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## What Are the Scientific Notions Formed in Mathematics Discipline in SCI and SSCI Databases?

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### Abstract

This study historically analyzes the scientific output of Mathematics to describe its structure, notions and scientific origin using the historiographical method. The research data consisted of scientific outputs of Mathematics in ISI database, Science Citation Index (SCI) and Social Science Citation Index (SSCI) during 8 years (1990 to 2007). The data collection tool was the search engine and the analysis part of the WOS and also HistCite™ software. According to White (2003), the sample of the study was circa one percent of the studied data (i.e. 120 documents) that was analyzed based on two different aspects: Local Citation Score (LCS) and Global Citation Score (GCS). The research results show that with regard to Local Citation Score (LCS), five scientific clusters were formed and all of them were related to different fields of “Mathematics Education”. Based on Global Citation Score (GCS), there were no significant scientific cluster in this field, and this is while the amount of Global Citation Score was significantly more than Local Citation Score. According to the findings it seems that:

1. The major scientific clusters and transitions in Mathematics are mostly related to theoretical fields as this issue has caused a new paradigm in this discipline.
2. The amount of this scientific field’s influence on Applied Mathematics is much more than the non- Applied Mathematics.

**Keywords:** Mathematics, Historiography, Local Citation Score, Global Citation Score, Scientific Clusters, Mathematics Education, Applied Mathematics, Citation Analysis.

### Introduction

A clear perspective on the background of a scientific discipline including the most influential theoretical ideas and its origin and foundations can be achieved through a historical study of it.

In historical study of a discipline the paradigms and notions which were influential in its development are defined and analyzed during a specific period of time. To achieve this aim, scientific publications are the most important tools utilized and citations and references are two fundamental elements for such assessments.

For assessing the citation chains among documents, different indicators such as the author

co-citation, the document co-citation, bibliographic coupling and also created scientific relations in a peripheral field become clearly evident.

Mathematics is one of the fields in which transitions and changes of ideas occur slowly and compared to other scientific areas such as Chemistry which consists of a huge number of international scientific publications, it is developing slowly. Mathematics has an important position in the structure and context of science as one of the most important basic scientific fields, and its applied section is closely related to many other fields such as Computer, Physics, Mechanics, etc. Therefore, in this study the structure of Mathematics is historically assessed in an 18-year period and specific scientific notions are analyzed from two different dimensions: citations received from inside the field of Mathematics and citations received from all scientific fields in Web of Science (WOS).

There is a basic assumption that the bibliographic information contained in a collection of published scientific articles is sufficient for the purpose of recapturing the historiographic structure of the field. Because citation indexes utilize the cited works of thousands of authors, it is assumed that collectively they call out the basic works in any field. Gaps may exist in the documentation provided by individual authors, but collectively they produce a fairly complete picture of the historic background of the topic (Garfield, Pudovkin, & Istomin, 2003).

### **Research question**

What influential scientific notions (the clusters based on the relationship among most cited papers) have been created in Mathematics discipline during 1990 to 2007?

### **Research Objective**

This study aims to describe the structure of Mathematics (the notions have been formed during 18 years) in order to find which area of Mathematics has been more influential and more dynamic.

### **Review of literature**

Some researchers believe that there is a difference between Mathematics and other fields and there is a doubt about using bibliometric indicators in Mathematics. For example, Luwel and Moed (1998) discovered that the publication delay (the time span between acceptance and publication of an article) is longer in Mathematics and Technical Sciences compared to other fields. By studying a small sample, they concluded that a decrease in the publication delay leads to a major decrease in the cited half-life of the journals in this field.

On the other hand, Korevaar (1996) conducted a study entitled “Validation of bibliometric indicators in the field of Mathematics” to answer the mathematicians’ doubts about the differences between Mathematics and other fields and the inefficiency of bibliometric indicators and the efficiency of citation in evaluating the scientific output of

Mathematics. To achieve this aim, he compared the professionals' opinions in evaluating scientific journals and papers on Mathematics with the citation score of those journals. The research results showed that the journals which were evaluated by professionals as high quality journals also had a high citation count. Journals with lower quality scores and evaluations obtained lower citation scores. The score of elevated articles, from the citation mean perspective was 15 times more than the received citation mean with regard to the total number of articles on Mathematics. He concluded that the mathematicians' viewpoints concerning the evaluation of scientific journals and articles were highly compatible with evaluations based on bibliometric indicators. Korevaar's research confirmed the validity of the application of bibliometric indicators as well as the citation accreditation to the scientific outputs evaluation of Mathematics.

Some other researches show a strong relationship between Mathematics and other fields specially Medicine and Theoretical Studies. Small, Sweeney and Greenlee (1985) defined the co-citation bond between different subject fields. The most important and interesting part of their findings was the co-citation bond between Mathematics and the Bio-Medical field in which both formed a combined cluster. Klai (1995) evaluated the scientific publications of Croatia in the ISI database between the years 1990 and 1991. The findings showed that the researchers in medical fields have collaborated with researchers in the field of Science & Mathematics. Wagner-Dobler (2001) in his research based on understanding the cooperation pattern between researchers in the field of Mathematics showed that in different fields of science the authors' cooperation pattern differs greatly from this field. The most prominent cooperation level was observed in the fields in which the applied and theoretical studies of Mathematics had been combined.

On describing the scientific notions, Hamidi, Asnafi and Osareh (2008) studied scientific notions about bibliometrics and related fields. One of the important results of their study was the emergence of a scientific discipline called Webometrics (formed in 1997 and its development reached a peak in 2001-2003).

Generally, by reviewing and revising the texts some important points are noticed: 1. Despite some perceptions about the use of bibliometric indicators in evaluating the scientific publications on Mathematics, the use of these indicators are useful and valid in this field.

2. A large amount of research on Mathematics is interdisciplinary and is related to other fields especially Medicine and theoretical fields.

### **Research Methodology**

Due to citation behavior of Mathematics which is different from other disciplines in Basic Sciences, we decided to study mathematical scientific outputs compressively. To this end, we retrieved scientific outputs of Mathematics in Science Citation Index (SCI) and Social Science Citation Index (SSCI) via Web of Science during 1990-2007. The necessary data was

searched among the mentioned data bases under the general topic of Mathematics (Ts=Mathematics). The total retrieved documents in both databases after removing duplicate records were 12300. Out of 12300 records, 6888 were in SCI and 5412 documents were in SSCI (data retrieved in December 2008).

For this research, we used the historiography method. The research data consisted of scientific outputs of Mathematics in ISI databases (now called Thomson Scientific) during the years 1990 to 2007, the data collection tool was the search engine and the analysis part of the WOS and also HistCite™ software. HistCite software facilitates the understanding of paradigms by enabling the scholar to identify the significant works on a given topic (Garfield, Pudovkin & Istomin, 2003).

The sample for this study according to White's research (2003) was circa one percent of the studied data (i.e. 120 documents). White (2003) suggests a range of 25-125 in mapping research for three reasons that he explains. The sample of the study was analyzed based on two different aspects: Local Citation Score (LCS)<sup>1</sup> and Global Citation Score (GCS)<sup>2</sup>.

### Research analysis

#### *Results of the study*

As mentioned before, 1% of the highly-cited documents were selected by HistCite software for the analysis of the data based on the LCS and GCS citations in SCI and SSCI during 1990-2007. Figure 1 shows a whole view of Mathematics LCS map. As can be seen in Figure 1, at least 5 clusters formed in this discipline during 1990-2007. One of the unexpected results of this study was that none of the subject areas of the 5 clusters in LCS map (Figure 1) were in Mathematics (pure and/or practical) while all 5 clusters were about Applied Mathematics in different social science subject fields. For a more clear definition of LCS map in Figure 1, we will define the clusters in this map one by one.

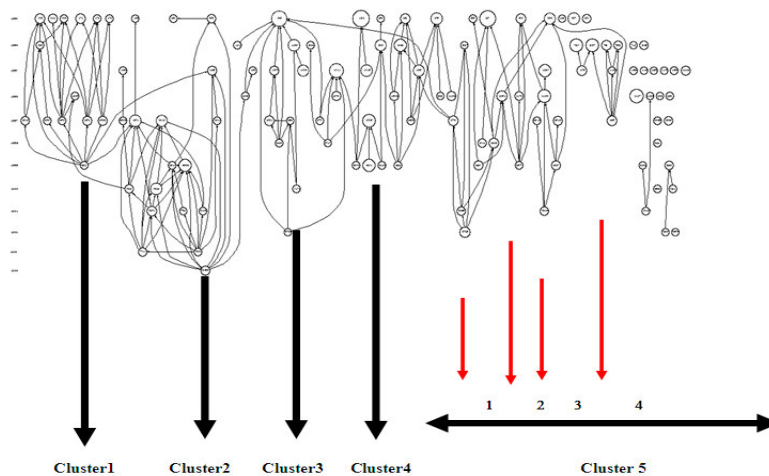
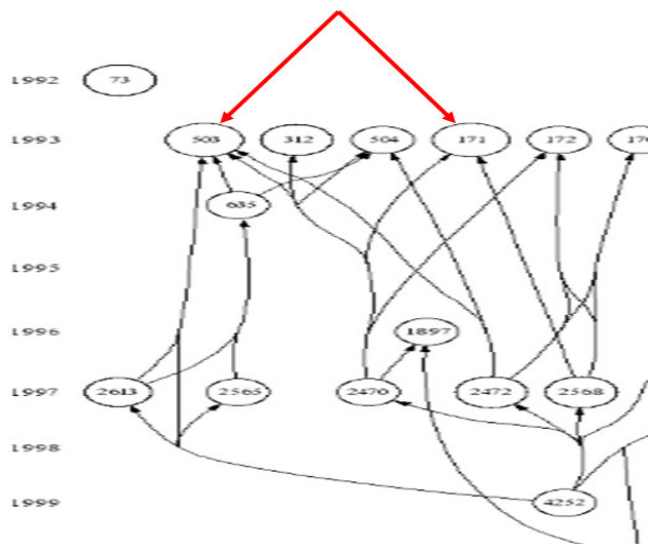


Figure 1. The important scientific notions formed in the history of Mathematics from 1990 to 2007 based on local citation score

Cluster number 1 or the first notion consists of 14 documents. It was formed during 1993-1999 in the field of “Except Children and Learning Disabilities in Mathematics”. The articles of Hofmeister and Hutchinson (Documents number 171 and 503) each with 25 LCS are the most influential articles and authors in this cluster (These documents are shown by flash in Cluster 1).

Most of the documents of this cluster are published in 4 journals (Learning Disability Quarterly, Journal of learning Disability, Remedial Special Education and Except children). The cooperation of Mercer and Miller in publishing two important articles in this notion is noticeable (Documents numbers 504 and 2472) and the self-citation of these authors has created part of the inner cluster links. Journal self citation is not observed in this cluster. Several journals have made close links with a very close subjective field. Universities and important institutes which took part in publishing these scientific notions are mostly from the United States of America and some from Canada (Cluster 1).



*Cluster 1.* The first scientific notion in the field of “Except children and learning disabilities in Mathematics”

Cluster 2 initiated in 1998 in a subject area related to the first cluster. In other words, Cluster 2 formed in continuation of Cluster 1. The subject of cluster 2 is “Incapability in Learning Mathematics”. Jerry’s article in 1999 by having 38 LCS citations was in the center of this notion. Other articles from that time to 2004 have made a direct or indirect link with this article. This document has been shown by a flash in Cluster 2 (Document number 4666).

Jordan and Jeary made a great contribution to the formation of Cluster 2 by publishing 4 and 3 articles respectively. The majority of existing links in this notion are the links and self-citations between the documents of these authors. The cooperation between authors is also an important process during the second scientific notion. Hanich and Kaplan are Jordan’s main collaborators from Dealer University in the United States of America who helped him in

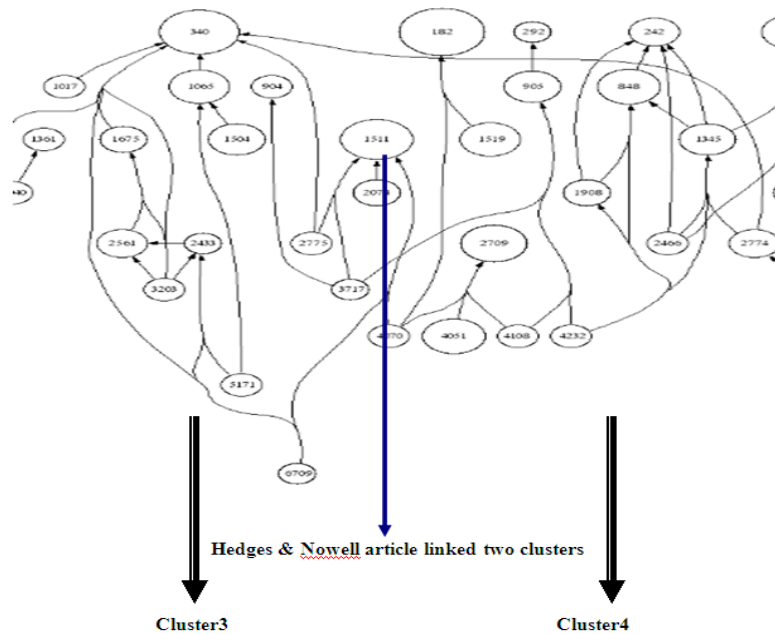
publishing 3 articles. Hoard and Hamson are also his main colleagues from British Columbia and Bull from Scotland's Aberdeen university works with Johnston, Roy and Scrif. The Journal of Learning Disability has contributed greatly to this scientific notion by publishing 6 important articles (Cluster 2).



*Cluster 2.* Scientific notion in the field of “Children learning incapability in Mathematics from the growth and cognition psychology perspective”

Two related scientific notions have formed the main core of Clusters 3 and 4. These two notions began with the articles of Eccles (56 citations), Stevenson (66 citations), Baker (14 citations) and Randhawa (24 citations) in 1993. The subject areas of these clusters are “The Relationship of Gender with Learning Mathematics” (Clusters 3 & 4).

Cluster 3 began with Eccles’s article in 1993 which is the most influential document in this cluster (Document number 340) and this cluster completed with Jacobs’s article in 2002 (Document number 6709). Cluster 4 also began with articles such as Stevenson’s article which is the most cited document in the fourth cluster (Document number 340) and this cluster ends with Spencer and Brown’s articles in 1999 (Documents number 4051 and 4108). In 1995 Hedges and Nowel’s article linked these two clusters through 34 LCS citations (Document number 511). This article (Gender Differences in IQ Test Scores) was published in Science Journal (Clusters 3 & 4).



*Clusters 3 & 4.* The third and fourth scientific notions in the field of “The relationship of gender with learning Mathematics”

In general, the third and fourth scientific notions which involve “The Sex Role in Learning Mathematics” are formed on the basis of the link between published documents by co-authors that are active in the same scientific field. Journal of Educational Psychology with 5 documents, Social Education with 4 documents and Child Development with 3 documents were contributing more to the formation of these notions than any other journals.

The last cluster in the LCS map is Cluster 5 with 4 sub-clusters. This mental notion which is in the field of “The Role of Educational Methods in Learning Mathematics” has begun with important articles from authors such as Ball, Mitchell, Fennema and Hiebert in 1993. Among these articles, Ball’s article with 61 LCS citations was the most effective article and it was published in the Elementary School Journal.

Ball, Fennema and Yackel’s articles with the most citation rate were the focal authors of this mental notion. These three documents are defined in Cluster 5 with arrow signs in three directions (Cluster 5).

The first sub-cluster in Cluster 5 was formed with the help of authors from American Universities. Midgley, Patrick and Anderman were the most important co-authors in this sub-cluster. This sub-cluster which begins in 1994 ends by Turner’s article in 2002 (Document number 6729).

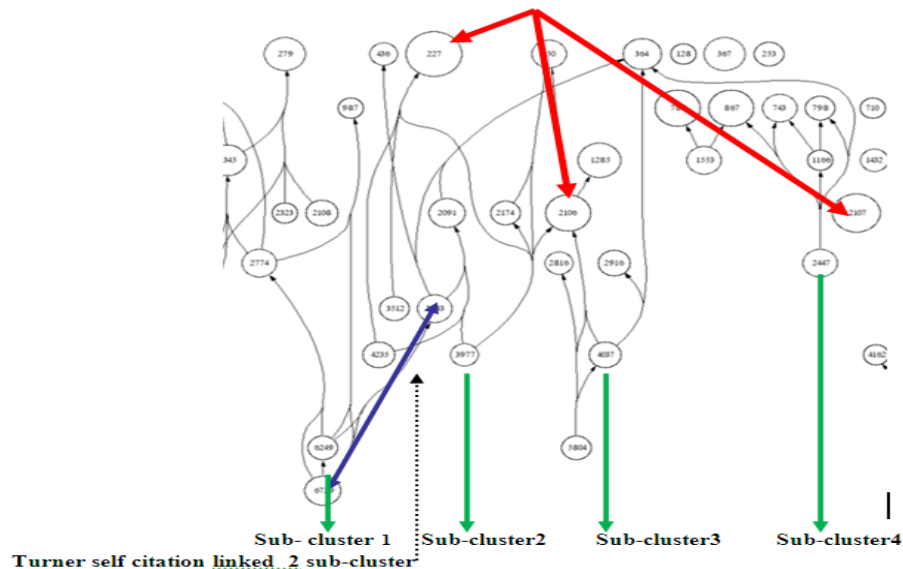
The second sub-cluster in this notion also was formed with the help of authors from American universities during 1993-1999. In 2002, Turner linked Cluster 1 and 2 through citations to his article which was published in 1998 (Cluster 5).

In this notion the most prominent journal was Journal of Educational Psychology and the

most collaborative university was Michigan State University.

The third sub-cluster of Cluster 5 began with Fennema's article in 1993 (Document number 450 in chart 5) and it was completed in 2001 with Garet's article (Document number 5804).

In 1994, this sub-cluster linked with the second sub-cluster via Wilson's article (Document number 3977). The American Educational Research Journal and Journal of Research Mathematics Education were the two journals which have published the most influential articles of this sub cluster. Fenema, Frank and Carpenter were the main contributors to this cluster and in the formation of this cluster's links. They have published three articles together.



*Cluster 5.* The fifth scientific notion in the field of “The role of educational methods in learning Mathematics”

Sub-cluster number 4 from the Cluster 5 was formed during 1994-1997. This sub-cluster was formed with the participation of six principal documents. 4 of these documents were published with the cooperation of Fuchs LS et al. (Fuchs D, Hamlett, Philips and Bentz) and the other 2 documents were published by Webb and his colleagues. The link between the published documents by these authors (self-citation) and also the mutual link between these documents lead to the creation of this cluster. This cluster has linked with the fifth main notion (Cluster 5) in the field of Mathematics through the citation of Fuchs's article (Document number 2447) to Hibert's article in 1993 (Document no 364) (Cluster 5).

Figure 2 Shows GCS map of Mathematics based on 1% (120 documents) of the most highly cited articles in the SCI & SSCI via WOS during 1990-2007. As can be seen in Figure 2 due to the fewer global links (only 30) among articles of this map, it is not as much crowded as the LCS map in this study.



Inspection of the GCS map showed that there observed not even one complete notion or cluster in this map, although there are at least 120 highly cited documents in the GCS map of Mathematics.

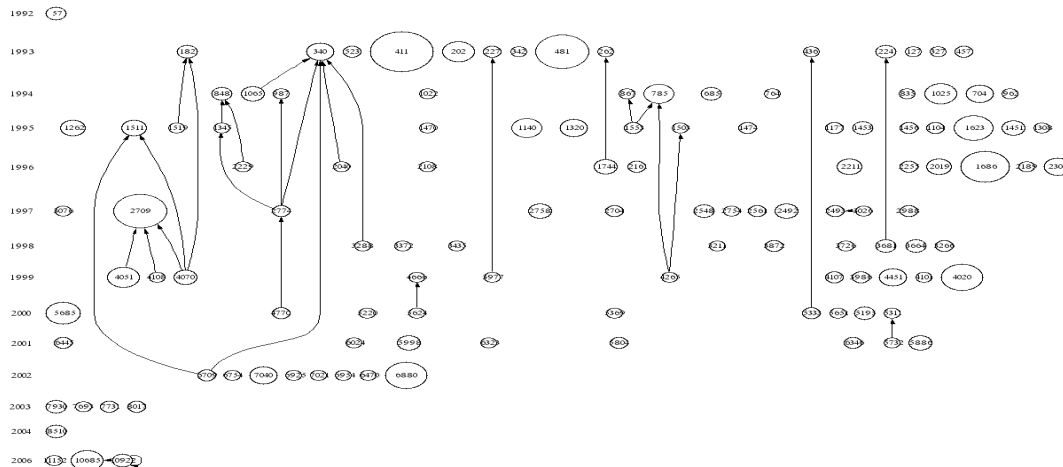


Figure 2. Formed notions in the GCS map of Mathematics during the years 1990-2007

### Discussion

The results of the study have revealed that the larger part of the influential scientific publications of Mathematics is related to the theoretical fields of “Mathematics Education”. Therefore, the majority of outstanding publications in journals about Mathematics education have been published. Analyzing the number of key words in influential articles also confirms this fact.

Analyzing the important processes in the history of Mathematics based on local citations indicates that the most affective cause of creating notions and scientific paradigms in this field is the formed connections based on specific subject fields and the schools and notions formed in the history of this science are a sub-category of “Mathematics Education” and the most outstanding authors, journals and notions are related to this area. It seems that the dynamic level of the theoretical fields of Mathematics has included most of the documents, journals, authors and other scientific notions. Therefore, the opinions that the change of ideas is slow in Mathematics and this field is steady and without motion have been greatly influenced by the considerable growth of theoretical and interdisciplinary fields especially the field of Mathematics education. Mathematics Education, which was considered as an independent field of research in the 20<sup>th</sup> century, is connected to teaching and learning Mathematics and its facilitating tools, methods and technologies. Research on Mathematics Education as interdisciplinary field of Mathematics is related to the field of Mathematics, General Teaching, Teaching Methods, Psychology, Sociology, History, Philosophy, Linguistics, Science of Logic and other sciences. Mathematics Education also obtains its method from

other sciences. From 1960, new fields in Mathematics Education have been brought about and the first congress of Mathematics in 1969 was held in Lyon and the second one in 1972 in Exeter. Since then it has been held every 4 years. At the end of 20<sup>th</sup> century establishing national and international standards in Mathematics Education has made this field dynamic.

Based on the previously mentioned statements it can be concluded that the field of Mathematics Education is an almost young field and is passing its first growth stages as an independent research field. Since it is developing in the field of research, the amount of published materials is more in comparison with the citable ones. This leads to a high citation in those kinds of articles (Ebrahimi, 2007). Additionally, because of being interdisciplinary, it is dynamic and also these publications have achieved a great position and therefore have reached a higher citation level. As an example, Steele & Stier's research (2000) shows that articles which drew information from a diverse set of journals were cited with greater frequency than articles having smaller or more narrowly focused bibliographies. This finding provides empirical evidence that interdisciplinary methods have made a measurable and positive impact on the literature. As a result, the fact that most of the highly-cited documents are related to the field of Mathematics Education and all scientific notions about Mathematics go under the sub-category of Mathematics Education can further reflect this issue.

On the other hand, in the discipline of Mathematics (pure and practical fields) short reference lists (with fewer than 6 references) are standard references (Leydesdorff & Bornmann, 2010). This citation pattern can cause fewer citations to these fields and as a result fewer notions.

In the next part of the research which is based on the historical analysis of Mathematics according to global citation score (GCS), the results indicate that the base of this criterion of the history of Mathematics has not revealed a specific scientific notion. The most significant reason for this is that since this part has been analyzed based on received citations from all areas of the Web Of Science databases, the articles of it have been either practical or interdisciplinary which have been cited from all other existing majors in the database. Provided that we assume that these types of articles are in touch with different fields such as Computer, Mechanical Physics, Electronic Physics, Civil Engineering, Medical Sciences, etc., it is not necessary for these interdisciplinary articles to be related to each other and share a bond. Therefore, due to this issue little bond has been created between them. If we compare the amount of bonds in Figure 2 which are 30 with those in Figure 1 which are 161, this issue would be confirmed once more that the existing articles in the first chart which have received citations from inside the field of Mathematics are those which are less practical and interdisciplinary and share more bonds. This is while the existing articles in Figure 2 which have received citations from all fields and domains are practical articles with less innate bonds.

To confirm the previous explanations, we have selected and organized 10 articles

randomly among those available in Figure 2 which are analyzed based on the imagined subjective field by the author (Table 1).

Table 1

*The Comparison of 10 Articles from Figure 2 Based on the Subjective Fields and GCS and LCS*

	<b>Author</b>	<b>Publication Year</b>	<b>Journal</b>	<b>LCS</b>	<b>GCS</b>	<b>Field</b>
1	Sullivan DM	1992	IEEE Transactions on Antennas And Propagation	0	136	Physics
2	Bandettini PA	1993	Magnetic resonance in medicine	1	1080	Medicine-Physics
3	Abarbanel HDI	1993	Reviews of modern physics	1	790	Physics
4	Gruber TR	1995	International journal of human-computer studies	2	437	Computer
5	Steele CM	1997	American psychologist	39	804	Psychology
6	American Psychologist	2002	Clinical neurophysiology	0	516	Psychiatry
7	Mcmanus JB	1995	Applied optics	1	138	Ophthalmology
8	Mergler D	1994	Environmental research	0	140	Environmental science
9	MC Carton CM	1997	Jama-journal of the american medical association	2	148	medicine
10	Baranyi J	1995	International journal of food microbiology	1	101	Microbiology

As it is observed, in these articles which have been published during 1992-2002 some were interdisciplinary with practicality in other fields. These 10 articles were approximately related to 9 scientific fields. The findings of Small, Sweeney and Greenlee (1985); Klai (1995) and Wagner-Dobler (2001) in revision section of the texts is a proof of such claim.

From other aspects, considering local citation score (LCS) and global citation score (GCS), it is shown that the documents of Mathematics have received between 13 to 64 citations from inside this field while from all scientific fields it has received between 72 to 1080 citations and this indicates that Mathematics have had an influential role in the practical part which is relevant to other sciences in comparison with the impractical part (pure or theoretical). In other words, the documents of the field of Mathematics have been cited more from the documents of other fields than the documents inside the field of Mathematics. Such notions convey that Mathematics is a science which can influence most scientific majors and play a better role in science as an interdisciplinary and practical field. Reviewing the texts

also indicates that the field of Mathematics has been quite influential in practical sections and fields especially Biology and Medicine.

### Conclusion

Generally, it shall be mentioned that the science of Mathematics is a science in which the transactions of ideas are quite fewer in comparison to other basic scientific fields. The appearance of theoretical and interdisciplinary fields have increased, enhanced and facilitated the publications and scientific notions in this field as this issue has caused a new paradigm in discipline of Mathematics.

Receiving a host of citations from documents of other fields to the documents of this scientific field (in comparison to internal citations, LCS) and also the outstanding effect of this scientific area on the interdisciplinary and practical fields confirm the result of this analysis about the connection between all formed notions in Mathematics and the field of Mathematics Education.

### Suggestion

Regarding this research, the authors suggest another study to investigate the scientific notions formed in Mathematics just based on Science Citation Index database (SCI).

### End Notes

1. Citations to an article from the retrieved data for this study.
2. Citations to an article in the collected data from the WOS.

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