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Identify the Main Knowledge Streams of Technological Learning in Joint R&D Projects in Petroleum Industry Based on Co-Word Method

Identificando las principales corrientes de conocimiento del aprendizaje tecnológico en proyectos conjuntos de I+D en la industria petrolera basados en el método de palabras compartidas

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ABSTRACT

In this paper, to determine the main knowledge streams of technological learning in joint R&D (JRD) projects in petroleum industry, the co- word analysis method is used. The knowledge map is drawn by reviewing 388 papers published in the study area from 2000 to 2021 in Scopus and Sage databases using VOSviewer1.6.16 software. Accordingly, by reviewing the existing knowledge, the two main concepts of knowledge management and technological innovation are identified. Then, using text mining method and drawing a concept knowledge map, 8 clusters are extracted and their relationships are analyzed using Netdraw software. Finally, the study period from 2000 to 2021 is divided into three main categories: organizational - communication characteristics, economic goals and concepts of innovation, and shown the most focus in recent years is in the field of innovation concepts.

Keywords: Technological learning, joint R&D projects, Knowledge map, text mining, clustering, co-word analysis.

RESUMEN

En este trabajo, para determinar las principales corrientes de conocimiento del aprendizaje tecnológico en proyectos conjuntos de I+D (JRD) en la industria petrolera, se utiliza el método de análisis de co-palabras. El mapa de conocimiento se elabora mediante la revisión de 388 artículos publicados en el área de estudio desde 2000 hasta 2021 en las bases de datos Scopus y Sage utilizando el software VOSviewer1.6.16. En consecuencia, mediante la revisión del conocimiento existente, se identifican los dos conceptos principales de gestión del conocimiento e innovación tecnológica. Luego, utilizando el método de minería de texto y dibujando un mapa de conocimiento conceptual, se extraen 8 clústeres y sus relaciones se analizan utilizando el software Netdraw. Finalmente, el período de estudio de 2000 a 2021 se divide en tres categorías principales: características organizacionales - de comunicación, objetivos económicos y conceptos de innovación, y se muestra que el mayor enfoque en los últimos años está en el campo de los conceptos de innovación.

Palabras clave: aprendizaje tecnológico, proyectos conjuntos de I+D, mapa de conocimiento, minería de textos, agrupamiento, análisis de co-palabras.

1. INTRODUCCION AND LITERATURE REVIEW

The iran economy has historically been increasingly reliant on foreign currency profits from crude oil exports. We must acquire better technology to address the issue of crude sales and production of petroleum products and attain self-sufficiency in the oil value chain. The gap between the technological levels of industrialized and developing nations is substantial. Technology transfer is unavoidable for bridging the technological divide between developing and industrialized countries. Today, technology transfer programs will be successful if the technology acceptor can accept and assimilate the technology without assistance. In other words, it is capable of autonomously operating and maintaining the process and enhancing, expanding, and developing technology. Without a suitable learning method, achieving this objective is practically difficult. In recent years, particularly before the imposition of harsh sanctions on Iran in 2012, many collaboration projects between Iran and other foreign countries have been implemented using various collaboration strategies. This claim is supported by well-known international companies like Shell and Total. Foreign partners have departed the area due to international pressure and the ban on Iran key industries, particularly the oil industry, and the void of a structured technological learning system that may assist the country continue its operations without foreign partners has become increasingly apparent. As a result of the absence of learning in Iranian enterprises engaged in cooperative projects, Iran either did not continue to operate after the exit of a foreign partner or considerably slowed its development.

"Technological Learning" is acquiring and enhancing technological skills to produce and manage technical change(Malerba, 1992). Technologicalcal Learning is a dynamic process(Carayannis & Alexander, 2002) that attempts to increase a company's competitiveness via the foreign technology acquisitio, the accumulation of technological aptitude, and the promotion of innovation(Xie & Li-Hua, 2008). Internalization, development, enhancement, and modernization of these skills, as well as demonstrating the company's capacity to absorb, distribute, and efficiently utilize foreign technologies, as well as the production of new technologies throughout time, are all evaluated in the technological learning process(Hansen et al., 2011). A significant portion of learning is embodied and meaningful inside an industry's enterprises, and a part of it is achieved via collaboration among these enterprises. Joint R&D is one sort of inter-firm collaboration. Joint R&D projects involve the collaboration of two or more institutions or persons to accomplish a specific objective(Aronson et al., 2001).

Numerous studies have addressed the topic of technological learning in JRDs. In most of these studies, researchers have discovered the characteristics influencing technological learning by analyzing partner behavior. By analyzing the literature on the factors that influence technological learning in JRDs, the four categories of organizational characteristics, communication characteristics, characteristics of JRD projects, and collaboration objectives are categorized as shown in Table 1.

Table 1. Factors that influence technological learning in JRD projects

Factors affecting technological learning in JRDs		References
Organizational characteristics	Level of trust between partners, Absorption capacity, Homogeneity in (goal/culture/procedures), Common scientific basis, Market share	(Cabral, 2000), (Selnes & Sallis, 2003), (Wagner & Hoegl, 2006), (Oxley et al., 2009), (Brodley, 2012), (Bell & Pavitt, 2015), (Lin, 2014), (Bäck & Kohtamäki, 2016), (Zadykowicz et al., 2020)
Communication characteristics	Common structure, previous experience of collaboration, geographical distance, vertical/horizontal communication, use of various formal/informal communication channels	(Dyer, 1998), (Johnson et al., 2004), (Weick et al., 2005), (Duso & Röller, 2010), (Fang et al., 2011), (Corsaro et al., 2012), (Huikkola et al., 2013), (Kohtamäki & Bourlakis, 2012), (Huikkola et al., 2013), (Lin, 2014),

		(Reilly & Sharkey Scott, 2014), (Bäck & Kohtamäki, 2016), (Zhang et al., 2018), (Jeon et al., 2019)
Features of JRDs	Intellectual property rights, the share of the parties in collaboration, market share	(Cabral, 2000), (Oxley et al., 2009), (Brodley, 2012), (Huikkola et al., 2013), (Kim et al., 2018), (Arranz et al., 2019)
Collaboration goals	Market development, product development, technology development, innovation	(Hurley et al., 1998), (Kamien et al., 1992), (Duysters & Lokshin, 2011), (Grönroos & Voima, 2013), (Arranz et al., 2020)

According to the litreture, no research has been conducted on the primary knowledge areas of JRD projects in the petroleum sector. According to what has been discussed, we must transfer technology to close the technological gap with developed countries. A technological learning plan is necessary for the success of technology transfer. The opetroleum industry, being one of the Iran most influential businesses with a significant economic impact, is no exception. In the sphere of policymaking, it is essential to address the issue of technological learning in the petroleum industry's JRD project efforts. It is essential to have a clear understanding of the boundaries and features of this concept to perform policy studies and provide suggestions.

Technological learning in JRD projects has been presented from several viewpoints. This study aims to construct these definitions and assess their interaction with other views in this area to establish the scope of the field of knowledge in question to an acceptable level. In this article, using VOSviewer and NETdraw software and the co-word analysis approach, an effort has been made to explore and discover tendencies that are not always clearly discernible from a qualitative examination alone. It is a novel way of clustering and constructing frameworks. After reviewing the text mining method's characteristics in the second section of the essay, the study methodology is described, and the knowledge maps and cluster's communication networks are constructed. The third portion analyzes the outcomes of the knowledge map and the network of clusters, while the fourth section provides a summary and conclusion.

2. METHODOLOGY

Co-word analysis and network analysis were used in this study. This research's study population consists of all publications indexed in the Scopus and SAGE databases from 2000 to 2021, a total of 388 articles, from which a knowledge map was created using an advanced co-word analysis approach, a text mining technique. Text mining is a subset of data mining. According to Fayyad et al. (1996), knowledge discovery is a non-obvious process of uncovering legitimate, novel, helpful, and eventually understandable patterns in data(Fayyad et al., 1996). Text mining is the extraction of patterns from natural language text. Text mining combines extracted information to generate new facts or hypotheses, which may be examined further via an in-depth examination of existing knowledge. Text mining aims to unearth undocumented and unidentified information(Camacho et al., 2020).

Text mining techniques are necessary for drawing a knowledge map of technological learning in JRDs projects in the petroleum industry, which includes counting the critical concepts of this knowledge, clustering as well as determining how the concepts relate to one another, and ultimately determining the volume of knowledge around each sub-area. The co-word analysis approach was utilized in this work, and VOSviewer software with a powerful graphical interface (Moral-Muñoz et al., 2019) was used to create knowledge maps and clustering. The Netdraw program was used to analyze word relationships in clusters. This software, created in 2000 by Freeman, Martin, and Burgati, produces graphical and network graphs (Moral-Muñoz et al., 2019). Based on the knowledge map, the major trends in technological learning in

JRDs projects in the petroleum sector were then identified and presented. A knowledge map is created by examining the terms used in the article's title, abstract, and text.

Calvin introduced the concept of co-word analysis in 1983, proposing that the placement of words in a text reflects its substance. Therefore, if we quantify the frequency of these co-occurrences, we may construct a network of scientific area concepts(Naghizadeh et al., 2015). The work of "Loz and LoMaria" in 1997 in the field of plant biology, "Bhatacharia and Besso" in 1998 in the field of dense materials in physics, and "Peters and von Ron" in 1993 in chemical engineering, and "Oniancha and Ochala" in 2005 in medical sciences are examples of the use of this method to draw the conceptual network of a field(Van Eck & Waltman, 2017).

Knowledge map are used in two ways: to display the quantitative dynamics of a set of ideas in a scientific subject (which in the map form a cluster) and to uncover linkages between concepts(Mas-Tur et al., 2020). Fig 1 reveals the main steps of this study.

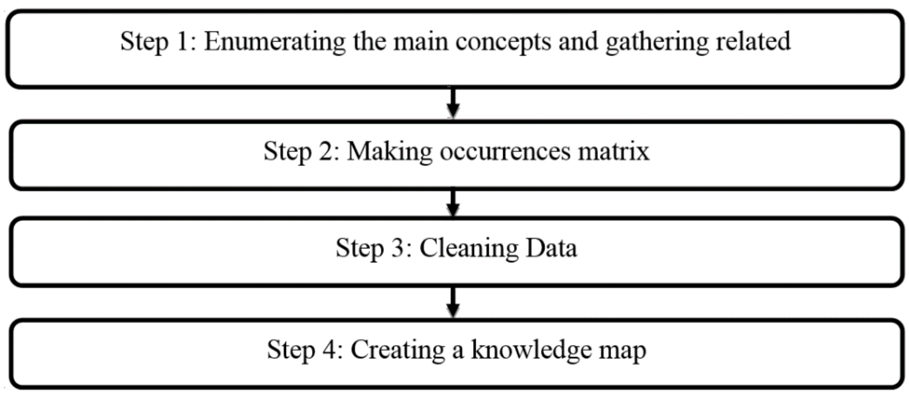

Fig 1. main steps of this study

Step 1: Enumerating the main concepts and gathering related

In order to enumerate the necessary ideas, the primary concepts were selected by analyzing 54 important and valid papers on the subject of technological learning in JRD projects. In the analysis of 54 cited publications, 36 key themes were uncovered. Following a study, 36 themes were divided into 15 key concepts (Table 2). In addition, almost all publications published on technological learning in JRD projects in the petroleum sector since 2000 were gathered from the Scopus and SAGE databases, totaling 388 articles.

Table 2. Identified keywords

Row	Identified keywords	Row	Identified keywords	Row	Identified keywords
1	Joint R&D Projects	6	Technological Learning	11	Exploitative Learning
2	Joint R&D Collaboration	7	Joint Learning	12	Explicit Knowledge
3	R&D Collaboration	8	Organizational Learning	13	Tacit Knowledge
4	Joint R&D Collaboration	9	Individual Learning	14	Petroleum Industry
5	R&D Collaboration	10	Explorative Learning	15	Oil and Gas

Step 2: Making occurrences matrix

After finishing the keyword counting step, reading all documents, and establishing the number of occurrences of each keyword in each document, an occurrence matrix must be created. The number of rows in the matrix represents the number of chosen words, while the number of columns represents the number of accessible documents. If a concept is present in a document, its associated value is the number of occurrences of that concept inside the document. To create such a matrix using the co-occurrence approach, you must input the terms in each search article and their frequency in the event matrix. As a result, some researchers opt not to count the number of words in the text and examine whether or not to address it, which simplifies the task but diminishes the map's validity. Due to the significance of this study's validity, the number of keyword occurrences on each page was calculated.

Step 3: Cleaning Data

This technique involves homogenizing singular and plural forms, removing country names, homogenizing words that are also shortened, and removing research methodologies, irrelevant words retrieved, and similar terms. Finally, by establishing a vocabulary frequency threshold of 2, only 84 original terms remained (this threshold has been set differently in different studies).

Step 4: Creating a Knowledge Map

VOSviewer1.6.16 software provided RIS files containing the articles retrieved from the specified databases, and the program produced a knowledge map in four forms titled Network Visualization, Overlay Visualization, Item Density view, and Cluster Density view. The retrieved software findings are shown in Figs 2, 3, 4, and 5, each illustrating a different aspect of this knowledge map.

The main concepts identified, their distribution, primary clusters, and the volume of concepts are illustrated in Fig 2. According to the size of the circles, the primary clusters are decided by the diversity of colors and the number of ideas employed.

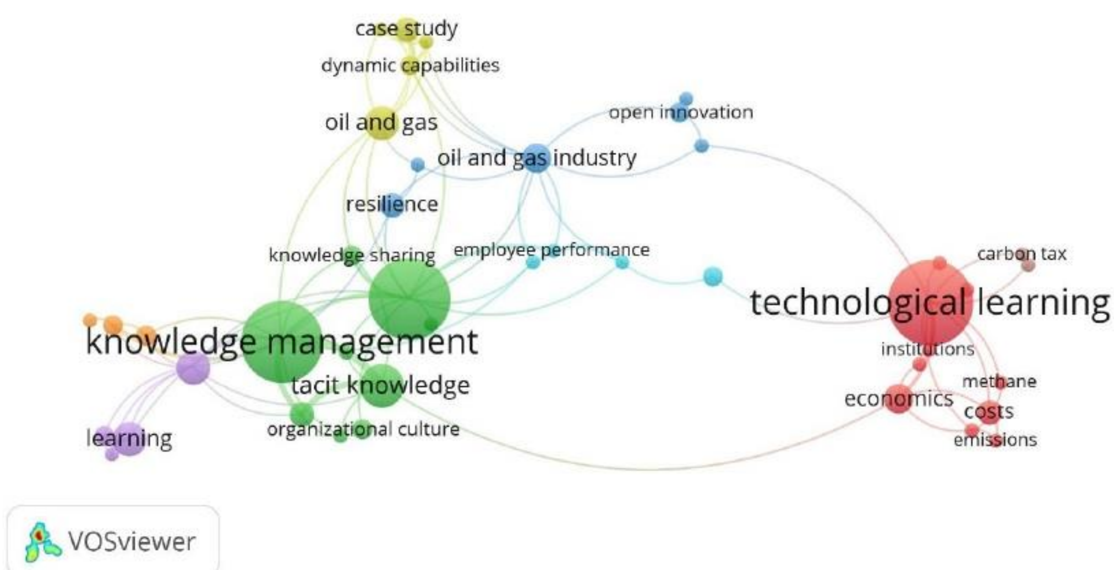

Fig 2. Network Visualization of technological learning in joint R&D projects in petroleum industry knowledge map

Fig 3 reveals the cluster's time trend. As can be seen, the concept of technological learning in JRDs prior to 2010 was primarily concerned with knowledge management and organizational learning. In contrast, open innovation, innovation system, organizational innovation, network analysis, literacy, and dynamic capability have become sharper in recent years.

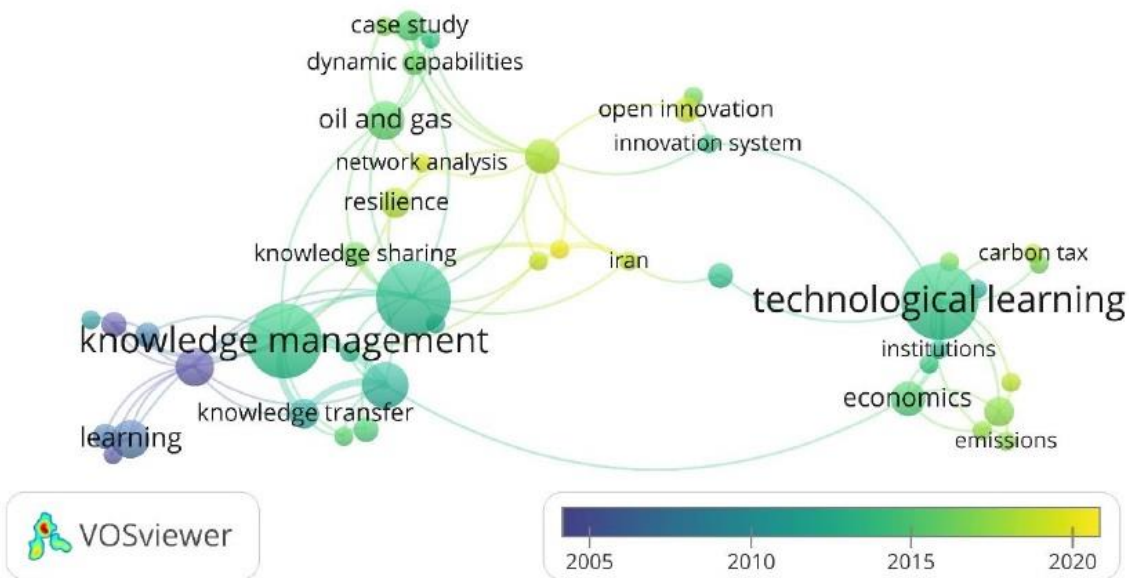

Fig 3. Overlay visualization of technological learning in joint R&D projects in petroleum industry knowledge map

Fig 4 shows the density of the identified main concepts. The concepts of knowledge management and technological learning have the maximum density, as seen in Fig 4.

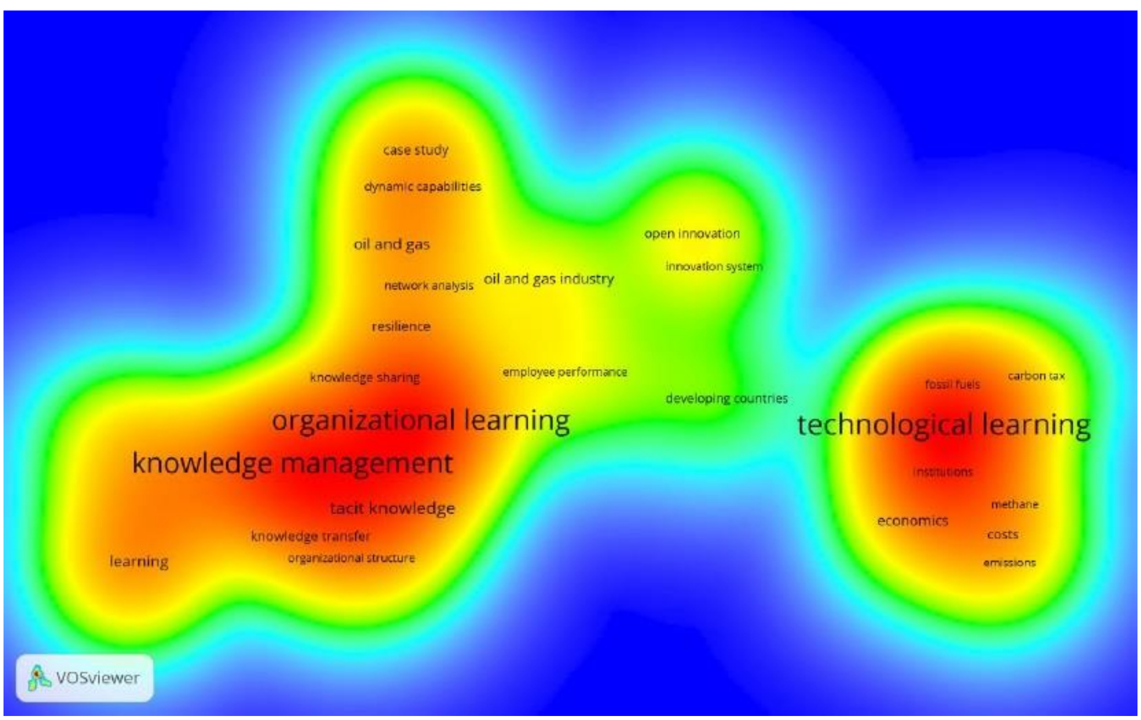

Fig 4. Density view of technological learning in joint R&D projects in petroleum industry knowledge map

Fig 5 illustrates the cluster density of the identified main concepts. The color distinction indicates the identified clusters. Fig 5 illustrates that the identified clusters are grouped into eight groups (Table 2). Following is an analysis of the clusters.

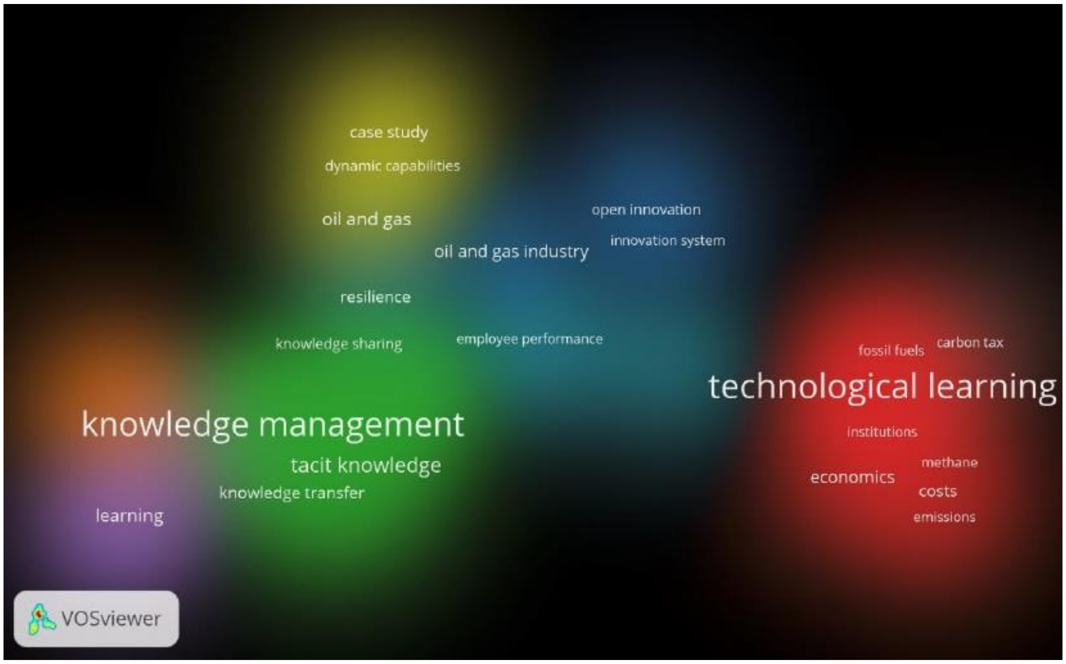

Fig 5. Cluster density view of technological learning in joint R&D projects in petroleum industry knowledge map

Table 3. Identified Clusters

Clusters	Co-words
Cluster 1	Knowledge management, knowledge sharing, knowledge transfer, learning organization, tacit knowledge, organizational culture, organizational learning, organizational structure, project management
Cluster 2	Technological learning, learning curve, experience curve, institutions, investment, fossil fuels, carbon tax
Cluster 3	Innovation system, open innovation, network analysis, resilience, prototyping, oil, and gas industry
Cluster 4	Learning, experience, knowledge, organization, oil, and gas
Cluster 5	Economic, policies, cost, emissions, methane
Cluster 6	Dynamic capability, dynamic supply chain, supply chain management, oil and gas, case study
Cluster 7	Employee performance, developing countries, Iran, organizational innovation
Cluster 8	Organizational learning, system dynamic, risk management

Cluster 1:

Table 3 and Fig 6 show that cluster 1 has nine concepts. "Knowledge management" and "technological learning" are most closely connected to other concepts in this cluster. The relationship between "project management" and "organizational structure", "knowledge sharing" and "organizational culture" is more significant than other concepts. "Knowledge management" and "organizational characteristics" are the core concepts of this cluster.

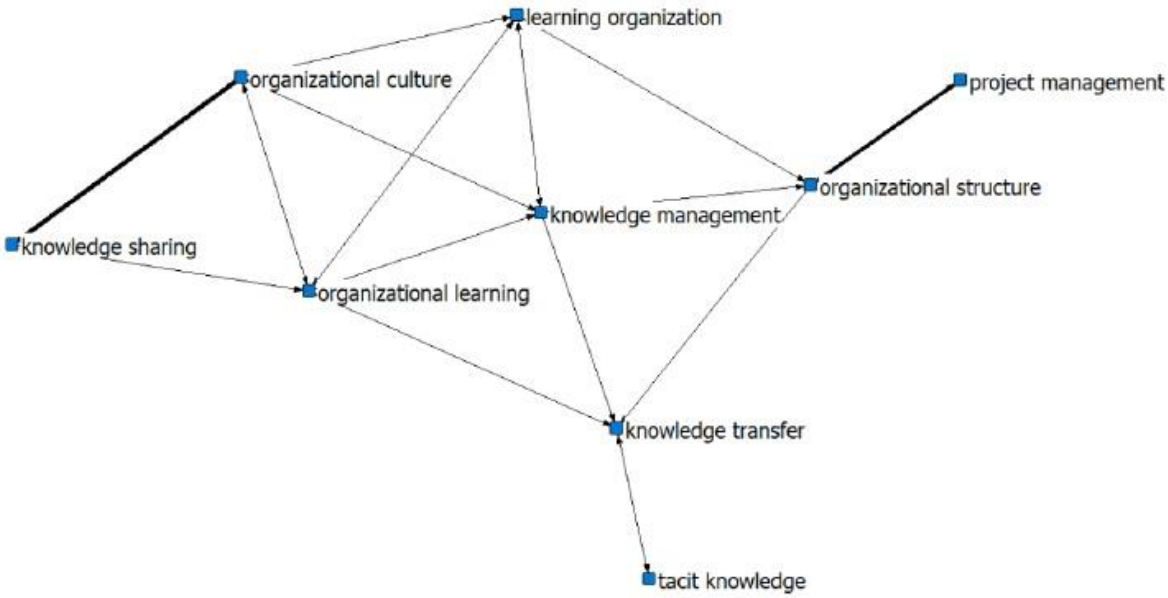

Fig 6. Cluster 1

Cluster 2:

In cluster 2, the concept of "learning curve" has the most significant connections to other concepts and is the cluster's most essential concept. The "learning curve" concept is connected to five concepts, the most closely related to "technological learning". As seen in Fig 7, the relationship between the concepts of the "carbon tax" and "fossil fuels" is greater than those of the other concepts. In general, this cluster focuses on concepts that pertain to the field of learning.

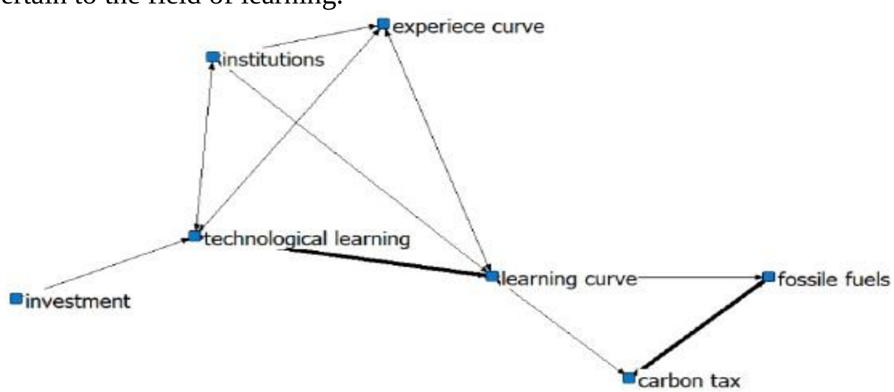

Fig 7. Cluster 2

Cluster 3:

Cluster 3 has six concepts. The most significant concept in this cluster is the "innovation system" concept which has the greatest connections to other concepts.

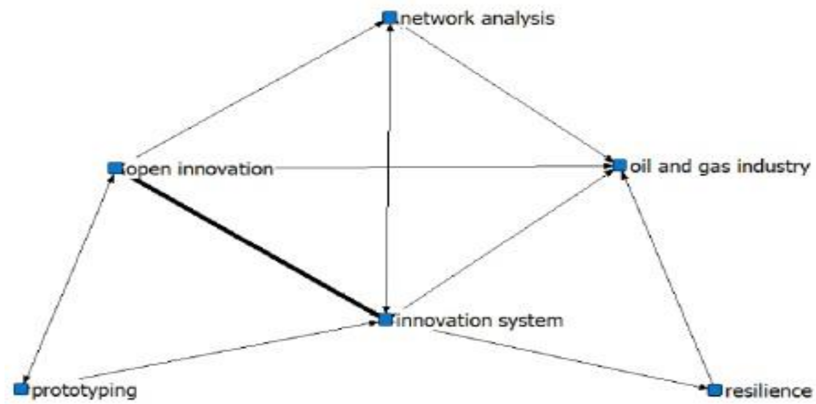

Fig 8. Cluster 3

Cluster 4:

This cluster includes five concepts. The concept of "oil and gas", which has the most significant connections to other concepts, is the cluster's most significant concept. This concept is closely associated with the concept of knowledge.

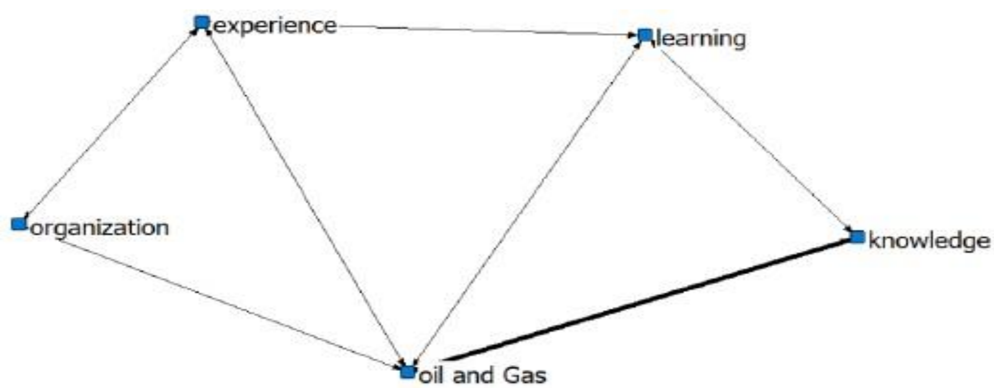

Fig 9. Cluster 4

Cluster 5:

This cluster has five concepts, each of which has four linkages. In other words, both concepts are significant. Moreover, the relationship between "politics" and "economics" is greater than that of other concepts.

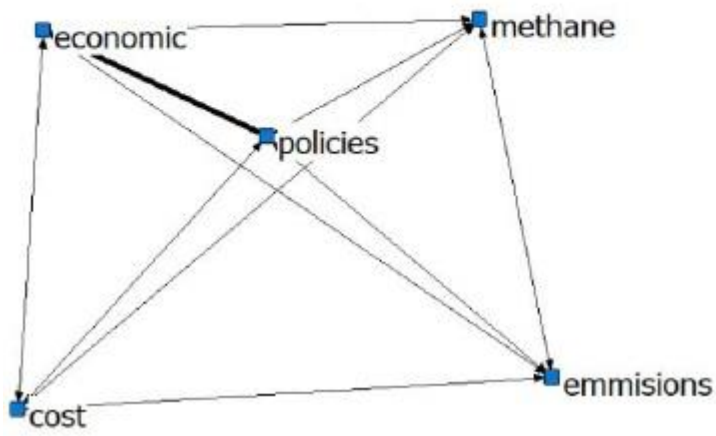

Fig 10. Cluster 5

Cluster 6:

Cluster 6 has five concepts. This cluster's most essential concept is "dynamic capability", and the strongest relationship is made between "oil and gas" and "dynamic capability".

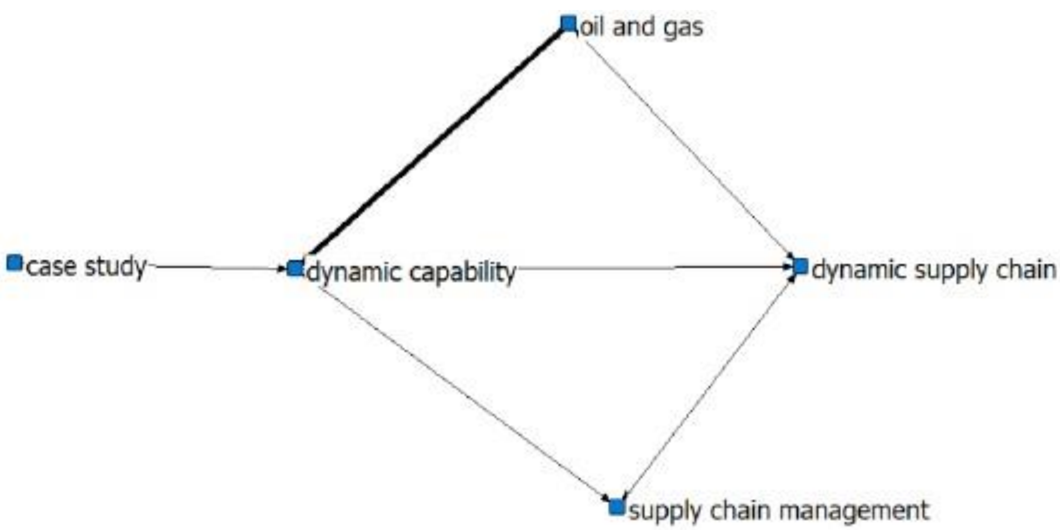

Fig 11. Cluster 6

Cluster 7:

This cluster has four concepts, each of which has three linkages. In other words, all concepts are significant. Moreover, the relationship between "organizational innovation" and "employee performace" is greater than that of other concepts.

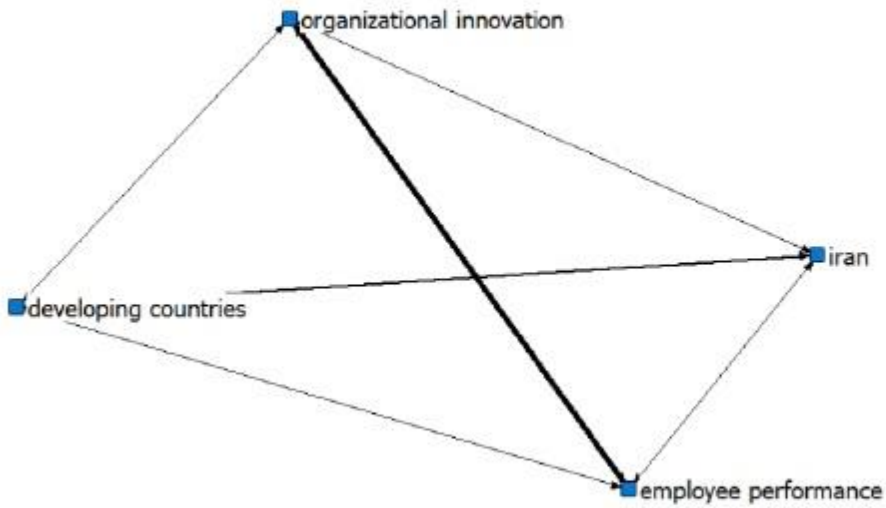

Fig 12. Cluster 7

Cluster 8:

Cluster 8 is the last cluster in this study. it consists of three concepts: "organizational learning", "system dynamic" and "risk management".

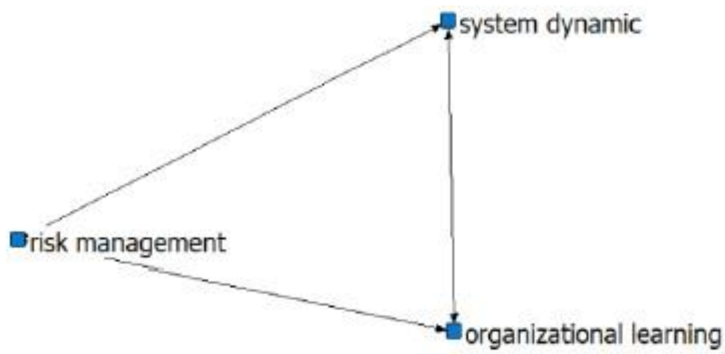

Fig 13. Cluster 8

3. DISCUSSION OF RESULTS

Since the early 1980s, science and technology policy philosophy in Europe, the United States, and Japan has increasingly shifted to foster JRD projects between corporations, universities, and other research institutions(Arranz & Fdez De Arroyabe, 2005). The establishment of JRD projects has fostered interactive processes and enabled partnering parties to profit from government-funded research(Arranz et al., 2020).

Different studies have examined technological learning in various kinds of technological collaborations. In most of these studies, researchers have identified the variables that influence technological learning by analyzing the behavior of partners and the kind of collaboration. The knowledge map derived from library research and studies makes it feasible to convey general trends and a particular category in technological learning in JRD projects for the petroleum sector. According to Fig. 3, "knowledge management" and "technological learning" are the most studied technological learning in joint R&D projects in the petroleum industry, with the most significant density of clusters and volume of studies and articles.

"Knowledge management" includes the four clusters 1,4,6,8. The concepts of "knowledge management", "organizational characteristics" and "communication characteristics" are conceptually comparable in all of these clusters, and the term knowledge management, as seen in cluster 1 (Fig. 6), is the most important and extensively used word in this field. According to the cluster analysis (Figs 6, 9, 11, and 13), the key concepts in "knowledge management" are "knowledge transfer", "knowledge sharing", and "tacit knowledge". In addition, organizational characteristics such as "learning organization", "organizational culture", "organizational learning", and "communication characteristics" such as "supply chain management", "dynamic supply chain", and "organizational structure"" have been used. Therefore, it is concluded that technological learning in JRD projects in the petroleum industry is formed via knowledge management mechanisms and that organizational characteristics and communication characteristics have a substantial influence on learning. There are numerous studies that demonstrates the significance of organizational characteristics in technological learning in JRD projects(Selnes & Sallis, 2003), (Wagner & Hoegl, 2006), (Oxley et al., 2009), (Gaugler K & Siebert R, 2007), (Huikkola et al., 2013). Common in R&D projrcts include studies (Duso & Röller, 2010), (Kohtamäki & Bourlakis, 2012), (Huikkola et al., 2013), (O'reilly & Parker, 2013) on the influence of communication characteristics on learning.

Despite being related to the concept of knowledge management, clusters 2, 3, 5, and 7 are primarily associated with technological learning. The intimate relationship between technological learning concepts, collaboration goals, and the characteristics of JRD projects are evident in these clusters. Cluster 2 shows that technological learning is the most important term used in this sector (Fig. 7). Examining the clusters of this field (Figs. 7, 8, 10, and 12) reveals that the main concepts in technological learning, alongside innovation concepts such as organizational innovation, open innovation, and innovation system, demonstrate the connection between technological learning and innovation. The literature in this area of study has a wealth of data about the effect of innovation on the objectives of a JRD project on technological learning(Arranz et al., 2020). The interaction between economic concepts and the sphere of technological learning in JRD projects is another aspect that is particularly visible in cluster 5 (Fig 10). As seen in Fig 10, politics and economics are highly intertwined. The analysis of this literature reveals, on the other hand, that economic objectives affect technological learning in JRD projects in the petroleum sector(Oxley et al., 2009),(Bäck & Kohtamäki, 2015).

The overlay of research on technological learning in JRD projects in the petroleum industry is another crucial aspect of Fig 3. As shown in Fig 3, the influence of organizational and communication features on the issue of technological learning in JRD projects in the petroleum industry has been the primary focus of study in this area until roughly 2010. In the studies published between 2010 and 2015, as seen in Fig. 3, the influence of economic ideas on technological learning in joint R&D projects in the petroleum industry was investigated further. Since 2015, studies have focused on the link between the ideas of innovation and their function in technological learning in JRD projects in the petroleum industry, as seen in Fig 3.

4. CONCLUSION

Using co-word analysis, a knowledge map based on 388 articles published between 2000 and 2021 in the Scopus and SAGE databases, and a review of the existing knowledge in the field of technological learning in JRD projects in the petroleum industry, this article attempts to identify and present the effects of the dominant knowledge streams in this field.

In light of what was said in the preceding section's examination of the data, the primary knowledge streams of the research area revolve around the two main concepts of knowledge management and technological innovation. The influence of communication features, organizational characteristics, economic aims, and innovation concepts on technological learning in JRD projects in the petroleum industry is represented by eight clusters derived from the research.

Also, based on the pattern of change over time, which is apparent in Fig 3, communication characteristics and organizational features were emphasized in the articles until 2010, after which the focus shifted to economic objectives and, subsequently, innovation concepts. As a result, scholars have been paying greater attention in recent years to the study of technological learning in JRD projects in petroleum using the ideas of organizational innovation, innovation system, and open innovation.

The first innovation of this study is the use of co-word analysis and knowledge map technological learning in JRD projects in the petroleum industry, which has found new and hidden patterns in knowledge in the form of clustering. In addition, the knowledge map derived from analytical and descriptive methodologies was reviewed. Compared to earlier studies in this sector, the combination of analytical and descriptive methodologies has improved the findings' reliability.

This article's second innovation categorizes technological learning currents in JRD projects. In academic contexts, classifying dominating streams and analyzing the link between clusters and their constituents enhances the potential of delving further into each stream in terms of its theoretical foundations and, subsequently, the dependability of analyses based on each stream. At the level of policymaking, it also enables policymakers to pick and optimize the optimal learning method for joint R&D projects based on their specific conditions.

Even though this article attempts to identify the main areas of technological learning in JRD projects in the petroleum industry, there are still many uncertainties that might be the topic of future study. The most crucial areas of uncertainty are:

- What is the link between innovative and technological learning in JRD projects in the petroleum industry?
- What variables influence technological learning differently in developed vs. developing countries?
- How do variables influence technological learning in JRDs efforts with other industries?

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