that an article is of high quality. The benefits of QC tools in research are as a concept and a standard method. QC tools can identify results comprehensively and support researchers in conducting research and drawing conclusions (Sutrisno, 2022).

Table 4.
Quality concept using QC tools

No	Concept	Author (Year)
1	Histogram of Second Order Gradient (HSOG)	(Kumar & Y, 2023)
2	Histogram Equalization (HE)	(Kumar & Y, 2023), (Yin et al., 2023), (Yang & Xuan, 2023)
3	Contrast limited adaptive histogram equalization (CLAHE)	(Kumar & Y, 2023), (Yin et al., 2023), (Hrishikesh Jaware et al., 2023)
4	Adaptive histogram equalization (AHE)	(Yin et al., 2023)
5	Gaussian-fitting gray histogram	(G. Liu et al., 2023)
6	Histogram Test Method	(Alegria, 2023)
7	Histogram of Oriented Gradient (HOG)	(Lv & Zhang, 2023), (Gou et al., 2023), (Sardar et al., 2023), (G & K, 2023)
8	Histogram-oriented optimized capsule network	(Chaudhari et al., 2023)
9	Gray-level histograms	(Al-Mansor et al., 2023)
10	Histogram analysis (HA)	(Malagi et al., 2023)
11	Radiographic histogram analysis (HA)	(Do et al., 2023)

12	Histogram-Based Gradient Boosting (HBGB)	(Srinivas & Mosiganti, 2023)
13	Error Histograms (EHs)	(Sabir et al., 2023)
14	Histogramming Time-to-Digital Converter (hTDCs)	(Sesta et al., 2023)
15	Accelerated Weight Histogram (AWH)	(Lidmar et al., 2023)
16	Histogram thresholding method	(Shi & Zhao, 2023)
17	Selective Apex Adaptive Histogram Equalization (SLAAHE)	(Sarkar & Mandal, 2023)
18	Scatter Diagram for Extreme conditions (SDE)	(Kodaira et al., 2023)
19	Statistical Process Control (SPC)	(Munir et al., 2023)

QC tools are important tools for researchers to support their research. Choosing the right QC tools will affect the quality of scientific research. The use of a QC tool can be used alone or together with other QC tools. QC tools are popular among researchers, academics and practitioners where QC tools will support each individual in completing their work. QC tools can be used to solve problems (George et al., 2018).

4. Conclusion

QC tools are applied to various types of research methods and business sectors, where a study uses 1-5 QC tools in a study. The majority of articles use experimental methods and the majority of studies are included in the trade sector. The most frequently used QC tools are histograms, flow charts and scatter diagrams. The benefits of QC tools in research are as a concept and a standard method. QC tools are important tools for researchers to support their research. QC tools can be used to solve problems. Based on the results of a review of 100 articles, it was found that the QC tools that have not been used in research are check sheets and cause and effect diagrams, there has been no research in the financial sector and there has been no research that combines experimental and case study methods. Suggestions for further research are research in the field of Engineering that discusses sectors included in manufacturing (Basic and Chemical Industries, Various Industries, Consumer Goods Industries) using a combination of experimental and case study methods and applying QC tools including check sheets and cause and effect diagrams.

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