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# A BIBLIOMETRIC ANALYSIS OF EDUCATIONAL RESEARCH PUBLICATIONS ON LEAN MANUFACTURING: IDENTIFYING KEY THEMES AND TRENDS

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**Abstract:**
Since there is so much empirical research in the field of lean manufacturing, to provide a comprehensive overview of the literature on this subject, a bibliometric analysis was required. Through science mapping and multi-dimensional bibliometric analysis, this study aims to identify common themes in the most-cited research on lean manufacturing. A bibliometric analysis was conducted using VOSviewer, including keyword occurrence, co-authorship network, and bibliometric coupling network analyses. From the 4,648 results in the SCOPUS database search, the 100 most-cited articles were analyzed. The analysis found four research clusters: "lean manufacturing," "productivity," "manufacture," and "value stream mapping." It was also found that most of the most-cited papers came from journals with a Q1 ranking. Based on these results, scholars work to learn as much as they can about the field. The results are important to researchers because they show how far the research on lean manufacturing has come. As far as the author knows, no other study has been done on bibliometric analysis of the topic. By making a scientific map of what is known about lean manufacturing, this study adds to what is already known.

***Key words:*** *Bibliometric analysis, Lean Manufacturing, Productivity, Manufacture, Value Stream Mapping*

## INTRODUCTION

On February, 2023, the phrase "lean manufacturing" was looked up in SCOPUS using titles, abstracts, and keywords. This search came up with a total of 4,648 results, the oldest of which was from 2017. Even though these aren't many and aren't very old, this study defines lean manufacturing as a method that stands out in the market as a way to rise productivity while improving quality and financial return [1]. It can be used in small, medium, and large businesses [2] and in any business sector to find a way to stay in business [3].

One of the most important things right now for a business to stay in the market is to be competitive [4]. This situation makes it hard for organizations to find management models that help them grow [5]. Lean manufacturing is one of these methods that has been gaining traction in the sector [6]. Its defining feature is the pursuit of cost reduction through the elimination of waste, which can be categorized into seven or eight different categories: excess production, transport or transference, waiting (time at hand), defects, over- or incorrectly processed goods, excess inventory, unnecessary movement, and a lack of employee creativity [7, 8].

Before it can be used, the lean system needs a deep change in the way an organization thinks [9]. This, according to [10], depends on a good understanding of Toyota's genes and DNA; without this, the system "is a lifeless drawing of a house." One thing that can affect how lean is put into place is the organization's culture. [11] revealed that the key to a successful project is for everyone on the team to share their experiences and lessons learned. [12] found that the integrated JIT-lean practices road map is made so that managers and practitioners can understand how the different practices affect the successful adoption of the JIT-lean manufacturing system.

Bibliographic research had been accomplished in lots of fields, these include medicine [13], business [14] management, the environment [15], and education [16]. Still, to discover if there had been any bibliometric research accomplished on lean manufacturing, I did a complicated seek with inside the SCOPUS database in February 2023 the use of the identical parameters and the word "bibliometric" as my foremost facts seek.

Only three results came back from the search, and only one of them are somewhat related to the current search, other two are only focused on specific fields. The related one is the bibliometric analysis by [17], which only looks

at implementation of lean manufacturing. I plan to do a much broader search that includes lean manufacturing in all fields.

So, I did this bibliography assessment to fill in the gaps I found in the literature, and I did the following. 1) Explore how hundreds of the best-known Lean papers have been published and cited. ii) See how specific countries around the world contributed to and collaborated with the publication of the Top 100 articles on Lean. and iii) identify the major journals citing the top 100 lean papers.

**LITERATURE REVIEW**

Researchers from different fields have different ideas, plans, thoughts, and suggestions about lean, which is used in many different areas [18]. But "lean" usually refers to the idea of making things without wasting anything [19]. Most experts see lean as a way to get rid of waste. [20]said that lean was a way to give people the most value by getting rid of waste through process and human design. Some researchers describe lean as reducing buffering costs [21], getting rid of waste throughout the value stream of a product, [22] or finding and getting rid of waste in the supply chain's value stream [23].

[24] suggests that you can also describe lean by what it does for you or why you should use it. For example, [20] defined lean as a way to improve operational efficiency, find value and waste, gain knowledge, and create a culture of continuous improvement to support sustainability in process operations and business management. [25] revealed that organizations can make their employees more aware of sustainability by reducing rework, which often uses more materials and energy than is necessary.

Other researchers have used the theory of lean tools to describe what lean is. For example, [26] called lean a production method that puts people first. [27] also said that Toyota's production strategy is expanded by lean manufacturing. Also, lean is a multidimensional approach that includes just-in-time production (JIT), continuous and uninterrupted flow (cellular layout), well-maintained equipment (TPM), a well-established quality system (TQM), and a well-trained and empowered workforce (HRM). According to [28, 29], all of these things have a positive effect on operations/competitive performance.

[30] said that there isn't a single, clear meaning of lean because different researchers have different ideas about what it means. But this debate has caused the meaning of "lean" to change over time. Even though there may be gaps in some areas, this gives experts a chance to learn more about and improve the lean philosophy. So, lean can be thought of as a way to get the most out of lean tools by getting rid of waste, gaining more knowledge, and creating a mindset of continuous improvement.

[31] did study on the different ways that lean practices are put into place and how well they work. Their research showed that companies that used lean practices a lot did better in terms of wait time, inventory, and turnover, but not always in terms of quality and delivery on time. Lean manufacturing has been recognized as a powerful technique for improving business performance, including profitability, sales, and customer satisfaction [32, 33], as well as social performance [34, 35], green supply chain performance [36], and sustainable performance [37, 38]. [39] also looked at the relationship between environmental management and the operational performance of 75 Brazilian companies. They found that lean practices were linked to environmental management in a good way. [40, 41] did a systematic review of the literature to find out how implementing lean affects the environmental performance of companies.

[42] asserts that the desire for raw materials made from wood has both good and bad effects on society, the environment, and the economy. [43] concluded that organizations use lean methods based on their own goals and plans. Most people who work with Lean agree that the main reasons to use it are to improve customer satisfaction and product quality [24, 44, 45]. But there are some differences between other things. For example, [24] found that lower costs are a big reason why Indian processing industries are adopting lean. [44] study on the benefits of LM implementation in the Moroccan industry, on the other hand, found that lower costs were the least important reason. In the same way, [46] stated that the most important reasons for adopting lean were improved efficiency and better housekeeping, but [24] argued that there was no reason to improve space use and supply chain efficiency.

**METHODOLOGY**

Science mapping is used in this paper to show what is already known about lean manufacturing. Science mapping is a way to analyze books and other academic work using bibliometric [47]. An interesting type of bibliometric (or scientometric) analysis involves finding and illustrating the links between changing and growing scientific ideas over time [48, 49]. You can look into these connections using different units, like keyword, author, publication, journal, institution, and country [50].

[50] found that a science mapping analysis can be broken down into seven steps: getting the data, pre-processing it, extracting the network, normalizing it, mapping it, analyzing it, and showing it. But many of these steps don't seem to be separate because the software does them all at once with just a few ticks of the mouse. For example, the VOSviewer software runs the five steps of network extraction, normalization, mapping, analysis, and visualization almost immediately after the necessary parameters are set. Some authors say that these steps can be done in just three steps: finding the data, getting the data, and analyzing the data [16]. Here are the steps I took to gather and analyze the data for this study.

**Criteria of searching**

Researchers can use a number of bibliographic sources, which are online databases, to look for data for bibliometric analysis and get it. The most important ones are Google Scholar, SCOPUS, and the Institute for Scientific Information (ISI) Web of Science (WoS) [50]. In this review, the researcher used the SCOPUS database because it has

more publications and covers more journals in the field of social sciences than the WoS database [16]. Google Scholar wasn't chosen because i) it's hard to get bibliometric data from its database and (ii) its indexing rules aren't as strict as those of SCOPUS and ISI (WoS).

The first step of this study is to define the terms or keywords that will be used to gather information about lean manufacturing. The keywords should tell you something, and you should pay attention to word derivatives and word equations. The Scopus database (www.scopus.com) is the best indexer in the world for finding high-quality reference articles.

This stage tries to find the most relevant articles from the first search term results and store them. This search was done in 2023, and it turned up 141 documents that were written between 2017 and 2023. So, only journal articles and conference papers written in English came up in the search results. CSV files are exported for all first search results. Name of author, citation name (author), title of document, year, title of source, volume, publication, page, number of citations, type of source, DOI, abstract, keywords, and conference information are all included.

**Getting and cleaning data**

Once the data was found in the database, Comma-Separated Values (.csv) files were exported as described above. Because the SCOPUS website has limits, I can only export the full bibliometric data for the first 2,000 entries right away. For my analysis, I only need the data from the 100 most-cited articles, so I only exported the first 2,000 and did not bother with the rest.

Next, the researcher cleaned up the data by finding entries that were missing or wrong. A good way to accomplish this is to make sure that no important field is left out of the fields (columns) and that the data in the fields matches the field title (for example, the publication name shouldn't appear in the author field).

During the process of cleaning the data, wrong or missing entries were taken out. After the data was cleaned up this way, the remaining entries were put into a separate Microsoft Excel (.xls) file. For analysis, the new file was saved as a Text (tab-delimited) file so that it could be easily imported into VOSviewer.

**Bibliometric analysis**

Keyword maps, co-author networks, citation and co-citation networks, and bibliographic link networks are the most common types of bibliographic networks in scientific mapping [49]. To conduct this research, the researcher used a keyword map, co-authors from several countries, and a network of bibliographic links. To make the results more interesting, the researcher also included an analysis of publications, citations and major journals where the 100 most cited papers in Lean were published.

There are many different kinds of software that can be used for mapping in science. These include INSPIRE [51], HistCite [52], VantagePoint [53], CoPalRed [53], CiteSpace II [54], Gephi [49, 55]. The researcher used VOSviewer, which can be found at www.vosviewer.com, to see bibliometric maps and networks in this study. In addition to this, the data from VOSviewer was used to make graphs in Microsoft Excel.

In science mapping, there are different ways to show how results look. Most researchers use methods that are based on distance, graphs, or time [49]. In all of these ways to show a map, there are two main parts: the "nodes," which are circles, and the "edges," which are the lines that connect the nodes. Depending on how the nodes and edges look, each of the three ways to look at maps gives different meanings to the maps. In the distance-based method, how close two nodes are to each other shows how strong the connection between them is. In other words, if the nodes are close together, the relationship between the two things is stronger [56]. In the graph-based method, on the other hand, the distance between nodes doesn't tell you anything about how they are related. These connections are instead represented by edges. If a facet isn't shown, there's no connection between the 2 shapes [49]. In the closing kind of visualization, referred to as timeline-primarily based totally or temporal analysis [50], the nodes are organized vertically primarily based totally on sure time periods, and their horizontal distance indicates the connection among entities [49].

The VOSviewer program uses a distance-based method to show bibliometric networks. But the edges can also be shown if the researcher wants to see more [49]. In my analysis, I chose to also show the edges. So, there are three things to keep in mind when reading the bibliometric maps in this study:

1) The size of the nodes shows how often an entity shows up (its frequency).
2) When nodes are close to each other, it means that the connections between the entities are stronger.
3) The thickness of the lines between any two nodes shows that both of those things are present.

**RESULTS AND DISCUSSIONS**

**The distribution of scholarly works and citations**

Figure 1 is a graph that shows how the 100 most-cited articles are spread out over time, as well as how many documents were published in each year and how many times they were cited.

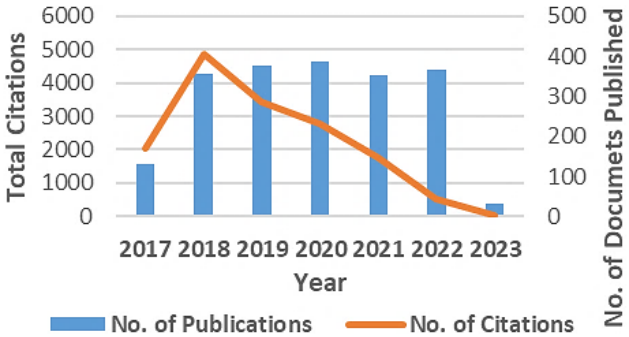


*Fig. 1 Publications by yearly*

The graphs show that the number of articles about lean manufacturing has grown steadily over time. In 2017,

there were 130 publications, but by 2022, the figure has risen to 367. Also, the number of highly cited articles seems to be going down in 2019 and 2020 (by 375 and 386, respectively), but the average number of citations for those articles is steadily going up. So, the slope is going down because it takes longer to get citations for the most recent publications than for those that came out earlier. So, I think that in the long run, the ratio of highly cited articles to the total number of publications on the subject will stay the same. Also, the number of highly cited articles shows that researchers are still interested in both the publications and the topic. So, even after a few decades, lean manufacturing is still a popular and important topic.

**International cooperation and contribution**

Figure 2 illustrates the share of the one hundred most-mentioned papers that have been posted through authors from diverse nations.

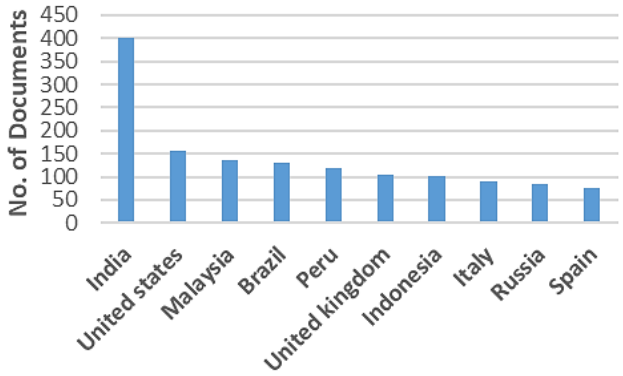


***Fig. 2 The contribution of numerous nations***

For simplicity, the figure only shows countries that have contributed to at least seventy publications. As the results show, India has contributed a lot more than the other countries (400 publications) to the most-cited literature on lean manufacturing. The number of publications from India is more than twice as many as those from the United States, which is the next-closest competitor. Also, the top two countries, India and the United States, were responsible for 555 publications, which shows that they are far ahead of the rest when it comes to highly cited literature on the topic. On the other hand, the results show that the few countries that showed up in the analysis contributed less than 100 publications (Italy, Russia, and Spain). This seems to show that more research needs to be done on lean manufacturing all over the world, especially in the Europe and also in the Asia.

Since the total number of contributions from all the countries is more than 100 (which is the number of publications looked at in this study), this shows that the countries that contributed have worked together in some way. So, VOSviewer was used to set up a way for these countries to work together, and the results are shon in Figure 3.

The results show that India and the United States have worked together with other countries 24 and 28 times, respectively. The United States ranks top (link strength = 88) and the United Kingdom ranks second (link strength = 86) when collaboration strength is considered. Also, India is in third place when it comes to the number of links, but China beats Italy when the strength of the collaboration is taken into account. China's strength of collaboration is 71, while Italy's is 61. These results show how important it is for researchers from different countries to work together on papers that get a lot of attention.

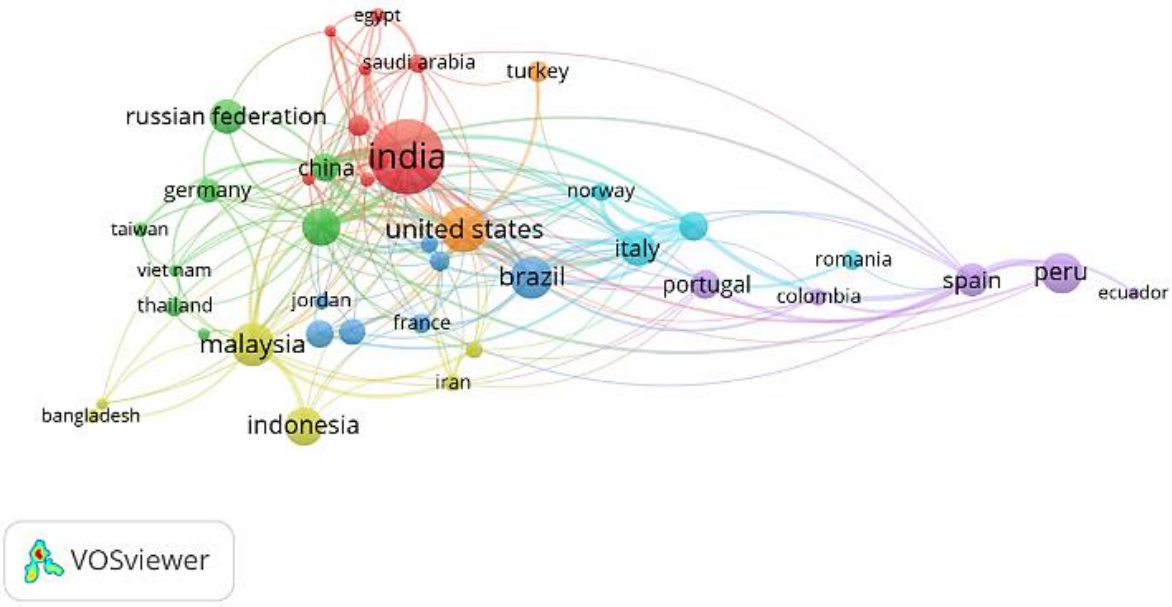


***Fig. 3 The contribution network of numerous nations***

**Key journals**

I did more research to find out which top journals published the 100 most-cited articles about lean manufacturing. The results showed that the papers are published in many different journals. In fact, at least one of the 100 most-cited articles has been published in 40 different journals. Yet, just ten of these publications have published two or more of those pieces. Table 1 summarizes the details of these ten journals. Because the number of publications in each journal is the same, Table 1 ranks the journals based on how many times their publications have been cited.

According to the outcomes in Table 1, all however one of the pinnacle journals is ranked Q1 with the aid of using ScimagoJR. This is one of the most obvious things to notice. This is a sign that most of the highly cited articles about lean manufacturing come from high-quality journals. Moreover, there are two journals that are not available according to Scopus (proceedings of the international conference on industrial engineering and operations management and procedia manufacturing). I then examined the scores in Table 1's second-to-last column, which provides the source-normalized impact per article (SNIP). SNIP divides the entire number of citations that a journal could receive in that topic field by the average number of citations per paper in that journal [49]. Thus, SNIP scores greater than one indicate that the journal's average number of citations per article is greater than the journal's citation potential in its subject field. According to the results in Table 1, all of these top journals had SNIPs smaller than one, with 2.18 being the highest.

**Keywords**

I also did research to find out what the main ideas were that the 100 most-cited articles looked at. This become executed via way of means of the use of VOSviewer to examine how frequently phrases regarded together (each the ones selected via way of means of the authors and people selected via way of means of the journals). Figure 4 shows how things turned out. Based on the results, the information in these publications can be put into four main groups. In order of cluster size, the most important keywords in each of these groups are "lean manufacturing," "productivity," "manufacture," and "value stream mapping.

***Table 1***

***Top-most frequently cited sources***

| Journal Name | TP | TC | CPP | Cite Score | SNIP | SJR |
|---|---|---|---|---|---|---|
| proceedings of the international conference on industrial engineering and operations management | 109 | 166 | 2 | N/A | N/A | N/A |
| iop conference series: materials science and engineering | 80 | 159 | 2 | 1.1 | 0.34 | 0.25 |
| international journal of lean six sigma | 54 | 648 | 12 | 7.2 | 1.64 | 0.79 |
| lecture notes in mechanical engineering | 53 | 67 | 1 | 0.7 | 0.39 | 0.19 |
| materials today: proceedings | 51 | 366 | 7 | 2.3 | 0.57 | 0.35 |
| advances in intelligent systems and computing | 50 | 147 | 3 | N/A | 0.30 | 0.19 |
| procedia manufacturing | 46 | 541 | 12 | N/A | N/A | N/A |
| acm international conference proceeding series | 37 | 22 | 1 | 1.0 | 0.31 | 0.32 |
| journal of manufacturing technology management | 37 | 1080 | 29 | 12.4 | 2.18 | 1.90 |
| lecture notes in networks and systems | 36 | 7 | 0.2 | 0.7 | 0.24 | 0.15 |

**Note: TP stands for total publication; TC stands for Total citations; CPP stands for citation per publication; SNIP stands for source normalized impact per paper; SJR stands for Scimago Journal Ranking**

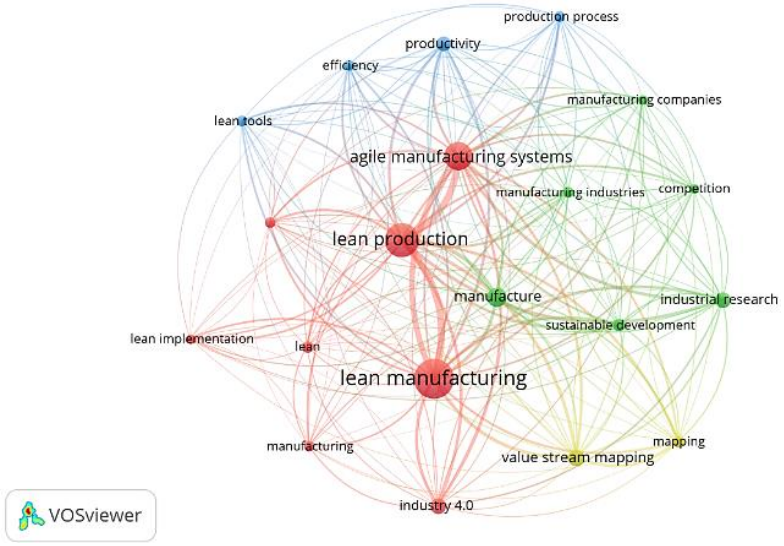


***Fig. 4 Matching network for the most common keywords***

"Lean manufacturing" is the word that comes up most often (19 times) in Cluster 1 (keywords = 8). Even though it is in the first cluster, this keyword is the one that is used the most often in the whole map. This shows that researchers have thought about it when writing about lean manufacturing. This keyword is strongly linked to the ideas of lean production and agile manufacturing system, both of which are in Cluster 1. It also has strong ties to a number of keywords from Clusters 2 and 4. For example, the strength of its links with manufacturing and value stream mapping are 124 and 133, respectively.

The word "manufacture" is used 18 times in Cluster 2 (which has 6 keywords). This word is also the second most used word in general. The results show that manufacture has strong links with lean production and lean manufacturing (link strength of 159 and 124, respectively), all of which are in Cluster 1. Also, the word "manufacture" has strong ties to a number of keywords from the second and fourth clusters. In this way, it shows strong connections with Industrial research and value stream mapping, each of which has a link strength of 39 and 42 respectively.

Figure 4 shows that The first and 2nd clusters are near every different. inside the visualization network, however, the different clusters are some distance away. This shows how closely related the keywords in these clusters are to each other compared to the keywords in the other clusters. This shows that there is a different way of thinking about lean manufacturing. So, they tend to be more interested in lean manufacturing, which is more common in the market and economy field.

The most important word in Cluster 3 (with 4 keywords) is "productivity," which comes up 19 times. The third most common word overall. Yet, its connections to other concepts are weaker than those of the first and second clusters' principal terms. In this way, it doesn't have strong links to any other keywords outside of the cluster. Also, the relationships between the keywords within the cluster seem to be weak because two of the keywords (efficiency and lean tools) are in a group by themselves, far from the other keywords in the cluster. Even so, the main key work in this cluster (productivity) has close links with one other key work in the same cluster (production process with link strengths sixteen). Lastly, for the last cluster, most of the results show that mapping and value stream mapping go together well.

**Citation network**

I also examined the references cited in these 100 articles to determine if there were any overlaps between the works cited by the 100 most-cited articles on lean manufacturing. This was done with the help of VOSviewer and a bibliometric coupling analysis. Figure 5 shows the results that the software for this subject came up with.

Based on the works that are cited in the 100 most-cited publications, the results show that they can be put into five groups. For example, those who looked into lean manufacturing are in the red cluster on the right. In the same way, the group of light green dots in the bottom-left corner of the map shows that the lean approach has been tried out in manufacturing. The distance between these two clusters and between the nodes and the fact that there are not many connections between them shows that the work cited in these two publication groups is not very similar.

Two groups on the left side of the map, one at the top (purple) and one above the center, show how different the works that have been cited are (in dark blue). These two groups of studies tend to focus on i) lean manufacturing in very specific settings and (ii) increasing productivity with lean tools and lean sigma. The fact that the nodes in these two clusters are spread out shows how different the literature cited within and between these two groups of publications is.

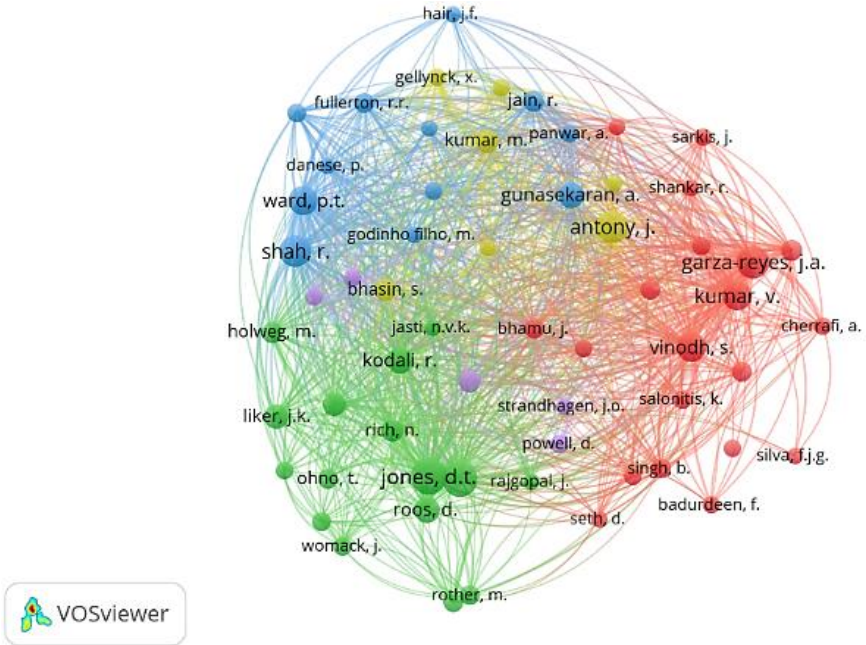


***Fig. 5 Collaborative network connections among renowned authors***

## LIMMITATIONS

Current bibliometric research is limited in several ways. First of all, I only used a single database to look through the literature. Even though I believe that other databases like Dimensions, PubMed, and WoS are reliable, I think that the results from the SCOPUS database would be enough because it has a wide range of social sciences. I'll admit that the results might be a little different if data is taken from a different database or from a mix of databases. Lastly, I could only look at data from the 100 most-cited papers in my analyses. If I had used all the papers found in the first search, the results could have been very different. So, the next set of conclusions must be understood in light of these limitations.

## CONCLUSION

There are some intriguing results from this bibliometric analysis of the most-cited educational works on differentiated instruction. The findings showed that many academics are interested in the subject, as seen by the rise in publications and citations. In this paper, the researcher looked at how many articles have been written about lean manufacturing. The researcher also looked at how scholarly work was cited and published from 2017 until the date of the search, which was February 2023. In addition, the researcher looked at the 100 most-cited articles on the subject to see what countries contributed and how they worked together, as well as the most critical journals where these articles are published. Using keywords and examining the references provided in the articles, the researcher also presents a map of what is known about the topic.

The researcher found that since 2017, the number of publications and citations about lean manufacturing has been going up, but the number of highly cited articles seems to be going down in 2019 and 2020. Also, it was noticed that most of the publications come from India and that there are not many from Europe. I have come to the conclusion that international collaboration and the number of publications that get a lot of attention are linked in a good way. I found that almost all of the key journals where these articles are published are high or middle-ranked. I also found that all of these journals have a significant effect on the field they are in. So, I think researchers should look at least two journal metrics, like quartile ranking and SNIP.

In this research, it was shown that combining lean manufacturing with other management systems helps the growth of an organization. Lean manufacturing must be supported by leading technologies for this integration to happen. Information and knowledge must be accurate, and how it is handled, stored, and, most of all, access has become a deciding factor in the competitive business world. So, as technology has grown, the ability to recover information and knowledge has become an important part of making decisions and running businesses.

In this way, the main contribution of this work is to find something that seems to be missing in the literature: a way to store the lessons learned while putting lean manufacturing, its principles, and tools into practice.

## ACKNOWLEDGEMENTS

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