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Research Article

Identifying the Effects of Co-authorship Strategies on the Citation-based Performance of Scholars: A Social Networks Analysis

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ABSTRACT

Research impact is the extent to which the work by a researcher and its citations are utilized by others. The main objective of this research was to determine scientific collaboration strategies (Middle, Independent, Bridging, Complex, Bonding, Dyadic) used by researchers in nuclear science and technology and to investigate the relationship between these strategies and the increase or reduction in the number of received citations with accordance to the utilized strategy. Network analysis method was utilized to provide an understanding of the relations and interactions of co-authors as well as identify their co-authorship strategies. The research population included all authors of the articles published in SCI-EXPANDED in nuclear science and technology field from 2009 to 2011 as well as their citations from 2011 to 2016. After determining measures of individual-centered network (size, constraint and efficiency), a combination of methods introduced by Rumsey-Wairepo and Kuzhabekova was utilized with some modifications to identify co-authorship strategies. Bridging, bonding, independent, isolate and dyadic co-authorship strategies were the most preferred ones by authors in this field, respectively. Those researchers having applied independent strategy had a higher citation performance in comparison with other researchers while those using isolate strategy had a lower citation performance. Finally, a model was presented based on the influence of applying co-authorship strategies on the number of received citations. These findings help researchers increase their number of received citations and improve their research impact with creating and applying co-authorship strategies consciously and strategically. So far, no research has been conducted concerning the influence of applying different co-authorship strategies on citation performance of researchers and this research is the first one.

Keywords: Research impact, Citation impact, Research collaboration, Scientific collaboration, Social network analysis, Co-authorship strategies, Cohesive structure, Structural holes, Nuclear science and technology.

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INTRODUCTION

For most researchers, it is necessary to do research of high quality and quantity.[1] After putting too much effort on research, researchers usually expect to be able to publish their research results and be among those effective in creating, transferring and sharing knowledge with works having the required research impact. Research impact is the recorded or auditable occasion of the influence of a research on actors of the society.[2] In academic context, research impact usually refers to the number of citations a researcher receives,[3] a higher research impact will lead to more citations to the works published by the researcher. The studies have indicated that scientific collaboration would result in a higher research impact for the collaborative authors.[4-8]

Co-authorship is the product of scientific cooperation.[9] And is the most formal manifestation of intellectual cooperation among authors in scientific research productions.[10] It involves the participation of two or more authors in the production of a study leading to a scientific output of a greater quality and quantity than could be achieved by an individual.[11-13]

The co-authorship network indicates multiple relationships among researchers some of whom are authorship coworkers

sharing their knowledge indirectly in the published articles.[1,14] Such an interconnected chain of relationships constitutes a social network in which valuable resources are shared in the forms of information, understanding, and knowledge through the conduct of social interactions. This network can provide its members with collectively owned capital known as social capital.[15] This capital has been proven to positively influence knowledge production,[16] knowledge transfer,[17,18] and knowledge contributions.[19] Through social interactions, members of co-authorship networks can benefit from social capital and widen their horizons of understanding and awareness and, in turn, achieve better outcomes.[17,20,7]

Several different scholars and theoreticians have discussed the social capital resulted from social networks the most important of whom are Burt, Granovetter, Woolcock, Coleman and Putnam.[26]

Using network cohesive structure introduced by Coleman[25] as well as structural holes by Burt[22] and based on two main types of node configuration (constraint and efficiency) developed by Burt, Rumsey-Wairepo,[21] identified five different co-authorship network structures including cohesive structures, structural holes, middle, independent and complex. He also proposed isolate and dyadic strategies for those researchers who published their scientific works alone or mostly with one other researcher[22] (Table 1).

Following Rumsey-Wairepo, Kuzhabekova[24] also made use of social capital as well as social network structure theory and social capital theory proposed by Coleman and Burt so as to classify co-authorship network strategies.[23] He slightly modified the strategies proposed by Rumsey-Wairepo; bonding and bridging labels were used instead of cohesive and structural holes, respectively, and the label "complex" was replaced with the label "combination". In this research, like in the researches by Rumsey-Wairepo[23] and Kuzhabekova,[24] social capital theories proposed by Coleman and Burt were applied. In addition, bonding social capital by Putnam and bridging social capital by Granovetter were also employed. To identify co-authorship strategies, an eclectic combination of the two methods proposed by Rumsey-Wairepo[23] and Kuzhabekova[24] was utilized with some modifications. Only two of the three modifications made by Kuzhabekova in co-authorship strategies proposed by Rumsey-Wairepo were accepted including bonding and bridging since these two were compatible with the social capital classifications made byWoolcock and Narayan[25] and Putnam[27]. Between complex strategy proposed by Rumsey-Wairepo and combination strategy by Kuzhabekova, the former was used since Kuzhabekova explained the reason for changing the name of complex strategy to combination as, "a researcher using this strategy combines bonding and bridging strategies". Rumsey-Wairepo,[23] however, elaborated, "… when an academic scholar demonstrated both high cohesion and high structural holes strategies, this scholar was categorized with a more complex co-authorship strategy. This strategy may be indicative of an academic scholar who is adept at selecting the most advantageous strategy for the particular situation and interchanging them". Therefore, the complex label was deemed more appropriate. Finally, the strategies in this research were classified as isolate, dyadic, bonding, bridging, independent, middle and complex.

This research was different from the two previous ones both in geographical scope of research population and subject matter.

Table 1: The viewpoints of scholars on social capital.

Theoreticians	Theory	Description
Ronald Burt	• Structural holes theory • Network cohesion • Constraint and efficiency	• As the network size increases, the network density decreases and the hierarchy in the network is less highlighted, the social capital will grow (Rainie and Wellman 2012). • The strength of social capital is merely related to structural holes (Burt 2004). • A cohesive network is of a high density and high mean strength of ties (Burt 2001). • the size, density and mean strength of ties so as to detect the extent of presence of structural holes (Rumsey-Wairepo 2006).
Mark Granovetter	• Week Ties Theory • Bridging social capital	• Weak ties with members outside the group lead to facilitate the flow of information and success of group members. • It is not strong bonding relations but weak bridging ties which guarantees the success • There is a strong emphasis on communication networks among different people (Weng et al. 2015).
Michael Woolcock	• Bonding social capital • Bridging social capital • Linking social capital	• Weak ties with members outside the group lead to facilitate the flow of information and success of group members (Rouxel et al. 2015).
James Coleman	• Network cohesion	• Social capital is primarily resulted from cohesion which develops trust and cooperation among individuals (Hanneman and Riddle 2005).
Robert Putnam	• Bonding social capital	• It establishes personal trust among those who have friendly relationships (Beugelsdijk and Smulders 2004). • Strong bonding relations may hinder freedom, innovation and motivation to progress in group members (Putnam 2001).

In Kuzhabekova's study, the scientific outcomes in cardiology in Russian journals were investigated and in that of Rumsey-Wairepo, the scientific outcomes of higher education in 4 top journals were studies. This research, nonetheless, was not limited to any geography or journal and the method of data elicitation made it more comprehensive. Furthermore, since the field of nuclear science and technology is of strategic significance for most countries and its nature is different from that of other areas of science, it is probable that the researchers in this field are willing to adopt co-authorship strategies. Moreover, no similar research has been conducted so far in fundamental sciences and most researches have been in medical sciences and humanities. Thus, it was essential to carry out such study.

The research behavior of researchers is under the influence of research type and production of various research outputs, in other words, specialization of science and use of information and communication technology have increased the number of patterns of scientific collaboration (e.g. Large research groups). When these strategies are applied in research projects, the role and position of researchers will be indicated to differ considerably; the differences in subject fields and roles of researchers are regarded as key factors in understanding co-authorship networks and their relationship with research impact and productivity.[27] In conducting joint research projects, the type of co-authorship relations among different researchers determines their intellectual and personal relationships. When a researcher does a research in collaboration with others, more relationships are formed between him/her and other researchers[1] and co-authorship strategies might also be different. Some researchers don't take part in scientific collaboration at all, some collaborate in research only with a limited number of people and some others with a great number. Some work repeatedly with the same person and some others only once collaborate with other researchers. A network of co-authorship relationships among researchers in publishing several scientific outputs forms their ego-centered co-authorship network. Although such ego-centered network might not be consciously formed by the researcher, the combination of co-authorship relationships leads to an ego-centered network structure which can be used to detect, describe and assess co-authorship strategies.[22]

Various researches have emphasized the need for further research on co-authorship strategies.[28-32] and a number of researches have also linked co-authorship with citation performance and reminded that scientific collaboration and its embedded structures deeply influence the quality and quantity of scientific outputs; therefore, researchers have paid much more considerable attention to features of co-authorship and its influence on citation performance (Uddin, Hossain, and Rasmussen, 2013). This illustrates the importance of taking co-authorship strategies and their quantitative and qualitative influences into consideration in different disciplines to be able to more widely extend these strategies and their influences in research.

With a good understanding of the existing co-authorship strategies, researchers would be able to make more conscious choices from among different strategies. Through understanding the way these strategies influence citation performance, they can develop their position by increasing their social capital and enhancing their area of expertise. Thus, the present study used network theory to investigate the relationship between co-authorship strategies and citation performance as well as the number of citations to the articles published by researchers.

Research questions

In scientific collaboration network of researchers in nuclear science and technology:

1. To what extent are different co-authorship strategies (including isolate, dyadic, bonding, bridging, independent, middle and complex strategies) utilized by the researchers?
2. Is there any significant relationship between a certain co-authorship strategy used by the researchers and the number of citations to the articles?
3. What is the influence of using different co-authorship strategies by researchers on the number of citations to their articles?
4. Utilization of which co-authorship strategy leads to an increase in the number of received citations and which strategy results in a decrease in the number of received citations?

Research Methodology

In this research, network analysis method was utilized to provide an understanding of the relations and interactions among co-authors and to identify co-authorship strategies in nuclear science and technology. Social network analysis is a set of developed analytic tools to analyze relational structure and its impacts on individual behaviors and systemic performance.[33] The most important characteristic of this approach is that the detailed interpretation and analysis based on the attributes of independent cases are turned into the interpretation and analysis of the phenomena based on the relationship among independent factors of a system.[34] It also shifts the focus from individuals and their attributes to pairs of individuals and their relational ties.[35] The statistical population of this research consisted of all authors of the articles published in the field of nuclear science and technology in Science Citation Index Expanded (Clarivate Analytics) from 2009 to 2011 as well as their citations from 2011 to 2016 (Table 2). First, to collect data from Web of Science Core Collection, the following formula was used in advanced search section:

WC= (Nuclear Science and Technology) DocType=All document types; Language=All languages

Indexes=SCI-EXPANDED Timespan=2009-2011

And related records were retrieved and saved. To avoid bias, Editorials, Letters and Corrections were deleted from document types since they are single authored by nature. The next stage was preprocessing of saved data. Since the data retrieved from Web of Science Core Collection had some misspellings in names of the authors or contained different spellings of the same names, the preprocessing was done to detect and correct wrong cases and various spellings of the same names. Thereafter, a design was proposed to create relation matrices in this study to be used as inputs for UCINET. The co-authorship of these researchers was obtained via Bib excel Software.[36]

Previous studies have revealed that a significant bibliometric research must at least take a three-year window as citation period.[1,37] Thus, in this study, as in the study by Li *et al*.[1] in order to collect data about citation performance of researchers, the articles published by the researchers within a 3-year period were made use of and the number of citations to these articles were retrieved within a 4-year period. The citation data of each article were collected two years after its publication. For instance, if an article was published in 2010, its citation data were collected from 2012 and later. The reason for considering a 2-year period was that in citation studies, the period of two years is usually taken as an interval to receive citations. In Journal Citation Reports (Clarivate Analytics),[1] also a two-year period is considered to allow a time interval for the citations to be given to articles.

The number of citations in this research was collected from Science Citation Index Expanded since it provides with the experience and records of an author and his/her publications as well as all citations given to each of his/her publications. Nevertheless, citation data in Science Citation Index Expanded also include self-citations leading to a bias in estimating the influence of research impact of an article.[1,38] Therefore, in this study, as in the previous study, to prevent such bias in research, the citations given to each article in a three-year period were manually counted without taking self-citations. In this research, each citation from an author or his/her co-authors in an article was regarded as self-citation and was subtracted from the number of citations. Thus, the citation performance of a researcher was obtained by subtracting the number of self-citations from the total number of citations given to the articles published by that author in the citation window.

1 JCR: available at: https://jcr.incites.thomsonreuters.com/JCRJournalHomeAction.action

Table 2: Citation window for articles from 2009 to 2011.

Time period	Year	Citation window (four years)
2009-2011	2009	2011-2014
	2010	2012-2015
	2011	2013-2016

In this research, social capital theories were used including those proposed by Coleman,[25] Burt[22] and Granovetter (1973) as well as a combination of the methods of Rumsey-Wairepo[23] and Kuzhabekova[24] which investigated the influence of co-authorship strategies on the productivity of researchers in higher education and cardiology, respectively. They were utilized in a different field (nuclear science and technology), within a different domain (international) and with a different source of collecting data (Web of Science Core Collection).

Kuzhabekova[24] did some corrections to co-authorship strategies presented by Rumsey-Wairepo[23] and introduced a set of co-authorship strategies. Totally, seven strategies were proposed including isolate, dyadic, bonding, bridging, independent, middle and combination.

The strategies used in co-authorship network structure in nuclear science and technology were identified as follows. First, a table was utilized to depict the relationships among researchers. UCINET Software automatically restored the social network of each researcher based on the mentioned table. After applying certain instructions, UCINET Software presented a set of measures of individual-centered network including size, constraint and efficiency of all individual networks. The outputs of UCINET Software were tabulated in Excel Software in text file format. The data included in this table were the names of researchers, network size, constraint measure and efficiency measure. Then, the data of the table in Excel were manipulated to identify the strategies employed by the researchers. The list of all authors using isolate or dyadic co-authorship strategies was prepared by formulization and was extracted from the table in Excel. The lists of researchers were saved in separate sheets naming isolate and dyadic. In the next step, a list of researchers with middle co-authorship strategy was provided as follows:

Efficiency and constraint of individual-centered network calculated by UCINET Software were divided to three parts i.e. high, low and medium by percentile formula in Excel. For the timespan 2008-2010 the values were 0.567 and 0.735. For constraint, cut off point values were between 0.180 and 0.400.

All records whose values of constraint and efficiency were in the second one-third (medium) were determined. The list of the achieved results was copied in a separate sheet and all

records of researchers with middle strategy were deleted from the main table in Excel.

Finally, in order to determine which researchers used independent, complex, bridging and bonding strategies, the following methods were adopted in Excel. First, the main table of Excel containing isolate, dyadic and middle strategies was used to calculate mean efficiency and mean constraint values via mean formula in Excel. Mean constraint and mean efficiency values were 0.383 and 0.643, respectively.

Then, via Excel formulas, constraint and efficiency values were divided into high and low based on being higher or lower than the mean.

The remaining records of the table of Excel, which were not located in isolate, dyadic and middle strategies, were located in one of the four remaining strategies by applying filters in their efficiency and constraint. High constraint and high efficiency were placed in complex strategy, low constraint and low efficiency in independent strategy, low efficiency and high constraint in bonding strategy and high efficiency and low constraint were placed in bridging strategy. The results of this section were also saved in separate sheets. Finally, for statistical analyses, all sheets were saved in a single sheet containing the names of all researchers, their strategies, number of research citations and number of scientific outputs.

Findings

The frequency and percentage of co-authorship strategies utilized by researchers in nuclear science and technology is presented in Table 3.

As shown in Table 3, 1172 (26.7 percent) researchers in nuclear science and technology used bridging strategy, Bonding and independent patterns with 901 (20.6 percent) and 765 (17.5 percent) ones, were the next priorities, respectively.

In order to investigate whether there was any significant difference between using co-authorship strategies and the number of citations received by authors, one-way ANOVA test was applied. Previously, the assumptions of this test were investigated and the distribution of dependent variable data was also assessed using Kolmogorov-Smirnov test. The value of (Z) was 0.793 and Sig was 0.555 which was more than 0.05, hence, data were normal and the assumption of using one-way ANOVA test was met (Table 4-5; Chart 1)

The research results in the mentioned test demonstrated that regarding citation performance of authors, there was a significant difference among authors using co-authorship strategies i.e. using different co-authorship strategies was effective at 0.95 level of confidence (F=3.144 and p>0/005) (Table 5)

Table 3: Percentage and frequency distribution of authors based on co-authorship strategy.

Co-authorship Strategies	Frequency	%
Middle	475	10.8
Independent	765	17.5
Bridging	1172	26.7
Complex	594	13.6
Bonding	901	20.6
Dyadic	257	5.9
Isolate	218	5.0

Table 4: Comparison of mean of citation performance of researchers based on strategies.

Strategies	Frequency	Average Number of Cited Articles	Standard Deviation	Standard Error
Middle	475	4.5503	4.25464	.12908
Isolate	765	2.8590	1.63618	.12304
Dyadic	1172	3.1060	2.19035	.15927
Independent	594	6.5463	4.18357	.08275
Bridging	901	4.9630	4.35539	.17428
Bonding	257	4.7958	3.75014	.07452
Complex	218	5.2459	4.22253	.10574
	4382	5.1453	4.13996	.06543

Table 5: Investigation of influence of co-authorship strategies on citation performance of researchers via ANOVA test.

	Sum of squares	Degree of freedom	Mean of squares	F value	Level of significance
Intergroup	312.769	6	52.128	3.144	.005
Intragroup	6251.555	377	16.582		
Total	6564.325	383			

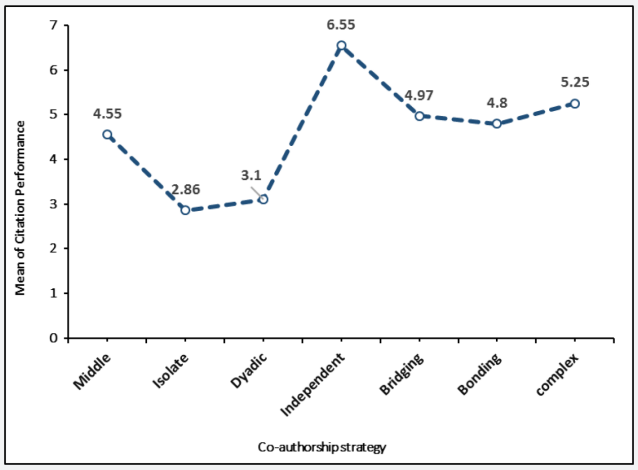

Chart 1: Mean of Citation Performance of Co-authorship Strategies.

Table 6: Paired comparison of the influence of co-authorship strategies on citation performance of researchers via LSD post hoc test.

Pairs of strategies		Difference of Means	Standard Error	Sig.	95% Confidence Interval	
A	B				Lower Bound	Upper Bound
Middle	Isolate	1.69126	1.44341	.242	-1.1469	4.5294
	Dyadic	1.44426	1.23721	.244	-.9884	3.8769
	Independent	-1.99607*	.78472	.011	-3.5390	-.4531
	Bridging	-.41270	.74689	.581	-1.8813	1.0559
	Bonding	-.24555	.80578	.761	-1.8299	1.3388
	Complex	-.69563	.95546	.467	-2.5743	1.1831
Isolate	Dyadic	-.24700	1.66245	.882	-3.5158	3.0218
	Independent	-3.68732*	1.35972	.007	-6.3609	-1.0137
	Bridging	-2.10396	1.33824	.117	-4.7353	.5274
	Bonding	-1.93681	1.37198	.159	-4.6345	.7609
	Complex	-2.38688	1.46491	.104	-5.2673	.4935
Dyadic	Independent	-3.44032*	1.13846	.003	-5.6789	-1.2018
	Bridging	-1.85696	1.11272	.096	-4.0449	.3310
	Bonding	-1.68981	1.15307	.144	-3.9571	.5774
	Complex	-2.13988	1.26222	.091	-4.6218	.3420
Independent	Bridging	1.58336*	.56856	.006	.4654	2.7013
	Bonding	1.75051*	.64396	.007	.4843	3.0167
	Complex	1.30044	.82360	.115	-.3190	2.9199
Bridging	Bonding	.16715	.59728	.780	-1.0073	1.3416
	Complex	-.28292	.78764	.720	-1.8316	1.2658
Bonding	Complex	-.45007	.84368	.594	-2.1090	1.2088

*. The mean difference is significant at the 0.05 level.

The descriptive results of ANOVA test indicated that bridging strategy had greater influence on the number of received citations than other strategies. Based on the results of post hoc test, there was a significant difference in applying different strategies. The analysis of level of significance and difference of means demonstrated that independent strategy had the most positive effect on citation performance of researchers compared with other strategies while isolate strategy had the least positive effect on citation performance of researchers.

As depicted in the citation performance of researchers in middle strategy was higher than in isolate and dyadic strategies and was lower than in other strategies. Among them, only the difference between the mentioned strategy and independent strategy was significant (at 0.05 level). To wit, middle and independent strategies had different influences on citation performance of researchers and since the mean of citation performance of researchers in middle strategy was lower, this strategy led to a lower citation performance as compared with independent strategy. According to the point that the difference in citation performance of researchers in middle strategy was not significant compared with other strategies, these strategies were identical to middle strategy concerning citation performance of researchers.

The comparison of citation performance of researchers in isolate strategy with other strategies revealed that the mean of citation performance of researchers in isolate strategy was lower than in dyadic, independent, bridging, bonding and complex strategies. These data demonstrated that this difference was lower with dyadic strategy and higher with independent strategy than with other strategies. The differences (except for the one between isolate and independent strategies) were not statistically significant at any of 0.01and0.05 levels; thus, in citation performance of researchers, there was no difference between taking isolate strategy and other strategies except for

independent strategy and all strategies except for independent strategy resulted in conditions similar to that of isolate strategy concerning citation performance of researchers. According to the point that the difference between citation performance of researchers in this strategy and independent strategy was significant, applying isolate strategy led to a lower citation performance in comparison with independent strategy.

Mean of citation performance of researchers in using dyadic strategy was 3.44 degrees different from mean of this variable when taking independent strategy and was lower than that. The significance test showed that this difference was significant at 0.01 level. The difference between dyadic strategy and bridging, binding and complex strategies was 1.85, 1.68 and 2.14, respectively. However, the observed differences were not significant. Eventually, it can be pointed out that the citation performance of researchers in applying dyadic strategy was lower than when using independent strategy. Moreover, citation performance of researchers when using dyadic strategy was identical to use of bridging, bonding and complex strategies and dyadic strategy had an effect similar to that of the aforementioned strategies on citation performance of researchers.

The difference between mean of citation performance of researchers using independent strategy was better and more improved than those taking bridging and bonding strategies. The statistical test also proved the differences as significant. Furthermore, regarding this variable, there was no statistically significant difference between using independent strategy and complex strategy and such differences can be attributed to random factors rather than the applied strategies. It can be concluded from the acquired results that the citation performance of researchers when using independent strategy led to better conditions than when using bridging and bonding strategies, nevertheless, the citation performance of researchers in independent strategy was not significantly different with complex strategy and these strategies had similar conditions in this regard and their influence on citation performance of researchers was relatively similar. Unlike in other strategies, citation performance of researchers in independent strategy had a significant difference with other strategies, except for complex strategy, and was higher. However, the difference in citation performance of researchers in other strategies with each other was not significant.

The results of data analysis indicated that mean of citation performance of researchers when applying bonding strategy was less different than when using other strategies (except for independent strategy) and these differences were not significant at any of the 0.01 and 0.05 levels. From among different strategies, only the difference between citation performance of researchers in this strategy and in bonding and complex strategies have not been discussed. The difference in citation performance of researchers in this strategy was higher than in bonding strategy and lower than in complex strategy, nonetheless, as previously mentioned, these differences were not statistically significant. Therefore, these strategies had similar conditions concerning citation performance of researchers.

The results of data analysis demonstrated that mean of citation performance of researchers when taking bonding strategy was lower than when applying complex strategy, however, the difference in mean of citation performance of researchers in these two strategies were not statistically significant. Hence, these two strategies resulted in similar conditions regarding citation performance of researchers and there was no difference between them.

DISCUSSION AND CONCLUSION

The main objective of this research was to determine the scientific collaboration strategies applied by researchers in nuclear science and technology and to investigate the relationship between these strategies and increase or reduction in the number of received citations with accordance to each applied strategy. In this research, data were gathered from the articles published by researchers in the field of nuclear science and technology in Clarivate Analytics (Web of Science Core Collection). In this web, the field of nuclear science and technology contained 32 journals. The collected data were used by the researchers of this study to understand and analyze the scientific collaboration methods, scientific collaboration strategies, research productivity, scientific collaboration networks and the number of citations received by researchers. Although data collection was carried out in such a way to entirely cover all articles published in Web of Science Core Collection in nuclear science and technology, in effect, all articles published in this field were not included since there might be articles relevant to this field published in journals other than the journals considered in this study. Therefore, the present study provided with a relatively complete network of scientific collaboration in nuclear science and technology and made use of indices of network theory to analyze this scientific collaboration.

The research results showed that the co-authorship strategies introduced by Rumsey-Wairepo[23] and revised and utilized later by Kuzhabekova,[24] also were made use of in the field of nuclear science and technology. The strategies preferred by authors in this field were bridging, bonding, independent, isolate and dyadic strategies, respectively. Although bridging strategy was difficult to be adopted since finding and communicating with most potential co-authors takes too much time and money, it was the most dominant strategy in co-authorship network of nuclear science and technology. Adding young and low-experienced researchers to co-authorship teams, developing cooperation among universities and adding people from other fields to this field by collaborative

research are some other ways to facilitate the application of bridging strategy.

In nuclear science and technology, the percentage of articles written collaboratively in comparison with single-authored ones was 95. This percentage was higher than the co-authorship percentage of articles in mathematics (36 percent) and in biomedicine (79 percent).[13] Moreover, it was higher than co-authorship percentage in articles in education field in which the percentage of co-authored articles in comparison with single-authored ones was 60.6%.[49] This difference, is partly due to the difference in nature of these sciences. The researches in mathematics are mostly developing the theories and are typically done by single authors and in isolation. The researches in biomedicine, chemistry and nuclear technology, however, are mostly done in laboratories by a large group of scientists. This is why the ratio of co-authored articles in biomedicine, chemistry and nuclear science and technology was higher than that of mathematics.

The comparison of the results of researches on use of co-authorship strategies in some scientific fields is presented in chart 2.

It is concluded from the comparison of these researches that the degree of collaboration and co-authorship in fundamental sciences is much higher than in humanities and social sciences. It is due to the nature of these fields since fundamental sciences, particularly nuclear science and technology, require more laboratory facilities, tools and persons as well as the presence of researchers with diverse expertise.

The results of data analysis showed that in nuclear science and technology, those researchers who applied independent strategy in their articles, had a higher citation performance as compared with other researchers in this field while those using isolate strategy showed a lower citation performance. Finally, based on the results of data analysis and testing research

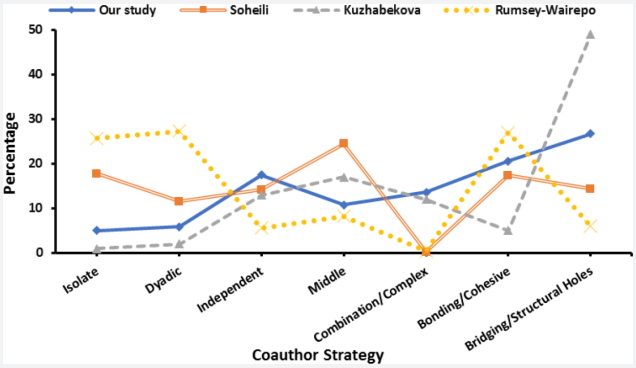

Chart 2: Comparison of the results of researches conducted on use of co-authorship strategies.

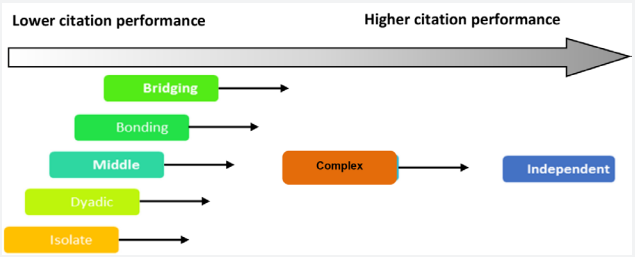

Figure 1: Ranking of co-authorship strategies in terms of their effect on individual citation performance.

hypothesis, the following model (Figure 1) is presented for researchers in nuclear science and technology:

Authors using independent strategy are those who write articles with others but rarely with the same people; they often work collaboratively with different people of the same group. Since they work with different people of the same group, such researchers are gradually more known and observable to that group. This can lead to a greater number of citations and higher citation performance over time. Since co-authors of the researcher using independent strategy are different, this would result in a reduction in self-citation, a higher citation performance and consequently, an increase in research impact. Furthermore, making direct ties with different people of the same group can bring about certain advantages including knowledge sharing and complementary skills,[39] For example, if two or more author's co-author an article, each contributes a certain amount of knowledge to the paper; therefore, each author gains new knowledge through direct interaction and intergroup discussions. If authors have the same background knowledge, they benefit from bringing their own point of views to the topic, which deepens the discussion[4,5] and if authors have complementary knowledge, they benefit from learning each other's research and domain of expertise (Avkiran 1997). If authors have completely different knowledge backgrounds, they can benefit from each other's economies of specialization without investment in developing the specialization themselves[40] and most probably produce new knowledge resulted from the combination of the two different knowledge backgrounds. This knowledge sharing and creation, consequently, results in higher research quality and higher citation performance for each author.[7,4] Hence, direct ties are expected to stimulate combination and exchange of knowledge and resources and provide researchers with access not only to new knowledge but also to new experiences and thus, an increase in citation performance might be a possible outcome. Moreover, if authors of the same article are from different countries and regions, there is the possibility of bringing about more citations to that work since each author or researcher might be among well-known

experts of that country, region or university. This would naturally lead to a higher citation performance.

Constraint measure is made by repeated ties in cohesive networks. With the increase in network constraint, the number of citations received by researchers is reduced. Therefore, those researchers having more ties with other researchers might lose their freedom. In other words, these researchers are more constrained and this depends on the relationship among other researchers. [40] Thus, higher constraint means lower structural holes and results in a more closed network with more cohesion.[19] This suggests that as the network structure has more cohesion, the citation performance of researcher is reduced and according to Coleman,[25] using this approach would reduce citation performance and consequently, would lead to a lower social capital. Since the network structure of co-authors using independent strategy has moderate cohesion and efficiency, these researchers have more freedom and can have an important connecting role in making scientific relations. Having such role will not only help improve personal knowledge but also will make the researcher better known among other authors and receive more citations. Thus, researchers resort to co-authorship with other researchers who are also co-authors with each other and help improve cohesion (as an obstacle in improving research impact and citation performance) in their scientific collaboration network. The present research clearly proved that there was a relationship between network structure and co-authorship strategies as well as the number of received citations. These results help researchers increase their number of received citations and improve their research impact with creating and applying co-authorship strategies consciously and strategically.

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CONFLICT OF INTEREST

The Authors declares that there is no conflict of interest.

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