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BIBLIOMETRIC ANALYSIS OF THE WOS LITERATURE ON RESEARCH OF SCIENCE TEACHER FROM 2000 TO 2017

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Abstract. *In order to explore the development of research of science teacher(RST), 904 articles from the Web of Science (WoS) core set based on bibliometric methods through R software were analyzed in this research. Specifically, it examined the co-occurrence relations of countries/regions, major journals, most cited references, and hot keywords from the macroscopic, mesoscopic and microscopic level of RST. The results showed that the core strength of RST is mainly from traditional industrialized countries such as the United States, Australia, and Britain. And some top journals in science education (such as Journal of Research in Science Teaching, Science Education) has to pay more attention on RST, it may also appeal to lots of top journals in general teacher education (such as Journal of Teacher Education, Teaching and Teaher Education). The research on science teachers was guided by several educational theories about teacher research, such as the teacher epistemological belief, reflective practice, and PCK. Moreover, theories in science education such as scientific literacy, scientific conceptual change also becomes the theoretical basis for science teachers' teaching practice and scientific inquiry instructing. The knowledge, key competences, dispositions, and professional development of science teacher are the main keywords and hot topics in the field of RST.*
Keywords: *science teacher research, bibliometric analyses, Web of Science.*

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Introduction

The science teacher plays a significant role in improving students' scientific literacy, which is an important goal in science education in countries and international organizations. In the past century, science education has not only occupied an important position in the school curriculum, but also has become an important aspect that cannot be ignored in education policies of various countries (Abell, 2000). Stepping into the new century, with the promulgation of many "national scientific standards" (e.g. the US NGSS), science education has once again triggered a wave of global reform (NRC, 2012). Among them, reformers begin to realize that new science courses or innovative teaching techniques need to be implemented by science teachers, and they believe that the reform of science teachers is a crucial factor in promoting the reforms in science education (Abell, 2000). In science education, competent science teachers are the decisive factors for students' science learning (NRC, 1996; NRC, 2012; Shaharabani & Tal, 2016). Therefore, science teachers are the key to education reform of all kindergarten to Grade 12 science subjects (K-12).

However, it is worth noting that until the advent of this century, the reform of international science education has always been carried out around science curricula and science learning, and there has been a lack of corresponding attention to science teachers' competences (Abell, 2000). Rumberger (1985) pointed out that one of the important reasons why students' scientific literacy has not been effectively improved is the lack of competent science teachers. In its 19th issue in 2013, *Science*, a leading international journal, published a special issue named *Grand Challenges in Science Education* (Hines, Mervis, Mccartney, & Wible, 2013). The specific content of the challenge is not only related to individual science learning, the topic on science teachers has also received great attention. Among them, the topics related to science teachers' professional development, science teachers' core skills and teaching strategies and science teachers'

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ICT skills, etc. This reveals that the RST is becoming a hot topic in the field of science education research at present, and appeals to the attention of many academic institutions and scholars.

As a "special group" in the team of teachers, science teachers' teaching idea, professional dispositions and teaching behavior not only directly affect students' learning outcome, but also have effect on their scientific literacies such as scientific attitude, subject matter, scientific thinking skills and scientific methods (Barnhart & Van, 2015; Maeng, 2016; Park, Chu, & Martin, 2016; Sakiz & Gonul, 2017; Sansone, 2017; Van Breukelen & Van Meel, De Vries, 2017; Wallace & Brooks, 2013). As the organizer, participant and leader of science courses' practice, the basic idea of science course can only be achieved by science teachers' specific implementation and organization, and finally transformed into the students' realistic scientific literacy (Ingersoll, 2011). However, due to the backwardness of the economy in many countries, schools are not only lacking in hardware equipment, but also a formal team of science teachers (Adams & Gupta, 2017). Many school-aged children are rarely able to receive formal science education, and some children do not even receive informal science education (Abell, 2000). It shows that science teachers play an irreplaceable part in the implementation of science curriculum teaching, and competent science teachers are the vital factors in the reform of science curriculum and promotion of students' adaptation to the challenges caused by the development of science and technology.

In addition to the lack of competent scientific faculty in teaching practice, the focus of RST in the science education is not enough as well. And most of RST papers pay more attention on teachers' attitudes, beliefs and identities, and few of them systematically analyze the content of RST (Bryan, 2012; Cronin-Jones, 1991; Enochs & Riggs, 1990; Moore, 1973; Osborne, Simon, & Collins, 2003). For example, Cronin-Jones (1991) explored the influence of teachers' beliefs on science teaching practice in two different situations, and the results turned out that although some elements of teachers' belief structure do promote the implementation of the curriculum, their structure of belief is not consistent with the implementation philosophy of the curriculum. Moore (1973) developed the science teaching attitude scale, which has been divided into three dimensions: emotional attitude to science teaching, attitude to science content and process, and view about science teachers' role. Bryan (2012) pointed out the research on the science teacher's belief has been formed in a very complete and comprehensive research system in last two decades. However, Osborne, Simon and Collins (2003) found that for some research on scientific attitude, primary and middle school students are the main objects of research, and the research on the attitude of science teachers is much less. Therefore, analyzing the research on science teachers has important reference value for further exploring science teachers' status and understanding their functions in science teaching and learning practice.

Research Focus

Limited by the technique of statistical tools, the general reviews of RST are mainly based on the ways of meta-analysis or meta-synthesis, which belong to qualitative analysis. Specifically, the contents of the review were mainly about knowledge review, belief review and attitude review of science teachers, and there is little review of RST from a macro perspective, letting alone quantifying the articles of RST from the perspective of bibliometrics (Bryan, 2012; Osborne, Simon, & Collins, 2003; Schneider & Plasman, 2011). This research aimed at exploring and analyzing the fundamental situation and attention of the RST in global science education research since the beginning of the 21st century by using bibliometrics. In order to understand the above content, the number of annual publications of the core collection of WoS literature on the science teacher was counted firstly in this research. Based on collected data of literature, the major countries or regions that occupy the leading and center in the field of science teacher research were further analyzed in the research from the macroscopic perspective. Then, the core journals, key articles, highly cited references and highly influential authors RST were analyzed from the mesoscopic level. Finally, the RST high frequency keywords and main topic areas were analyzed from the micro perspective.

Therefore, the research questions were carried out as follows:

1. What are the main countries, main journals, and main articles of RST?
2. Do bibliometrics effectively explore the theme and keywords of RST?

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Research Methodology

General Background

Several years ago, the collection and quantitative analysis of scientific literature were basically done manually (Garfield, 1972). However, after the 21st century, due to the rapid development of information technology, the processing of document data has accelerated (Chen, Ibekwe-Sanjuan, & Hou, 2010). R-studio mapping software was used for bibliometric analysis and descriptive analysis in this research. The R environment provides many packages (e.g. the bibliometrix package) related to bibliometrics through its official repository. The bibliometrix R package can be very useful for quantitative studies of bibliometrics by authors, keywords, citation networks and even historiography (Aria & Cuccurullo, 2017). It can visualize the bibliography of scientific literature by means of bibliometrics, which can provide researchers with intuitionistic data and models, and facilitate them to discover some important information of research topics. This research used R software to visualize and quantify the scientific literature in the RST field. The scientific literature from the WoS core collection 2000-2017 was extracted. The purpose of this research was to explore the research actuality and main topics in the RST field by performing quantitative analysis on these data.

Data collection

In this research, the data used for bibliometric analysis were collected from the core collection of WoS, including the Social Sciences Citation Index (SSCI), Science Citation Index Expanded (SCI-E), Conference Proceedings Citation Index-Social Science & Humanities (CPCI-SSH) and on so on. For example, SSCI and SCIE are authoritative citation index databases which are widely used in the humanities and social sciences and natural sciences respectively, both of which are located on the WoS platform. The retrieval topic was set as "science teacher" and the retrieval time of the data in this research was 2000-2017. Finally, a total of 904 publication records were obtained using above parameters after eliminating non-English articles.

Data Analysis

The reference data in this research was dealt with matrix creation, data reduction and network matrix creation, which were automatically processed by software R. Bibliometric analysis of above procedures mainly includes co-citation, collaboration, co-occurrence, clustering, network mapping and so on (Aria & Cuccurullo, 2017). Finally, the descriptive result and the collaboration network of countries, authors, sources, key words and hot topics of RST can be achieved via R. Additionally, the bibliometrix R package provides metrics such as h-index, which quantifies the centrality and influence of countries/regions, authors and sources on RST (Aria & Cuccurullo, 2017).

Research Results

The Annual Scientific Production of RST

The annual scientific production of RST articles can be divided into three stages. Firstly, from 2000 to 2004, the annual output of the research paper was kept at the lowest level with almost no significant increase. However, things have changed dramatically since 2005 (the second stage). Specifically, the annual scientific production of RST articles continued rapid growth until 2013. In the recent years (the third stage), although the number of RST articles has a slight decline in 2014, it recovered rapidly in 2015 and reached an unprecedented peak in 2017. It can be found that the research about the science teacher has gained lots of attention since 21century according to Figure 1.

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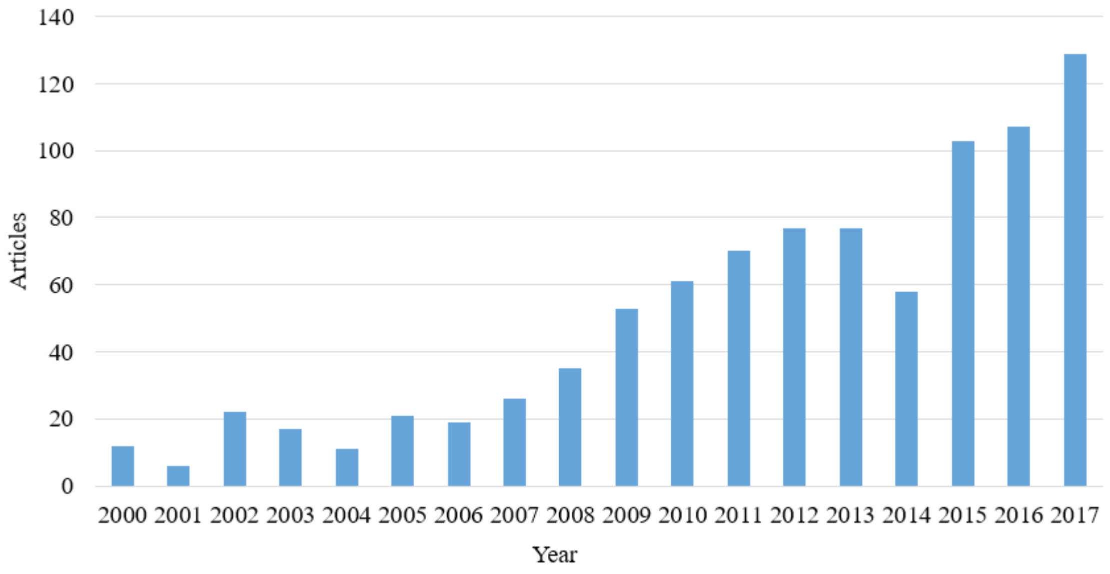

Figure 1. The annual scientific production of RST from WOS.

Macroscopic Level

It can be seen from the Table 1 that the top 20 countries have been collected based on their publications of RST. Only a simple statistics of the number of papers published by various countries on RST cannot represent their influence and popularity in this field. Therefore, other key indicators such as SCP, MCP, TC and AAC have been obtained by statistical calculation. Among them, SCP (Single Country Publications) represents the production of each county; MCP (Multiple Country Publications) represents cooperation and production among multiple countries; MCP_Ratio represents MCP divided by the sum of articles; TC represents total citations and AAC represents average article citations.

The number of published RST papers, SCP and TC values in the United States is far higher than those in other countries or regions, indicating the centrality and leadership of the United States in the global RST. Specifically, USA published 282 RST articles during 2000-2017, and all those RST papers have been cited more than 3000 times (3319) since 2000, and the average article citations of RST articles reached to 12.293 times. Besides, some countries, such as Turkey, Australia and United Kingdom have higher values on the above three indicators as well, demonstrating their significance in the field of ST. However, some countries have inconsistency among indicators of Article publications, SCP and TC. For example, Spain has a fifth production of RST while the TC value ranks eighth (drop by 60%) and AAC value eleventh (drop by 120%), and the value of TC and AAC even did not reach the average level (138<280, 5.111 < 7.133). It can be found that Spanish scientific papers of RST have advantages in number, but the overall quality of the paper in the field becomes less satisfactory. The same goes for Turkey which has the second largest output of RST papers. However, Turkish total papers in AAC only reach to 4.982, which is far from the average level of 7.133. In contrary to Spain, Singapore and the Netherlands have less production, but have a high value of AAC. The value of AAC from Singapore and the Netherlands was cited firstly and secondly, respectively, indicating their overall quality of the RST papers in the field are much higher.

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Table 1. Descriptive analysis of countries.

Country/Region	NP	NP%	SCP	MCP	MCP_Ratio	TC	AAC
USA	282	0.40929	256	26	0.0922	3319	12.293
TURKEY	109	0.15820	94	15	0.1376	543	4.982
AUSTRALIA	37	0.05370	30	7	0.1892	287	7.757
UNITED KINGDOM	28	0.04064	25	3	0.1071	223	7.964
SPAIN	27	0.03919	25	2	0.0741	138	5.111
TAIWAN(CHINA)	17	0.02467	14	3	0.1765	186	10.941
CANADA	16	0.02322	13	3	0.1875	163	10.188
KOREA	14	0.02032	7	7	0.5000	74	5.286
SOUTH AFRICA	14	0.02032	12	2	0.1429	54	3.857
BRAZIL	12	0.01742	10	2	0.1667	17	1.417
ISRAEL	12	0.01742	11	1	0.0833	84	7.000
NETHERLANDS	12	0.01742	8	4	0.3333	156	13.000
CHINA(Mainland)	11	0.01597	8	3	0.2727	21	1.909
GERMANY	11	0.01597	7	4	0.3636	51	4.636
SWEDEN	8	0.01161	5	3	0.3750	98	12.250
THAILAND	7	0.01016	5	2	0.2857	31	4.429
SINGAPORE	6	0.00871	6	0	0	99	16.650
ARGENTINA	5	0.00726	2	3	0.6000	9	1.800
NEW ZEALAND	5	0.00726	4	1	0.2000	36	7.200
GREECE	4	0.00581	3	1	0.2500	26	4.000
Average Value	31	0.04623	27	5	0.2269	280	7.133

NOTE: SCP = Single Country Publications; MCP = Multiple Country Publications; MCP_atio = MCP divided by sum of articles; TC = Total Citations; AAC = Average Article Citations

After clarifying the basic situation of each country in the RST paper, the research continued to use R to visualize the cooperative relations between various countries/regions, seen as Figure 2. The nodes in the Figure 2 are the main countries, the size of nodes and fonts is determined by their publications, and the lines between nodes represent the co-occurrence relationship of countries/regions. The number and thickness of lines in the nodes indicate the closeness or looseness of the links among different countries/regions. According to the correlation analysis of main countries, the co-occurrence results show that the United States is absolutely central in terms of node size, number of connections, and thickness, which are basically consistent with the parameters of SCP, and MCP in Table 1.

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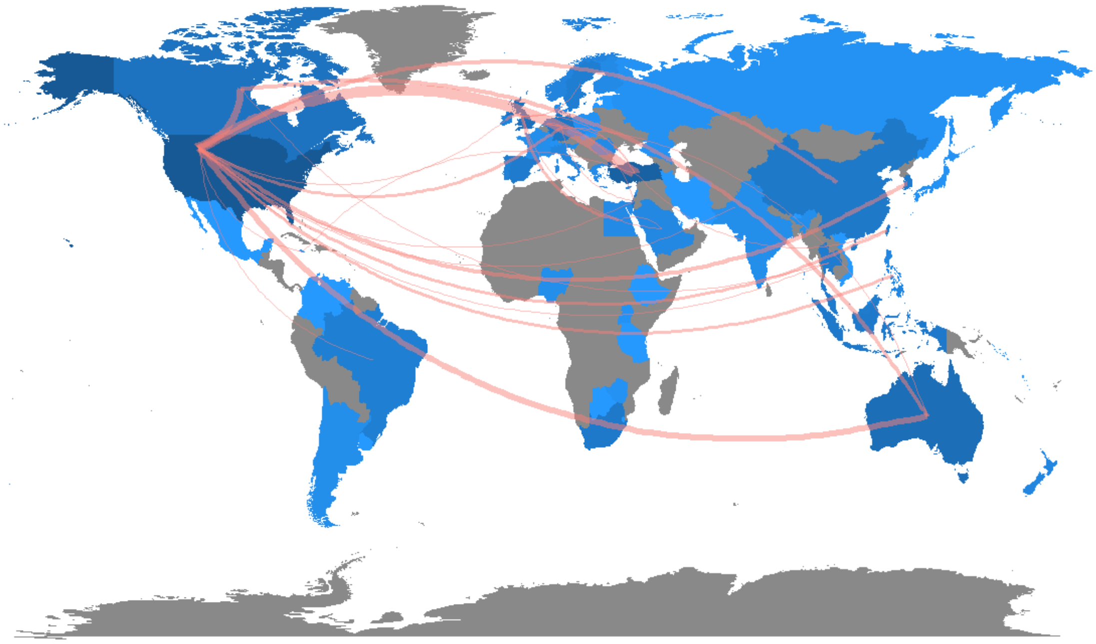

Figure 2. The co-occurrence relations of countries/regions.

Mesoscopic Level

In the macroscopic level, the research focused on the countries and regions that published RST papers. In order to further explore the sources and authors of the RST articles, the research continued to analyze the publications of journals involved in RST, and the highly cited papers, the highly cited references of RST, and the top authors in RST.

Major journals

The research collected the top 20 journals which published the maximal RST articles (See Table 2). It can be found that the publications of journals like the *International Journal of Science Education* (IJSE), *Research in Science Education* (RSE), *Journal of Research in Science Teaching* (JRST), *Science Education* (SE) accounted for 70% of top 10 journals' publications, indicating their leading effect and importance in the area of RST. It also can be found that the top 20 journals were all most famous sources in the field of science education, indicating RST is one of the most active areas. However, there are some journals such as *Teaching and Teacher Education* (TTE)*, Journal of Teacher Education* (JTE) and *Teachers College Record* (TCR), which are the leading journals in teacher and teaching research, indicating RST is one of the most highly valued fields in teacher research as well. Moreover, *Computers & Education*, *and Innovation and Creativity in Education* are two leading journals in the education field of computer-based learning.

In order to analyze the most influential journals in RST, five indexes were calculated by using R software, which mainly include h index, g index, Total Citation (TC) and NP (Number of Publication) (see Table 2). All these indicators, to a certain extent, reflect the influence and importance of journals in the field of RST. It can be seen from the Table 2 that JRST and SE are far superior to other journals in all above indicators, indicating their considerable influence and impact in RST. Besides, IJSE and RSE have optimistic values on all indicators as well. It is worth noting that both TTE and JTE have entered the top 10 in the rank of all indicators. TTE and JTE are the two most influential journals in the field of teacher research, indicating that the field of teacher education also pays great attention to the research on science teachers. However, it can be also found that there have been only ten RST papers published on JTE, which ranks the last of all journals. JTE's IF ranks first in teacher education, just higher than SE and a little below JRST, which are the two top journals in science education.

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Table 2. Top 20 active journals in the RST research.

Source	*h*	*g*	*TC*	*TC%*	*NP*	*NP%*	*IF (2017)*
JOURNAL OF RESEARCH IN SCIENCE TEACHING	26	43	2032	20.68	68	6.78	3.210
SCIENCE EDUCATION	26	44	2050	20.86	65	6.48	3.035
INTERNATIONAL JOURNAL OF SCIENCE EDUCATION	21	34	1294	12.17	77	7.68	1.325
RESEARCH IN SCIENCE EDUCATION	16	23	777	7.91	74	7.38	1.568
JOURNAL OF SCIENCE EDUCATION AND TECHNOLOGY	9	17	335	3.41	29	2.89	1.375
TEACHING AND TEACHER EDUCATION	9	17	572	5.82	17	1.69	2.473
SCIENCE & EDUCATION	7	12	148	1.51	17	1.69	1.265
JOURNAL OF SCIENCE TEACHER EDUCATION	6	8	124	12.62	52	5.18	NULL
JOURNAL OF TEACHER EDUCATION	6	10	259	2.64	10	1.00	3.180
INTERNATIONAL JOURNAL OF SCIENCE AND MATHEMATICS EDUCATION(IJSME)	5	8	87	0.89	17	1.69	1.086
COMPUTERS & EDUCATION	5	5	59	0.60	5	0.50	4.538
STUDIES IN SCIENCE EDUCATION	5	5	202	2.06	5	0.50	3.455
EURASIA JOURNAL OF MATHEMATICS SCIENCE AND TECH-NOLOGY EDUCATION	4	7	72	0.73	19	1.90	0.903
TEACHERS COLLEGE RECORD	4	6	49	0.50	6	0.60	1.072
JOURNAL OF BALTIC SCIENCE EDUCATION	4	5	46	0.47	22	2.19	0.638
INNOVATION AND CREATIVITY IN EDUCATION	4	5	31	0.32	8	0.80	NULL
CHEMISTRY EDUCATION RESEARCH AND PRACTICE	3	5	26	0.27	8	0.80	1.621
RESEARCH IN SCIENCE & TECHNOLOGICAL EDUCATION	3	4	27	0.27	13	1.30	0.513
JOURNAL OF BIOLOGICAL EDUCATION	3	4	21	0.214	4	0.40	0.633
EURASIAN JOURNAL OF EDUCATIONAL RESEARCH	2	3	10	0.10	7	0.70	NULL

NOTE: h: h index; g: g index; TC: Total Citation; NP: Number of Publications; IF: 2017 ISI impact factor

Main references

The most cited research papers that above mentioned provide important achievements of scholars involving in the research of science teachers and their frontier researches of science teachers, and references below can provide us with the important literature, basic theory and sources of standards for the above research (See Table 4). Table 5 lists the 20 most cited references, and it can be concluded that all these references can be divided into four categories: national standards of science education, science teachers' knowledge (such as PCK, misconceptions, conceptions of nature of science (NOS), self-efficacy belief, and research of science teaching practice.

The most cited reference is the *National Science Education Standards* (NSES) which was first published in 1996, and its total citation has reached 176. Science teachers' ability such as planning and designing the inquiry program, guiding and facilitating science learning, engaging in ongoing assessment of teaching and learning, organizing and managing classroom environments has been stressed in the chapter of the professional development of science teachers in NSES. Additionally, many scholars paid attention to the knowledge and concept research of science teachers since Shulman (1986, 1987) and Posner (1982) proposed the concept of PCK and theory of conceptual change, respectively. For example, Magnusson, Krajcik and Borko (1999) proposed a framework on teachers' PCK,

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which contains knowledge of science curricula, assessment of scientific literacy, students' understanding of core ideas and instructional strategies. Van Driel, Verloop and Vos (1998) considered teaching experiences contribute to the generation of PCK, and sufficient subject knowledge is an important basis for the formation of PCK. Van Driel, Jong, Verloop (2002) investigated the development of PCK of 12 preservice chemistry teachers' chemical thinking, and the result showed that pre-service teachers were increasingly aware of the need for clear links between the macro level and the micro level in the context of chemical teaching, and chemical teachers' PCK mainly influenced by their teaching experiences and their advisors.

Another long-term goal of science education is to develop students' conception of NOS. Primary and secondary students' conceptions of NOS have been emphasized in quite a few articles. Similarly, the research of science teachers' NOS also received much attention. Lederman (1992) conducted a review of researches of NOS owing to lack of both empirical studies (both quantitative and qualitative), and it can be found that science teachers have not developed a full understanding of NOS, and the disciplinary academic background of teachers does not significantly affect their understanding of NOS. Abd-El-Khalick and Lederman (2000) summarized two ways to improve conceptions of NOS: the first one is implicit attempts which utilized engagement in scientific inquiry activities, and the second one is the explicit attempts which utilized elements from history of science, philosophy of science and sociology of science.

Finally, research of science teachers' teaching practice has been given aboard much attention since Schon (1983) and Wenger (1998) respectively put forward the concepts of *Reflective Practitioner* and *Community of Practice*, and their academic papers have high citations as well in RST (Table 4). For example, Del Carlo, Hinkhouse and Isbell (2010) developed a framework for science teachers' reflective practice based on Schon' study, and elements such as technical reflection and critical reflection become the core components of their reflective practitioner framework. Moreover, Forbes and Skamp (2016) explored science teachers' involvement in a professional development community of science practice, and the result showed that science teachers' view and practice about how to address the science teaching practice in secondary school changed significantly.

Table 3. Top 20 cited reference.

Cited References	TC
NATIONAL RESEARCH COUNCIL, 1996, NAT SCI ED STAND	176
SHULMAN L. S., 1986, EDUC RES, V15, P4, DOI:10.3102/0013189X015002004	92
SHULMAN L. S., 1987, HARVARD EDUC REV, V57, P1	82
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE (AAAS), 1993, BENCHM SCI LIT	62
PAJARES M. F., 1992, REV EDUC RES, V62, P307, DOI 10.3102/00346543062003307	56
MAGNUSSON S., 1999, EXAMINING PEDAGOGICA, P95	46
MILES M. B., 1994, QUALITATIVE DATA ANA	46
LEDERMAN N. G., 1992, J RES SCI TEACH, V29, P331, DOI 10.1002/TEA.3660290404	43
NATIONAL RESEARCH COUNCIL, 2000, INQ NAT SCI ED STAND	39
GROSSMAN P. L., 1990, MAKING TEACHER TEACH	38
ABD-EL-KHALICK F., 2000, INT J SCI EDUC, V22, P665, DOI 10.1080/09500690050044044	35
SCHON D. A., 1983, REFLECTIVE PRACTITIO	35
VAN DRIEL J. H., 1998, J RES SCI TEACH, V35, P673, DOI 10.1002/(SICI)1098-2736(199808)35:6<673::AID-TEA5>3.0.CO	35
WENGER E., 1998, COMMUNITIES PRACTICE	35
LINCOLN Y., 1985, NATURALISTIC INQUIRY	33
NESPOR J., 1987, J CURRICULUM STUD, V19, P317, DOI 10.1080/0022027870190403	33
LAVE J., 1991, SITUATED LEARNING LE	32

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Cited References	TC
GLASER B. G., 1967, DISCOVERY GROUNDED T	29
LEDERMAN N. G., 2002, J RES SCI TEACH, V39, P497, DOI 10.1002/TEA.10034	29
POSNER G. J., 1982, SCI EDUC, V66, P211, DOI 10.1002/SCE.3730660207	29

Leading scholars

The research further analyzed top 20 most productive and most cited authors in RST (see Table 4). It can be found that Davis, Luft and Ritchie have higher values on publications. For example, their h index and g index are higher than others. There are some exceptions like Berry and Kind. Their articles are highly cited, but they rank very bottom other indicators. Because the output of their articles is not high, and especially in recent years there has been no published article on RST. For example, Berry published three articles on RST in 2008, 2009, 2011 and 2013 respectively, and Bell published a total of four articles from 2011 to 2015. Both two of them scarcely have academic production of RST in recent years.

The indicators of Davis and Luft are relatively high, their work in the field of RST will be further classified. Firstly, Davis's articles on RST dated back to 2004 and continued to 2017 based on the result of WoS. In the early stage, Davis focused on science teachers' knowledge development in their teaching practice, such as subject matter knowledge (SMK) and PCK (Beyer & Davis, 2008; Davis, 2004). Subsequently, Davis' research transferred to the key teaching/pedagogical competences research of science teachers. For example, Davis (2010) developed a project to cultivate science teachers' ability of science teaching practice. Then, Beyer and Davis (2012) designed a reform-based curriculum to develop preservice teachers' pedagogical design capacity. Furthermore, Davis, Kloser and Wells (2017) studied science teacher educators' competence to cultivate novice science teachers' ability of participating in activities by using rehearsals. Secondly, according to the result of WoS, Luft's articles on RST dated back to 2004 and continued to 2017 like Davis. Luft pays more attention on the in-service science teachers' professional development (e.g. the newly hired/beginning/novice secondary science teacher) (Luft, 2007, 2011, 2015). For example, Luft (2011) explored beginning science teachers' development through a two-year mixed methods study, the result of science teachers' knowledge, belief and practice were strengthened through an induction program.

Table 4. Top 20 most influential scholars publishing in RST.

Most productive authors						Most cited authors					
NAME	*TC*	*NP*	*TC /NP*	*h*	*g*	NAME	*TC*	*NP*	*TC /NP*	*h*	*g*
DAVIS E. A.	201	9	22.33	6	9	NIESS M. L.	319	1	319.00	1	1
LUFT J. A.	302	8	37.75	6	8	LUFT J. A.	302	8	37.75	6	8
RITCHIE S. M.	89	8	11.13	5	8	BRYAN L. A.	265	3	88.33	3	3
DEMIRDOGEN B.	36	7	5.14	4	6	WINDSCHITL M.	232	4	58.00	2	4
MAENG J. L.	73	7	10.43	3	7	CRAWFORD B. A.	228	1	228.00	1	1
CLOUGH M. P.	70	6	11.67	4	6	DAVIS E. A.	201	9	22.33	6	9
FIRMAN H.	2	6	0.33	1	1	HANEY J. J.	191	2	95.50	2	2
KAYA O. N.	124	6	20.67	5	6	ABELL S. K.	185	2	92.50	2	2
MENSAH F. M.	25	6	4.17	2	5	LUEHMANN A. L.	168	2	84.00	2	2
EBENEZER J.	85	5	17.00	5	5	SETTLAGE J.	164	4	41.00	4	4
HERMAN B. C.	45	5	9.00	3	5	KIND V.	162	4	40.50	4	4

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Most productive authors						Most cited authors					
NAME	*TC*	*NP*	*TC /NP*	*h*	*g*	NAME	*TC*	*NP*	*TC /NP*	*h*	*g*
MARTIN S. N.	21	5	4.20	2	4	BERRY A.	156	4	39.00	4	4
OLSON J. K.	62	5	12.40	3	5	ATWATER M. M.	153	2	76.50	2	2
RAGONIS N.	18	5	3.60	3	4	VAN DRIEL J.	153	3	51.00	3	3
TOBIN K.	83	5	16.60	4	5	BELL R.	149	5	29.80	5	5
BELL R. L.	115	4	28.75	4	4	SOUTHERLAND S.	142	6	23.67	5	6
BERRY A.	156	4	39.00	4	4	VAN DRIEL J. H.	141	2	70.50	2	2
BIANCHINI J. A.	98	4	24.50	4	4	DE JONG O.	139	2	69.50	2	2
KIND V.	162	4	40.50	4	4	TSAI C. C.	135	4	33.75	4	4
ROTH W. M.	105	4	26.25	4	4	SOUTHERLAND S. A.	131	4	32.75	4	4

NOTE: h = h index; g = g index; TC = Total Citation; NP= Number of Publications; IF = 2017 ISI impact factor

Additionally, there are two authors (Niess and Crawford) published only one RST article, but the number of citations of these two articles is as high as 319 and 228 respectively, ranking first and fifth. Firstly, Niess's (2005) article published in TTE, which has been cited most frequently (TC=319, TC per Year=24.86. Niess's (2005) study focused on TPCK of preservice science teacher, and Niess (2005) pointed out that preparing science teachers to teach with technology is one of key competences of the science teacher in 21st century. Niess's work in TTE, to some extent, reveals his focus on science teachers in the research field of disciplinary teacher. Crawford (2007) investigated five student teachers' knowledge, beliefs, and efforts in enacting teaching science as inquiry over a year interns in a high school, it turned out to be that the teacher's complex belief has an important influence on preservice teachers' intentions and abilities.

There are also quite a few authors with high RST citations like Windschit, Abell, Van Driel and so on. Windschitl's (2003) outcome in SE paid an attention to the inquiry projects as well. Windschitl (2003) examined the influence of pre-service teachers' conception of scientific inquiry based on their experience in the course of science methods. Windschitl (2003) advocated that the scientific inquiry experiences should be attached to the cultivation stage of preservice education, and Windschitl believed that relevant experience in pre-service stage could be scaffolded to promote individuals to deeply understand the nature of inquiry. Abell (2008) and Kind (2009) both focused on PCK of science teacher since the notion of PCK has been developed in last two decades. Van Driel (2002) explored the development of PCK of preservice chemistry teacher by focusing on chemical thinking, which involved the transformation between the macro and micro levels. Additionally, Lumpe (2000) and Bryan (2003) examined and assessed science teachers' belief about science teaching context.

Microscopic Level

Most relevant keywords

After the macroscopic analysis of the country and the mesoscopic analysis of the journals and authors in the field of RST, the study conducted a micro analysis of the RST based on researchers' keywords and keyword-plus (see Table 5). Considering that the abstract in many papers does not contain *keywords*, WoS can provide researchers with *keywords-plus*. Therefore, the research collected all two parts of keywords for further research and analysis. It can be founded that all those key words can be classified into four dimensions which are science teacher education, science teachers' knowledge, science teachers' key competencies and dispositions. Firstly and most importantly, science teacher education, and its frequency ranked first among all the keywords. Additionally, keywords like professional development, teacher development, and teacher professional development all relate to science teacher education, indicating that science teachers' education and their professional development is a hotspot in the RST field. Secondly, the research of science teachers' knowledge such as PCK, SMK, TPACK, NOS and conceptual change

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has been paid much attention as well. Thirdly, keywords like inquiry, science teaching, argumentation, reflection, discourse, teacher learning and action research aimed at science teachers' key competencies, which also accounted for a very large percentage of all keywords in RST articles. Finally, the other focus of RST is science teachers' dispositions which mainly include belief, self-efficacy, identity and equity.

Table 5. Most relevant keywords.

Author Keywords(DE)	Articles	Keywords-Plus (ID)	Articles
Science teacher education	92	Education	160
Science education	63	Knowledge	100
Teacher education	38	Students	94
Nature of science	26	Beliefs	87
Pedagogical content knowledge	25	Conceptions	61
Professional development	23	Inquiry	60
Science teacher	19	Instruction	48
Science teaching	18	Classroom	46
Teacher beliefs	17	Reform	40
Science	16	Views	40
Inquiry	12	Science	36
Teacher development	12	Pedagogical content knowledge	35
Conceptual change	10	Professional-development	32
Pre-service science teachers	9	School	31
Self-efficacy	9	School science	30
Environmental education	8	Teachers	30
Pre-service teacher education	8	Framework	26
Teacher professional development	8	Attitudes	25
Chemistry education	7	Curriculum	25

Social relations of most relevant keywords

Although the most relevant keywords in Table 5 show their frequency in the RST field more intuitively, it does not explain the relationship among these keywords. Therefore, the study continued to explore the relations among the above keywords based on their co-occurence by social network analysis (see Figure 4). In the social network, the relevance and closeness between the keywords can be judged based on the number and thickness of the links between the keywords (Batagelj & Mrvar, 2004). It can be founded that keywords such as *science education, teacher education and science teacher education* have lots of connections and these connections are very thick. For example, keyword *science teacher education* is closely related to *professional development*, *PCK*, indicating RST focus on science teachers' PCK and professional development. It can be seen that keyword *science education* also becomes a very hot keyword, which also has close relation with *pre-service teachers*, *nature of science*, *teacher beliefs*, *identity*, *equity*, indicating that they are main topics in RST field (Luehmann, 2007; Nuangchalerm & Prachagool, 2010). Although the links between some keywords (such as misconception and conceptual change) in the social network are not as obvious as the keywords like teacher education, science education and science teacher education, the research on the conceptual change of science teachers is still an important topic in the field of RST, and has received lots of attention by many scholars (Kartal, Öztürk, & Yalvaç, 2011; Lawrenz, 1986; Stofflett, 1994).

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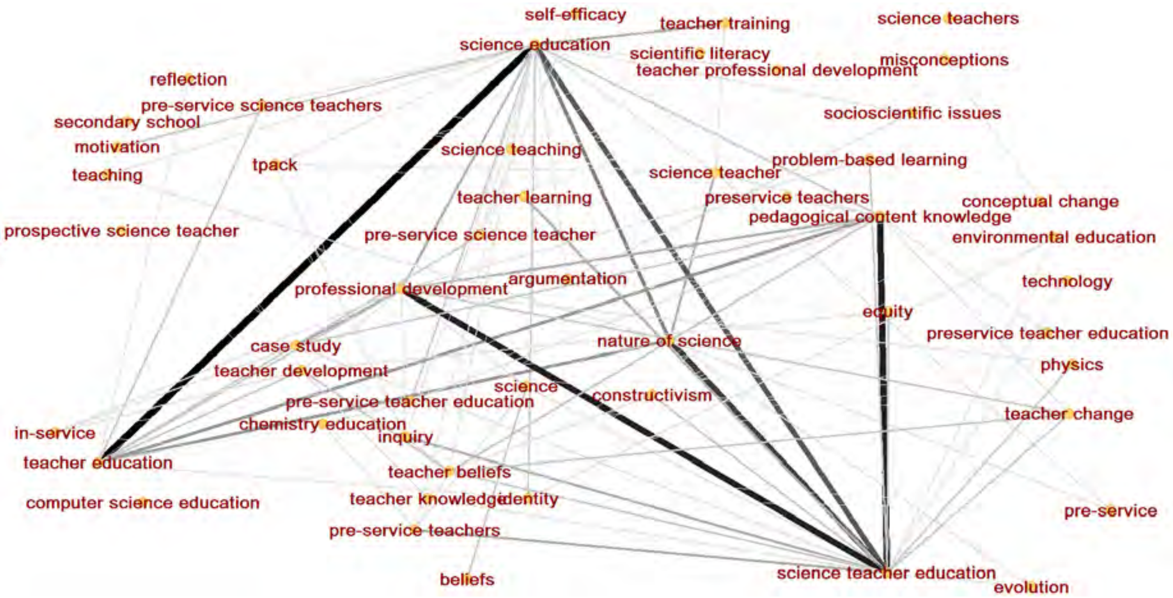

Figure 3. Most relevant keywords.

Discussion

Today, with the deepening of globalization and the rapid development of information technology in the world, how to innovate science teaching in school that can improve students' science literacy, which puts forward new challenges and requirements for the professional competence of science teachers in middle schools (Davis & Petish, 2006). Davis and Petish stressed that the current content of teachers in science education needs to deal with the challenges, which mainly include understanding of science subjects, subject matter, learner, teaching, learning environment and professional development. Therefore, the research on science teachers has received the attention and focus by many international scholars.

This research aimed to combine the international RST articles through the bibliometrics way, and then explore the major countries, core journals, highly cited literature and hot topics and keywords in the RST field from the macroscopic, mesoscopic and microscopic perspectives, respectively. It is helpful for researchers to clearly identify the status and characteristics of different countries or regions in the field of RST by analyzing the number of publications and cooperation in the field of RST from a macro perspective. Additionally, the analysis of the most influential RST papers and authors, as well as the core journals that publish RST papers, can help relevant readers and scholars in the RST field grasp the leading articles, authors and major journals from the mesoscopic perspective. Finally, analyzing the core topics and keywords in the RST field from a micro level can help researchers have access to catch the current themes and trends in the RST field.

From the bibliometrics analyses' results, it can be found that the publications on the research of science teachers has increased significantly since the new century (Figure 1). It has become increasingly popular in both developed and developing countries, where cooperation in the area of RST has become more frequent and closer (Figure 2). And it can be also seen in Table 1 that more and more countries or regions focus on RST (e.g.,Thailand, Indonesia, and China). The level of RST in a country relies on its research system and infrastructure of science education, and the strength of RST also reflects the country's scientific technology and industrial level. Additionally, the number of publications in the RST field is rapidly increasing in developing countries such as China and Indonesia. However, the influence and centrality of these countries in the field of RST still need a long time of continuous efforts and developments. The leadership of traditional industrialized countries such as the United States, Canada and Netherlands in the RST field is not only reflected in the high publications, but also in the high citation rate of articles published (e.g. TC and AAC). And their cooperation with other countries is very close (see MCP). Develo-

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ping countries with high population densities such as China and Indonesia should have made a difference in RST because these countries lack a large number of professional and competent science teachers. However, due to the uneven development of the domestic region, the path of cooperation with developed countries seems feasible.

Quite a few journals have been able to provide access and channels for RST scholars (see Table 2). It can be found that the attention to the science teachers is not only reflected in the field of science education, but also in the journals of common teacher education. Additionally, the interdisciplinary and transdisciplinary education is also given great attention to the science teacher. The research on science teachers has also been guided by educational theories in the field of teacher research, such as Pajares's teacher belief (1992), Schon's (1983) reflective practice, and Shulman's PCK(1986, 1987) (see Table 3). Moreover, theories in science education such as Miles'(1994) scientific literacy, Posner's (1982) theory of scientific conceptual change provides the theoretical basis for science teachers' teaching practice and scientific inquiry instructing. Nonetheless, it should be noted that RST is still not an entirely mature and compelete area, and it is still developing by adoptting more conceptions and frameworks (e.g. science teachers' knowledge, key competences, dispositions, science teacher education and their professional development) from other fields such as educational psychology, teacher education, and global cooperation (Table 5 and Figure 3). It can be found that the above contents show the following characterics in chronological order: the scientific attitude of science teachers in the 1960s and 1970s, the pedagogical content knowledge of science teachers in the 1980s, the science teachers' view on nature of science in the 1990s to the 21st century. Recently, there has been a gradual shift to the study of scientific thinking skills (such as scientific reasoning, scientific argumentation and scientific explanation) and core competence (e.g. core scientific teaching practice, and instructional design capacity) of science teachers. Generally speaking, the research of science teachers is complex and systematic, so it is difficult to make a systematic review of all RST articles. And What needs to be clear is that the research of science teachers must reflect nature of science, and the research should fully reflect the commonality, universality and generality of science.

Conclusions

The aim of this research was to provide a systematic overview of WoS literature on science teacher published in international journals by using bibliometric analysis with R software. Therefore, several conclusions were obtained based on the research questions.

Firstly, at present, the core strength of RST is mainly from western developed countries such as the United States, Turkey, Australia, Britain and Spain, which are the backbone of RST and have a high influence in this field. Although developing countries such as China, Brazil, South Africa and Thailand ranked fairly well in the number of publications, their TC and AAC values of RST papers were relatively low, and there was less cooperation and contact between countries. Therefore, developing countries need to continuously invest human and material resources to support domestic scholars to carry out in-depth learning and cooperation with other international scholars if they want to achieve the same influence in this field as the developed countries.

Moreover, the international RST field has attracted some top journals of science education (such as JRST, SE and IJSE), and the RST field also has been valued by top journals of teacher education (such as JTE and TTE). The attention on RST in international science education journal reveals that science teachers have become the research hotspots and trends in science education. However, it is worth noting that, unlike JRST and IJSE, which publish a large number of RST articles, some teacher research journals such as JTE and TTE are still insufficiently concerned about science teachers, indicating that the status and importance of science teachers in general teacher education research field still need to be improved. Additionally, this section also analyzes the main articles of RST and the main references for RST. The former research prefers the knowledge of science teachers (such as PCK, SMK, NOS) and key competences like scientific practice, while the latter one mainly contains the national science education standards (such as NGSS) and general teacher research results (such as Shulman's view about teacher knowledge and Schoen's research of reflective practice), etc. These articles in science education and teacher education research field provide important theoretical basis and reference value for international RST.

Secondly, the theme and keywords of RST was effectively explored by bibliometrics analyzing. Specifically, the main keywords and their relations in the field of RST were summarized and analyzed. The main keywords mainly involve several dimensions, such as knowledge, ability and professional development. Since the new century, the international science teacher education has experienced three themes: firstly, theme of RST mainly refers to and revolves around these documents and policies due to the science standards and documents issued by countries

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represented by the United States. The second topic mainly involves the research of science teachers' knowledge, skills, abilities and professional dispositions. The third one focuses on science teachers' education and professional development by constructing different professional learning communities.

It can be concluded that the main content of these documents (NGSS) mainly includes the following key elements: big ideas (core conceptions), learning progression, science and engineering practice. And these standards mainly focused on students' science learning, which involved three- dimensional performance expectations: core ideas, crosscutting concepts and practices. However, it is worth noting that the evaluation of these core concepts has gradually concerned the scholars and the government. They pay much attention to develop the measurement of evaluating students' science learning and conducted the quasi-experiment research in the designed science classroom.

Implications

Science education shoulders the important task of cultivating scientific and technological innovation talents and improving citizens' scientific literacy in the future, and science teachers with good competence become the most important factors in the development of science education and the cultivation of students' scientific literacy (NRC, 1996, 2012; Shaharabani & Tal, 2016). Many studies have shown that the lack of competent science teachers is one of the important reasons for the ineffective improvement of teenagers' scientific literacy (Rumberger, 1985). This phenomenon reveals that the research on science teachers is becoming a hot topic in the field of science education research, and has appealed to many academic institutions and scholars (Hines et al., 2013). As the organizer, participant and executor of science curriculum teaching and learning, the basic idea of science curriculum can only be implemented through the specific implementation of science teachers, and finally transformed into the realistic scientific literacy of students. However, at present, in both developed and developing countries, their science education and science teacher preparation are insufficient to meet the demands and expectations of the government, citizens and educators for the cultivation of scientific literacy (Ingersoll, 2011). It can be seen that science teachers play an irreplaceable role in the implementation of science curriculum teaching, and competent science teachers are a vital factor in the reform of science education and the development of students' scientific literacy.

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