A Scientometric Framework: Application for Knowledge Management (KM) in Industry Between 2014 and 2019

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Abstract— **It is always difficult to identify the most recent works that have been published, especially those published in recent years, due to delays in putting publications online, citations indexe, etc. Scientometry offers to researchers various concepts, models and techniques that can be applied to knowledge management (KM) in order to explore its foundations, its state, its intellectual core, and its potential future development. To this end, we have developed a scientometric KM framework to calculate the scientometric indexes related to a query introduced in the Scopus database, to facilitate research and monitoring of productivity and collaboration between the authors of KM in particular and also the dissemination of knowledge. The works between 2014 and 2019 are taken, the industry of services was omitted. It might help the decision makers and researchers to optimize their time and efforts. We used Unified Modeling Language (UML) to translate the development ideas of the scientometric framework structure into diagrams, and Delphi 7 to calculate the indexes and ensure other operations of research (about: articles, their authors, conferences, etc). This framework is only valid for Excel files extracted from Scopus or similar format. Finally, the relation between KM and industry 4.0 was established on found articles in Scopus.**

Keywords-Scientometric indexes; Knowledge management; Industry; industry 4.0, Scopus; UML; Delphi.

I. INTRODUCTION

KM is a concept having more attention in the last years; it was applied to the industry field as a process of creating, acquiring, transferring and using knowledge in order to improve the companies' performance. It is related to two types of activities: a) activities by which one attempts to document and appropriate individual knowledge within the organization and b) activities that facilitate human exchanges, in which uncodified knowledge is shared [1]. However, because of its novelty and for the reasons of delays in posting, indexes of citations, it is always difficult to identify the most recent and impacting published works. The sociology of sciences has exploited certain possibilities that mathematics and computer tools offer today to provide new analytical tools (library analysis, method of co-citations, method of associated words, etc.), around which a new discipline has been formed: the scientometry [2]. This discipline seeks to characterize science by the constitution of the objective laws of its development and finds its practicalities on the one hand in the quality of the tools it manipulates and on the other hand in the model of science on which it relies. It is based on the use of mathematical tools, and in particular on the statistical analysis of long series of clues deemed objectives, gradually extends.

In this context, a scientometric framework for KM was developed, able to calculate the scientometric indexes relating to a query in the Scopus database, to facilitate research and follow-up, productivity and collaboration between KM authors in particular, and the dissemination of knowledge.

Section 2 gathers some scientometric works. The followed methodology is presented in Section 3. Section 4 was devoted to realization and implementation of the scientometric framework. In Section 5, the relation between KM and Industry 4.0 is established and followed by a conclusion.

II. RELATED WORK

There are several precedent works related to KM. A relative scientometric analysis of KM [3] was presented, as a comparison between KM and Intellectual Capital (IC) journals, by the implantation of scientometric indexes using the programming language R. The results highlighted the best journals in KM and IC. Aitouche et al. [4] found that IC is an emerging field and scientific researchers are more productive and have immediate impact in it than those of KM field even though it is novelty. This comparison was observed through a bibliometric analysis of the evolution of KM and IC fields. Aitouche et al. [5] have done a keywords analysis in KM and IC. They observed that KM and IC have many common concepts such as management, performance, model, value. The keywords analysis allowed the identification of existing levels of meaning in scientific articles as well as the unexpected trends in each area. This work could be useful to prepare glossaries, ontologies and all semantic researches. In industry, Caviggioli and Ughetto [6] proposed a bibliometric analysis of the literature dealing with the impact of additive manufacturing on industry. It has gained momentum since 2012, in terms of the number of articles, received citations and number of involved authors. Empirical studies represent more than 50% of the sample, but they have mostly employed a case study approach. The result suggests that future empirical research could contribute further with the analysis of larger datasets and through the adoption of methods relying on surveys or action research.

Gonçales Filho and Campos [7] analyzed the lean manufacturing as a viable operations strategy; thereby identifying the lean production strategy adopted by companies in the various segments.

III. METHODOLOGY

In this section, we will present the used scientometric indexes, UML for design of the framework and used data.

A. Scientometric indexes

Table 1 describes the relative indexes used in this work; each index has an interpretation according to its definition.

TABLE I. MOST USED INDEXES.

Indexes	Description and/or formula
I-index	Number of citations of articles published in year N/ number of articles published in the journal in year N.
I10 index	Number of articles with at least 10 citations.
H index	Number of articles N, cited at least N times.
N index	It is calculated by dividing the H index by the number of years since first publication.
G index	Is the rank g of the article accumulating at least g^2 of citations?
Π-index	The introduction of a new impact index (π-index) aimed to privilege articles from highly influential journal, i.e. those that obtained a relatively high number of citations in all the analyzed articles. Π-index = $0.01\ C(P\pi) / C(P\pi)$; hundredth of the number of citations.
Citescore	Citescore = Number of citations of a journal / Number of articles in a journal
SCImago Journal Rank (SJR)	SCImago Journal Rank measures weighted citations received by the serial. Citation weighting depends on subject field and prestige (SJR) of the citing serial.
Source Normalized Impact per Paper (SNIP)	Source Normalized Impact per Paper measures actual citations received relative to citations expected for the serial's subject field.

B. Design with UML

«Unified Modeling Language» is a visual language consisting of a set of diagrams, each diagram gives a different vision of the project to be dealt with. Thereby, StarUml is used to form the essential diagrams (use case diagram and class diagram).

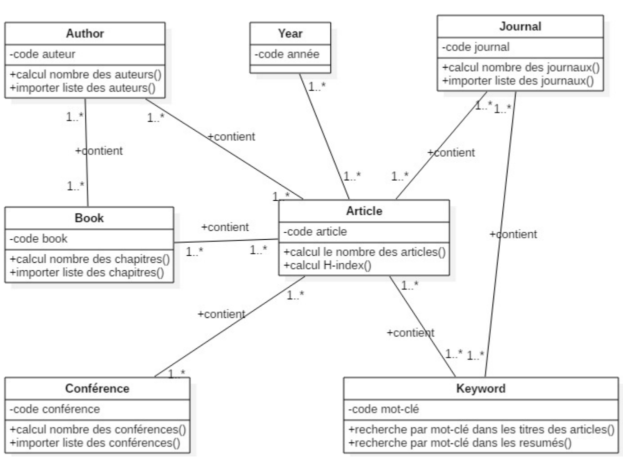

Figure 1. Class Diagram of scientometric framework.

In Fig. 1, we presented the class diagram. It contains 7 classes: author, who is the principal actor of research, then the article containing the majority of information. This latter is related to its keywords. The classes book, conference and journal represent the container of article. We need the class year to separate articles in time.

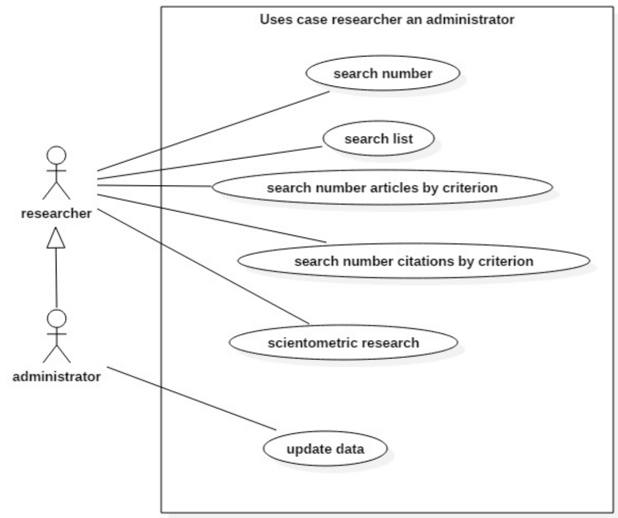

Figure 2. Uses cases of scientometric framework.

The uses cases diagram (Fig. 2) represents the functionalities of the proposed computing framework. It contains calculation of numbers, displaying lists, number articles by criterion, number citations by criterion, scientometric indexes and updating used data. The details are given in Section 4.

C. Collected data

The collected data for this framework is a set of articles concerning KM extracted, as an "excel" file, from Scopus (Fig. 3). The search in Scopus is accomplished with a query that finding articles, witch their titles contained the expression (KM AND (industry OR industrial OR manufacturing OR factory OR production OR product OR company OR firm OR enterprise OR organization)).

IV. REALIZATION AND INTERPRETATION

The framework offers several functionalities to calculate some scientometric indexes using an Excel database exported from Scopus containing the items of articles requested.

A. Calculation of numbers

This functionality (Fig. 3) allows calculating the number of articles, authors, journals, chapters, laboratory, and conferences. We found 198 articles, 542 authors, 9 chapters, and 50 conferences in our integrated database. These numbers reflect the huge practices of KM in industries.

Figure 3. Menu calculation of numbers.

B. Lists

This functionality (Fig. 4) allows importing the lists of authors, journals, chapters, laboratory, conferences, and country. It imports the list of the indicated criterion.

Figure 4. Interface of lists.

The lists allow the researcher to have a primary idea on who are the authors, what are the journals, conferences, books and countries, laboratories, participating to the KM in industry.

C. Number of articles by criterion

In this functionality (Fig. 5), we search the number of articles by criterion (author, journal, chapter, laboratory, conference, country) or even further, the number of articles for author, journal, chapter, laboratory, conference, country, using names everyone needed.

Figure 5. Number articles by criterion.

For countries, as it is observed from Table 2, the most producing countries are Germany, India, China, UK, Iran, USA and Malaysia. The more productive authors in KM applied to industry are Kifor C.V. with 4 articles, and, Tan L.P., Wong K.Y. and Paszek A., with 3 articles.

TABLE II. NUMBER ARTICLES PER AUTHOR AND PER COUNTRY

Author	Number articles	Country	Number articles
Kifor C.V.	4	**Germany**	**21**
Tan L.P.	3	**India**	**18**
Wong K.Y.	3	**China**	**14**
Paszek A.	3	**United Kingdom**	**13**
Samsir	2	**Iran**	**13**
Gao J.	2	**United States**	**13**
Twongyirwe T.M.	2	**Malaysia**	**12**
Lubega J.	2	Brazil	9

Table 3 shows that the biggest number of articles belongs to the ECKM (European Conference on KM Management) conference with 5 articles, then the journals “Advances in Transdisciplinary Engineering”, “journal of KM management”, “Lecture Notes in Computer Science”, “Advanced Science Letters” and “KM Research and Practice” with 4 articles.

TABLE III. ARTICLES BY JOURNAL OR CONFERENCE OR BOOK.

Journal or conference or book	Number articles
Proceedings of the European Conference on KM, ECKM	5
Advances in Transdisciplinary Engineering	4
Journal of KM	4
Lecture Notes in Computer Science	4
Advanced Science Letters	4
KM Research and Practice	3
Quality - Access to Success	3
Advances in Intelligent Systems and Computing	3
Procedia CIRP	3
International Journal of Applied Business and Economic Research	3

D. Number of citations by criterion

As the previous functionality, our search would be by criterion too for searching the number of citations (Fig. 6). The criteria are the same used in Section C.

Figure 6. Number citations by criterion.

Table 4 represents an ascendant classification of articles by number of citations. The most cited article is entitled “The effects of industry cluster KM on innovation performance” with 71 citations. The second cited one is entitled “KM and innovation in knowledge-based and high-tech industrial markets: The role of openness and absorptive capacity”. The precedent articles highlight the relation between KM and innovation.

Table 5 shows the most cited authors: Lai Y.-L., Hsu M.-S., Lin F.-J., Chen Y.-M., with 71 citations and Martín-de Castro G. with 23 citations. They are the pioneers of KM in industry, even if they are less productive than the authors mentioned in section B. They are not really evaluated by their productivity, but by their impact on the scientific society.

TABLE IV. CITATIONS OF ARTICLES

Article	Number citations
Lai Y.-L., Hsu M.-S., Lin F.-J., Chen Y.-M., Lin Y.-H., "The effects of industry cluster KM on innovation performance", 2014,"Journal of Business Research"	71
Martín-de Castro G., "KM and innovation in knowledge-based and high-tech industrial markets: The role of openness and absorptive capacity", 2015, "Industrial Marketing Management"	47
Hussain M., Ajmal M.M., Khan M., Saber H., "Competitive priorities and KM: An empirical investigation of manufacturing companies in UAE", 2015,"Journal of Manufacturing Technology Management"	23
Tan L.P., Wong K.Y., "Linkage between KM and manufacturing performance: a structural equation modeling approach", 2015,"Journal of KM"	22
Gonzalez R.V.D., Martins M.F., "Mapping the organizational factors that support KM in the Brazilian automotive industry", 2014,"Journal of KM"	22
Assouroko I., Ducellier G., Boutinaud P., Eynard B., "KM and reuse in collaborative product development - A semantic relationship management-based approach", 2014,"International Journal of Product Lifecycle Management"	17

The most countries having impact on the scientific society (Table 5) are Taiwan (98), Germany (51), Spain (47), Malaysia (41), UK (40), USA (38), India (38), Brazil (37) and China (36).

TABLE V. NUMBER CITATIONS BY AUTHOR AND COUNTRY

Author	Number citations	Country	Number citations
Lai Y.-L.	71	Taiwan	98
Hsu M.-S.	71	Germany	51
Lin F.-J.	71	Spain	47
Chen Y.-M.	71	Malaysia	41
Lin Y.-H.	71	United Kingdom	40
Martín-de Castro G.	47	United States	38
Saber H.	23	India	38
Eynard B.	23	Brazil	37
Tan L.P.	23	China	36
Wong K.Y.	23	France	27
Hussain M.	23	Austria	24

Table 6 indicates that the most cited institutions are Feng Chia University in Taiwan, University of Kaohsiung, Kaohsiung in Taiwan, University of Madrid in Spain, Cunef Business School in Spain and Abu Dhabi University in United Arab Emirates.

TABLE VI. NUMBER CITATIONS BY LABORATORY

Laboratory	Citations
Feng Chia University, Taichung, Taiwan	71
Department of Business Administration, Feng Chia University, Taichung, Taiwan	71
Department of Asia-Pacific Industrial and Business Management, University of Kaohsiung, Kaohsiung, Taiwan	71
Department of Leisure and Recreation Management, Asia University, Taichung, Taiwan	71
Business Administration Department, Complutense University of Madrid, Spain	47
Nonaka Centre for Knowledge and Innovation, CUNEF Business School, Spain	47
College of Business Administration, Abu Dhabi University, Abu Dhabi, United Arab Emirates	23
Department of Manufacturing and Industrial Engineering, University of Technology Malaysia, Skudai, Malaysia	22

Table 7 represents the most cited journals. It is found that the first cited journal is “Journal of business research” with 71 citations and the second one is “journal of KM” with 52 citations, followed by “Industrial Marketing Management” with 47 citations.

TABLE VII. CITATIONS BY JOURNAL

Journal	citations
Journal of Business Research	71
Journal of KM	52
Industrial Marketing Management	47
Journal of Manufacturing Technology Management	26
International Journal of Product Lifecycle Management	17
Total Quality Management and Business Excellence	16
International Journal of Computer Integrated Manufacturing	15
Journal of International Marketing	14
Business Process Management Journal	13
Journal of the Knowledge Economy	12
DFX 2014: 25th Symposium Design for X	12
Procedia CIRP	12

“European Conference on KM” (Table 8) is the most cited conference with 5 citations. The second and the third ones are “Advances in Transdisciplinary Engineering” and “Lecture notes in computer science” with 4 citations.

TABLE VIII. CITATIONS BY CONFERENCE

Conference	Citations
Proceedings of the European Conference on KM, ECKM	5
Advances in Transdisciplinary Engineering	4
Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	4
Proceedings of the ASME Design Engineering Technical Conference	3
Advances in Intelligent Systems and Computing	3
Procedia CIRP	3
Proceedings of the International Conference on Engineering Design, ICED	3
Procedia Engineering	3
Applied Mechanics and Materials	3

E. *Scientometric indexes*

This is where we could calculate the scientometric indexes (H-index, G-index, etc.). As it is exposed in Fig. 7, there is a group of authors where the i-10 index equals to 1; the highest value of H index is 2, and the highest value of G index is 3.

Figure 7. Menu scientometric indexes.

Table 9 indicates that all authors have an i-10 equal to 1 or 0. This means that the best author has 1 article cited with 10 citations: this is true only for the selected data.

The author could have an i10 index superior to 1 but using all his articles which are not present in our data.

The highest h index is 2. This means that these authors have 2 articles cited with 2 citations.

The highest G index is 3. This means these authors are the most cited, relatively; the exponential 2 of citations represents an improved h-index.

TABLE IX. SCIENTOMETRIC INDEXES OF AUTHORS

Author	I10-index	Author	H-index	Author	G-index
Eynard B.	1	Eynard B.	2	Paszek A.	3
Gonzalez R.V.D.	1	Richter A.	2	Tan L.P.	3
Tan L.P.	1	Kifor C.V.	2	Wong K.Y.	3
Wong K.Y.	1	Sivri S.D.	2	Krishnamurty S.	2
Al-Sa'di A.F.	1	Krallmann H.	2	Zhang C.	2
Abdallah A.B.	1	Shirouyehzad H.	2	Wang Y.	2
Dahiyat S.E.	1	Popescu D.I.	1	Eynard B.	2
Marques C.S.	1	Yildirmaz H.	1	Gonzalez R.V.D.	2
Leal C.	1	Atilla Öner M.	1	Gao J.	2
Marques C.P.	1	Herrmann N.	1	Eddy D.	2
Cardoso A.R.	1	Sarina T.	1	Richter A.	2

Table 10 represents the Π-index of journals (138), conferences (50) and books (9). It means that the journals are more cited and productive than conferences and books, because Π-index is an index reflecting the productivity and the impact in the same time.

TABLE X. Π-INDEX OF JOURNALS, CONFERENCES AND BOOKS

Π-index type	Value
Π-index for journals	138
Π-index for conferences	50
Π-index for books	9

It can be justified by the nature of journal articles containing more exhaustive insights, their experimentation and interpretation of results.

F. Update the data

Modifying or changing the file of the database, updating and integrating it, would be possible (Fig. 8). Data should have the same Excel format of the Scopus Excel exportation.

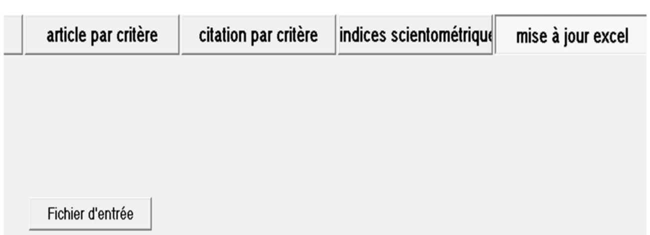

Figure 8. Update input data.

One can use this data or another database and introduce them in the Excel file, having the same items, and introduce it to the framework to have results.

V. SCIENTOMETRIC ANALYSIS OF KNOWLEDGE MANAGEMENT IN INDUSTRY 4.0

For this analysis, the expression (*"industry 4.0"* OR *iiot* OR *"industrial internet of things"* OR *"fourth industrial revolution"*) AND *"knowledge management*" in titles is used in Scopus to find 7 articles.

Table 11 shows that the number of articles on knowledge management and Industry 4.0 has been increasing over time. Germany is the most productive country. All authors have one article.

TABLE XI. PRODUCTION BY YEAR, COUNTRY AND AUTHOR

Year	Nb	Country	Nb	Authors and co-authors	Nb
2019	3	Germany	2	Arifiani, L., Budiastuti, I.D., Erika, W.K.	1
2018	2	Australia	1	Jermsittiparsert, K., Boonratanakittiphumi,	1
2017	1	Austria	1	Neumann, G., Evangelista, P.	1
2016	0	Colombia	1	Sarina, T.	1
2015	1	Finland	1	Cárdenas, L.J.A., Ramírez, W.F.T.,	1
2014	0	Indonesia	1	Möllenstädt, O.	1
		Italy	1	Brandl, P., Aschbacher, H., Hösch, S.	1

Table 12 presents the source of an article, even if it is a journal, conference or a book. Nb, N, CS, SJR and SNIP represent number of articles by source, notoriety, citescore, scimago journal rank, and source normalized impact per paper, respectively. Scopus does not find indexes for certain items. The Lecture Notes in Computer Science is the most cited (highest indexes) and it is the oldest source. It is followed by the CEUR conference.

TABLE XII. SOURCES BY INDEXES N, CS, SJR AND SNIP

Source title	Nb	N	CS	SJR	SNIP
International Journal of Engineering and Advanced Technology	1	2011	0.10	-	-
International Journal of Innovation, Creativity and Change	1	2013	0.20	0.187	0.306
Proceedings of the European Conference on Knowledge Management, ECKM	1	1999	-	-	-
The Palgrave Handbook of Knowledge Management	1	2018	-	-	-
Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	1	1937	1.06	0.283	0.713
CEUR Workshop Proceedings	1	1989	0.32	0.166	0.301
Mensch und Computer 2015 - Workshop	1	2015	-	-	-

Table 13 presents the affiliations of the authors of the articles; this is useful for a researcher to eventually collaborate with them.

Two German laboratories appear to make Germany one of the most productive countries in Industry 4.0 (third and fourth article). The collaboration between countries (Table 13) exists in the fourth article (Germany, Italy and Finland).

TABLE XIII. AFFILIATIONS OF THE AUTHORS OF KM AND INDUSTRY 4.0

Affiliation	Nb
Social Research Institute, Chulalongkorn University, Bangkok, Thailand; King Mongkul's Institute of Technology Ladkrabang, Prince of Chumphon Campus, Chumphon, Thailand.	1
Smart Production Solutions, Evolaris Next Level GmbH, Hugo-Wolf-Gasse 8-8A, Graz, A-8010, Austria; R and D Projects and Service Management, XiTrust Secure Technologies GmbH, Grazbachgasse 67, Graz, A-8010, Austria; Consulting and Project Management, XiTrust Secure Technologies GmbH, Grazbachgasse 67, Graz, A-8010, Austria.	1
Hauptgeschäftsführer Gesamtverband Kunststoffverarbeitende Industrie e. V. (GKV), Germany.	1
Technical University of Applied Sciences, Wildau, Germany; CNR-IRISS, Naples, Italy; School of Business and Management, Lappeenranta University of Technology, Finland.	1
Bina Nusantara University, Jakarta, Indonesia.	1
Universidad Distrital Francisco José de Caldas, Bogotá, Colombia.	1
Department of Marketing and Management, Macquarie University, Sydney, NSW, Australia.	1

Table 14 contains the frequencies of keywords proposed by authors in their articles. The keywords "knowledge management" (4) and "industry 4.0" (3) appear more than the others because they are contained in the titles of articles.

TABLE XIV. KEYWORDS FREQUENCIES IN ARTICLES

Keyword	Nb	Keyword	Nb	Keyword	Nb
Knowledge management	4	Data mining	1	Logistics	1
Industry 4.0	3	Degree of flexibility	1	Logistics and supply chain management	1
Supply chain	2	Digital technologies	1	Market situation	1
Academic literature	1	Disruption technology	1	Productivity improvements	1
Big data	1	Effective management	1	Service innovation	1
Big data analytics	1	Fundamental tools	1	Supply chain management	1
Business innovation	1	Information flows	1	Supply chains	1
Comparative advantage	1	Internet of things	1	Technological solution	1
Competitive advantage	1	Literature-based analysis	1	Thailand	1

"Logistics" and "supply chain" gathered appear 6 times; we understand primarily that industry 4.0 and KM are applied almost in logistics. "Technology" appears 7 times and "advantage" appears 2 times. Keywords give insights on trends of the researches on industry 4.0 and KM.

VI. CONCLUSION

In this work, we put to the researcher's hands a framework to facilitate finding what they are looking for, related to KM in the field of industry; KM is considered as a new discipline, so it is hard to find documentation related to it. Scopus is the biggest database containing abstracts, citations, conferences, books, subjects of research in various sciences. The data contains articles talking about KM and industry, extracted from Scopus, omitted the service industries and were introduced to the framework. Moreover, we chose Delphi to be the workspace of programming the scientometric framework. The value of the framework consists in the relative indexes calculated for a specific request; they do not exist in research databases.

The type of the updating file has to be "Excel" or a similar type, so, in this framework, we suggest that a computer scientist concentrates on developing this point, or even better searching for a way to integrate Scopus or other important database directly with the programming application.

A scientometric analysis is applied manually on 7 articles, making the relation between KM and Industry 4.0. The productivity and the impact of these researches is increasing over time and domains.

An interesting future development could be updating more than one database, and comparing them according to the calculation of the scientometric indexes using the framework. Furthermore, the databases could be related to different sciences.

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