

UNIVERSITY RESEARCH THEME MAPPING: A CO-WORD ANALYSIS OF SCIENTIFIC PUBLICATIONS

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ABSTRACT

There is a necessity for a research centre to identify its main research theme and its subject linkages. On the other hand, rapid growth in the number of scientific publications has raised extensive data issues. Thus, it is difficult to detect the main subject and its relationships using traditional methods. Some quantitative methods in data mining have been developed and applied to solve these problems. Co-word analysis, as one of the most powerful tools in content analysis, is able to find the interrelationship among research themes based on the co-occurrence frequency of word/phrase pairs. As a result, the trend in research theme development is identifiable and future research plans could be effectively determined. As a case study, research publications from Universitas Indonesia (UI) academicians during the last five years (2010–2015) were analyzed. The data source for this study, are all those articles which have been indexed in Scopus, EBSCO, JSTOR, and ProQuest. The study generated strategic diagrams which show research themes of UI publications in each year and over the last five years. The last five years' map shows that there are eleven main research themes in UI publications. This result can be used as a base for evaluating the previous research themes set by policy makers of UI.

Keywords: Big data analysis; Co-word analysis; Research theme mapping; Universitas Indonesia

1. INTRODUCTION

Research and publications are important contributors to many development aspects for a country, such as supporting economic growth (Pessoa, 2010), developing a health care system (Pasmans et al., 2013), and creating new technology (Glueckstern et al., 2001). Therefore, understanding the main research themes will be beneficial for a research centre in order to determine an effective direction for future research planning. However, understanding the main research themes and their linkages has been problematic as the number of publications is growing rapidly. Big data analysis is a suitable approach for this situation.

Content analysis, which is a systematic and replicative method to reduce the words of a text into several categories of content based on specific coding rules (Berelson, 1952; Krippendorf, 1980; Weber, 1990), can be applied to solve this problem. This quantitative method was often applied to analyse changes in trends related to the content of scientific theories and methodological approaches, by analyzing the content of an article in a journal within the theme of a particular discipline (Loy, 1979).

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Co-word analysis, as one of the most powerful techniques for conducting content analysis, is a highly effective method to map the strength of the relationship between research-based keywords that are derived from a particular research topic (Coulter et al., 1998). Keywords represent an important concept related to research analysis. If there are two research studies that contain the same keywords, then it can be said that they are related research (Wu & Leu, 2014). Co-word analysis is one of the most powerful tools in content analysis that offers a significant methodological approach to knowledge discovery (Callon, 1986).

As the oldest university in Indonesia, Universitas Indonesia has an extensive research archive. The last five years' worth of publications from Universitas Indonesia, was selected for a case study to apply the Co-word analysis method. According to the QS World University Rankings, UI, with a ranking of 310, was recognized as the only university in Indonesia that was included in the list of the 400 World's Best Universities in 2014. One of criteria for this honor, which was used in this ranking system, is the number of scientific publications in international journals indexed by international databases.

As the number of scientific publications grows rapidly, UI requires knowledge and a deeper understanding of its research excellence from those publications. A clear map of UI main research themes and trend is yet to be determined. DRPM-UI, a UI research directorate, which manages research grants in UI, has established ten main research themes. However, it was still not clear whether those ten themes represent overall the UI research publications. Those ten research themes defined are as follows: 1) Information, Communication, and Technology (ICT); 2) Restoring the Earth's Natural Support Systems; 3) Genome; 4) Culture; 5) Energy; 6) Governance, Democratization and Policy; 7) Urban Planning and Transportation; 8) Indigeneous Studies; 9) Nano and Advanced Technologies; 10) Poverty, Alleviation, Child, Family, and Community Issues.

To identify the UI main research themes for this case study, Co-word analysis was applied. By mapping various research themes of UI publications, the direction of UI research will be effectively determined within the analytical framework of content analysis.

2. METHODOLOGY

Scientometrics can be defined as a quantitative study of science (Hess, 1997). A scientometrics approach can be used to implement Performance Analysis and Scientific Mapping of research publications. Performance Analysis aims to evaluate scientific actors (states, universities, researchers) and the impact of research (Herrera, 2011), whereas Science Mapping aims to determine patterns of publication and the evolution of a science (Jacobs, 2010). Scientometrics have a higher level of accuracy when applied to analyse patterns in a large data set (including the number of publications from universities, states, or other large research centres). However, scientometrics are less suitable for evaluating a small data set (research produced by individuals or small research groups), (Russell & Rousseau, 2010). Big Data analysis using co-word analysis is an appropriate tool to be applied in order to find valuable insight from the large data set of publications. The following sections elaborate the methodology for conducting this study.

2.1. Dataset

The data used in this study is a collection of research articles published by UI academicians from 2010 to February 2015 in academic journals, which have been indexed in international databases such as Scopus, EBSCO, Proquest, and JSTOR. There are 2,618 articles and 6,774 keywords collected from all four databases with the affiliation names of "University of Indonesia" and "Universitas Indonesia". It can be seen in Figure 1 that most articles from the last 5 years came from Scopus. It supports the fact that Scopus is one of the largest

multidisciplinary databases of scientific literature in the world (Bar-Illan, 2008) and it has been very popular among researchers.

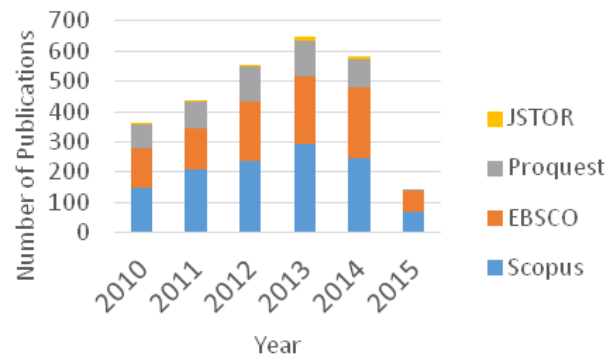


Figure 1 Document distribution

2.2. Data Pre-processing

After the data was collected, some procedures are performed to ensure the readiness of the data before being processed by co-word analysis. The procedures of data pre-processing are shown in the following stages of adding and grouping keywords. A keyword is an important component for processing data using co-word analysis. To support the accuracy of the data processing, the keyword must be representative or able to describe the content of the article properly. If there is an article with no keywords or having keywords that are not too representative, then keywords were added manually. Moreover, all keywords were grouped together based on their similarities. In this study, each keyword was placed manually in a group, either by subject category or a branch of science. For example, the words 'DNA', 'RNA' and 'Human Chromosome' were grouped into a set called 'Molecular Biology'. The same steps were repeated until all keywords belonged to a particular set.

2.3. Data Processing

SciMAT is a science mapping analysis tool that is used to perform the co-word analysis (Cobo et al., 2012), which is also used in this study. Co-word analysis calculates the co-occurrence pairs of items (words or noun phrases) to identify relationships between ideas in a theme of study. The index used in the similarity calculation of the co-occurrence matrix is an equivalence index.

An Equivalence Index (E_{ij}) is used to calculate the value of togetherness between two keywords. E_{ij} measures the likelihood of the keyword M_i occurring in a document where the keyword M_j existed and vice versa (He, 1999) as shown in Equation 1.

$$E_{ij} = (C_{ij} / C_i) \times (C_{ij} / C_j) = (C_{ij})^2 / (C_i \times C_j) \quad (1)$$

where C_{ij} is the number of documents in which there is a keyword pair (M_i and M_j), C_i is the M_i keyword frequency on all documents, C_j is the M_j keyword frequency on all documents.

Keywords that have a high correlation value based on an equivalence index are chosen as the central of a cluster. The depth of a cluster network to be formed is then specified using simple center algorithm with a threshold value. The threshold value is the minimum and maximum number of members in a cluster, which is determined subjectively based on the desired depth of analysis (Herrera et al., 2010). Keywords that appear at the top level or that first appeared in

each cluster are referred to as central theme and what appears after being referred are known as mediator words.

After all clusters are formed, research themes found are visualized by a strategic diagram. In the co-word analysis, a strategic diagram is used to illustrate the “local” and “global” context of research themes (Law et al., 1988). The *x*-axis shows the strength of the global context while the *y*-axis shows the strength of the local context. Density and centrality are the parameters used to measure the local and global strength respectively. Those two parameters are described on Equations 2 and 3.

$$d = 100(\sum e_{ij}/x) \tag{2}$$

$$c = 10 * \sum e_{kh} \tag{3}$$

where *i* and *j* is the keyword in one cluster theme, *x* is the total keyword in one cluster theme, *k* is the keyword in one cluster theme, *h* is the keyword in other cluster theme.

3. RESULTS

The results of the research theme mapping are shown in the visualisation of a strategic diagram shown in Figure 2. Over the last five years, there were 21 clusters of research themes that have been carried out by UI. The themes are mapped into 4 quadrants based on the measurements of density and centrality in a corpus of articles. Themes in Quadrant I are named as *Motor Themes*, Quadrant II as *Highly Developed and Isolated Themes*, Quadrant III as *Emerging or Declining Themes*, and Quadrant IV as *Basic and Transvrse Themes*, respectively (Cobo, et. al., 2015). According to Cobo (2015), themes in Quadrants I and IV are considered as important and are selected as the main themes. The study found that there are eleven UI main research themes during the period from 2010 until early 2015.

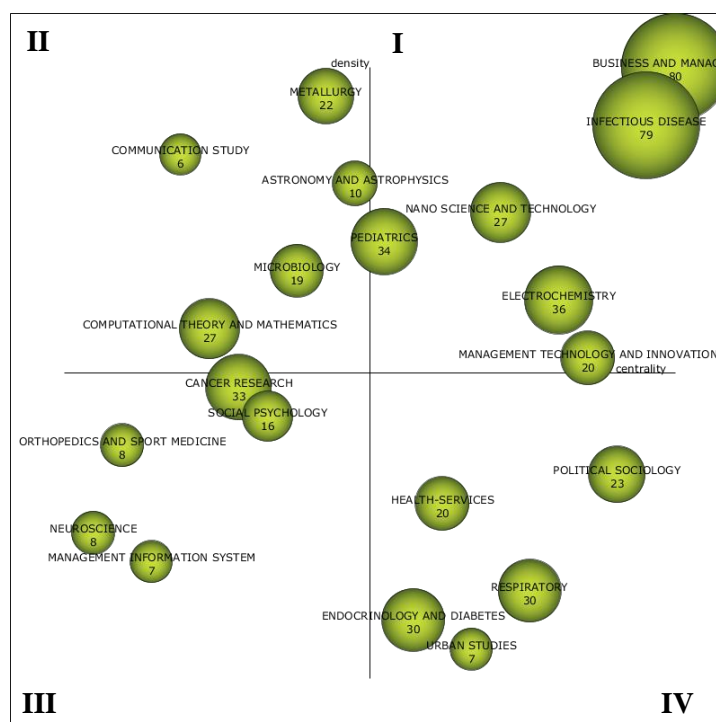


Figure 2 Strategic diagram for the 2010–2015 period

Each research theme is explained by a central theme and further explained by mediator themes (words) surrounding the central theme. An example of a cluster network of the Infectious Disease theme is shown in Figure 3. The Infectious Disease acts as the central theme that is supported by mediator themes or sub-themes such as pharmacology, epidemiology, virology and hepatology. Further analysis of all formed themes is explained in the next section.

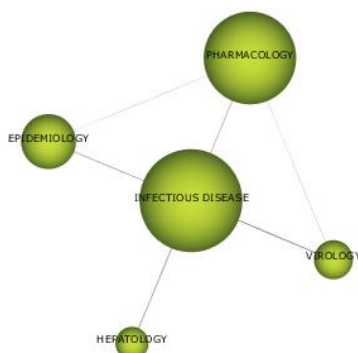


Figure 3 A cluster network of the Infectious Disease theme

4. DISCUSSION

4.1. Quadrant I: Motor Themes

Themes in Quadrant I are both well developed and important for the structuring of other research themes. Based on the strategic diagram shown in Figure 2 and Table 1, there are six motor themes which belong to Quadrant I.

4.1.1. Cluster I: *infectious disease*

This cluster is formed by the central theme *Infectious Disease* which is explained by keywords such as HIV, Tuberculosis, Malaria, etc. Four mediator themes that support this cluster are pharmacology, a sub-theme which discusses the biological effects of drugs on the body; epidemiology, a sub-theme which discusses infectious diseases at the population level; virology, a sub-theme which discusses the virus; and hepatology, a sub-theme which specially discusses liver diseases. All mediator themes in this cluster support the central theme which explain the causes, prevention or treatment of infectious diseases.

4.1.2. Cluster II: *business and management*

The central theme Business and Management is related to various disciplines such as economics, finance and banking, accounting, and industrial and organizational psychology. In general, the research theme Business and Management studies the internal and external aspects in managing an organization.

4.1.3. Cluster III: *nano science and nano technology*

The central theme Nano Science and Nano Technology covers research on the formation of nano particles and the application of nano technology (e.g. nanowires, nanocomposites). Nano Science is closely related to the sub-theme nuclear physics and heat transfer while the application of Nano Technology is associated with the sub-theme of non-renewable energy and electronic engineering.

4.1.4. Cluster IV: *management of technology and innovation*

The central theme Management of Technology and Innovation represents research on innovation, change management, technological assessment and knowledge management. Four sub-themes in this cluster are media broadcast (e.g. social media, digital media); policy studies (e.g. public policy, government policy); logistics and manufacturing system (e.g. automobile industry, supply chain, production planning); and education (e.g. knowledge, e-learning). These

sub-themes are closely related to the application of technology management and innovation in various themes.

4.1.5. Cluster V: electrochemistry

Electrochemistry is a research theme that discusses the interaction of electricity and chemical reactions. Mediator themes that support this cluster are organic chemistry (e.g. hydrocarbons, ethanol), electromagnetism (e.g. electromagnetic wave, electrodynamics), atmospheric science (e.g. atmospheric pressure, climate change), pollution and waste management (e.g. carbon dioxide, pollution control). Research on electrochemistry in atmospheric science and waste and pollution management is shown in the application of purifying water and measuring air pollutants. Meanwhile, organic chemistry is related to electrochemistry in the context of creating green chemistry.

4.1.6. Cluster VI: maternal and child health

This cluster is labeled as *Maternal and Child Health*. It is formed by two interrelated themes which are pediatrics, obstetrics and gynecology. The pediatrics theme discusses the health of infants and children, while the obstetrics and gynecology theme specializes in women's and mother's health during pregnancy, labour, and the time-period directly following childbirth. Both themes of food science and nutrition are related with maternal and child health in the management of balanced diets and healthy food. Meanwhile, the mediator theme Demography represents research on natality and mortality.

4.2. Quadrant II: Highly Developed and Isolated Themes

Themes in Quadrant II have well-developed internal relationships (highly specialized), but are considered less important to other research themes. Based on the strategic diagram shown in Figure 2 and Table 2, there are five themes which are categorized as specialized and peripheral themes.

4.2.1. Cluster I: metallurgy and material

This cluster is formed by the central theme of metallurgy, a theme that addresses physical and chemical properties of metals and alloys. Sub-themes of atomic and molecular physics and the mechanics of materials are related to the physical and mechanical behaviours of materials, while the sub-themes of biomaterials and ceramics and composites represent research on advanced materials.

4.2.2. Cluster II: molecular biology and microbiology

The Molecular Biology and Microbiology theme is comprised of two interrelated research themes which are microbiology, a central theme that discusses microscopic organisms, and molecular biology, a sub-theme that discusses the activities on the molecular basis of the biological system (e.g., DNA, RNA, chromosome). Physiology is a sub-theme which discusses the normal functions of living system. The theme Molecular Biology and Microbiology is mainly focused on the biological systems of microscopic organisms and their relationships with humans in terms of disease transmission and treatment.

4.2.3. Cluster III: information communication and technology

The Information Communication and Technology theme represents wide aspects of information technology and the integration of telecommunications and computers. The theme computational theory and mathematics discusses the algorithm of how a computer processes information. It is related to the sub-theme of Artificial Intelligence (AI) and Computer Graphics and Computer Aided Design in the context of computational theory and mathematical applications to create a smart device and software. Meanwhile, a computer network represents Communication Technology, such as the Internet, wireless network, and even Long Term Evolution (LTE).

4.2.4. Cluster IV: communication studies

The Communication Studies theme explores various interests in the processes of human communication. Mediator themes that support the central theme in this cluster are community practice (e.g. community service, community engagement), quality management (e.g. service quality, quality assurance), marketing (e.g. advertising, relationship marketing), and strategy and management (e.g. project management, strategic management). In general, this cluster represents the applications of communication skills in community and business interactions.

4.2.5. Cluster V: physical science

This cluster is formed by the central theme of Astronomy and Astrophysics which deals with the behavior and physical properties of celestial objects and phenomena (e.g. gravity and space). Four mediator themes that support this cluster are applied statistics (e.g. regression analysis and chi-squared test); condensed matter physics, a branch of physics that focuses on the condensed phases in the compaction of matter (e.g. solids and liquids); geology (e.g. soil erosion and soil analysis), and regional geography (e.g. Indonesia and Flores). In general, the theme of this cluster is related to natural sciences that study non-living objects or systems. Thus, this cluster is called Physical Science.

4.3. Quadrant III: Declining or Emerging Themes

Themes in Quadrant III are considered as emerging or declining themes because of their low density and centrality. Based on the strategic diagram shown in Figure 2 and Table 3, there are five clusters of themes which belong to Quadrant III.

4.3.1. Cluster I: cancer research

The Cancer Research theme represents the research conducted on the medical assessment and diagnosis of patients in the more focused area of oncology (e.g. tumors, oncologic surgery). Furthermore, it comprises research in the theme of cancer treatment using biomedical engineering and therapy (e.g. chemotherapy, chemo radiotherapy).

4.3.2. Cluster II: psychology and cultural studies

This cluster mainly focuses on the area of social psychology (e.g. social perception, attitude) and how it is related with research on mental health (e.g. anxiety, depression) and Human Computer Interaction (HCI). Social psychology also plays an important part in the psychological aspects of disaster management. However, there is a unique sub-theme in this cluster which is Cultural Studies that mostly discuss ethnicity and cultural values. Because of the interaction of these two disciplines, the theme of this cluster is defined as Social Psychology and Cultural Studies.

4.3.3. Cluster III: orthopedics and sports medicine

The Orthopedics and Sports Medicine theme is focused on the treatment of diseases and injuries that affect bones and muscles, especially sports injuries. Research on Chiropractic (e.g. acupuncture), Rheumatology, and Dermatology are discussed to treat sports injuries, diseases and infections. A sub-theme of Polymers and Plastics addresses materials in bone implants or casts.

4.3.4. Cluster IV: neuroscience

The Neuroscience theme is related to various studies of the nervous system. Neurology, anesthesiology and pain medicines are some specialties that specifically address the diseases of the nervous system. The sub-theme of geriatrics and gerontology comprises research on neurologic disorders in the elderly (e.g. Alzheimer's, dementia, etc.). Furthermore, a unique study of plant science is incorporated in this cluster that represents research on plants' behaviour in processing information.

4.3.5. Cluster V: management information system

The Management Information System theme is related to an interdisciplinary discipline of decision science and software engineering. The practice of Management Information Systems in the library is also discussed in the sub-theme of library and information systems.

4.4. Quadrant IV: Basic and Transversal Themes

Research themes in Quadrant IV basically have a great influence on other research themes, although themes have not well developed. Therefore, themes in Quadrant IV are considered as main themes, which are important for further development. Based on the strategic diagram shown in Figure 2 and Table 4, there are five clusters of themes which belong to this quadrant.

4.4.1. Cluster I: politics, sociology, and international relations

The Politics, Sociology and International Relations theme is related with different disciplines of social science. It is focused on the interaction of political sociology with the law, government affairs and international relations. It also covers topics related with government policy, for example, the policy on forestry.

4.4.2. Cluster II: health service management

The basic and transversal Health Service Management theme is related to different aspects of healthcare management. It collects the research conducted on public health, health information management (e.g. nursing information management, patient records) and application of data science (e.g. data mining) in understanding numerous health records.

4.4.3. Cluster III: internal medicine

The Internal Medicine theme is related to various conditions affecting the internal organs of the body. Some specializations of internal medicine are endocrinology (e.g. endocrine diseases), diabetes, hematology (e.g. blood diseases), and urology (e.g. genital diseases). This theme also covers the diagnosis and treatment of internal diseases such as in the sub-theme of toxicology and biotechnology.

4.4.4. Cluster IV: respiratory and cardiovascular research

Research in this cluster specializes in all aspects related with the knowledge of the respiratory and cardiovascular systems and their interactions. It covers a wide range of topics, such as cell biology, immunology, and endoscopy which seek an understanding of various diseases on respiratory and cardiovascular systems.

4.4.5. Cluster V: urban studies

The basic and transversal Urban Studies theme comprises a diverse range of disciplines to study all aspects of cities and urban life. This includes transportation, environmental science and management, civil engineering, and welfare economics.

Table 1 Motor Themes from Quadrant I

Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI
Infectious Disease	Business and Management	Nano Science and Nano Technology	Management of Technology and Innovation	Electrochemistry	Pediatrics
(1) Pharmacology (2) Epidemiology (3) Virology (4) Hepatology	(1) Economics (2) Finance and Banking (3) Accounting (4) Industrial and Organizational Psychology	(1) Heat Transfer (2) Nuclear Physics (3) Electric and Electronic (4) Non-Renewable Energy	(1) Media and Broadcast (2) Policy Studies (3) Logistics and Manufacturing System (4) Curriculum and Education	(1) Organic Chemistry (2) Electromagnetism (3) Atmospheric Science (4) Pollution and Waste Management	(1) Nutrition and Dietetics (2) Obstetrics and Gynecology (3) Food Science (4) Demography
Infectious Disease	Business and Management	Nano Science and Nano Technology	Management of Technology and Innovation	Electrochemistry	Maternal and Child Health

Table 2 Highly Developed and Isolated Themes from Quadrant II

Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V
Metallurgy	Microbiology	Computational Theory and Mathematics	Communication Studies	Astronomy and Astrophysics
(1) Atomic and Molecular Physics (2) Biomaterial (3) Mechanics of Material (4) Ceramics and Composites	(1) Molecular Biology (2) Physiology (3) Bacteriology	(1) Computer Network (2) Artificial Intelligence (3) Computer Graphics and Aided Design	(1) Community Practice (2) Quality Management (3) Marketing (4) Strategy and Management	(1) Applied Statistics (2) Condensed Matter Physics (3) Geology (4) Geography
Metallurgy and Materials	Molecular Biology and Microbiology	Information Communication Technology	Communication Studies	Physical Science

Table 3 Declining or Emerging Themes from Quadrant III

Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V
Cancer Research	Social Psychology	Orthopedics and Sport Medicine	Neuroscience	Management Information System
(1) Medical Assessment and Diagnosis (2) Complementary and Manual Therapy (3) Biomedical Engineering (4) Oncology	(1) Mental Health (2) Disaster Management (3) Human Computer Interaction (4) Cultural Studies	(1) Polymers and Plastics (2) Dermatology (3) Rheumatology (4) Chiropractics	(1) Neurology (2) Geriatrics and Gerontology (3) Anesthesiology and Pain Medicine (4) Plant Science	(1) Software Engineering (2) Decision Science (3) Library and Information Science
Cancer Research	Psychology and Cultural Studies	Orthopedics and Sport Medicine	Neuroscience	Management Information System

Table 4 Basic Themes from Quadrant IV

Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V
Political Sociology	Health Service	Respiratory System	Endocrinology and Diabetes	Urban Studies
(1) Government Affairs (2) Law (3) International Relations	(1) Public Health (2) Data Science (3) Health Information Management	(1) Immunology and Allergy (2) Cell Biology (3) Cardiology and Cardiovascular (4) Endoscopy	(1) Toxicology (2) Biotechnology (3) Hematology (4) Urology	(1) Environmental Science (2) Welfare Economics (3) Transportation (4) Civil Engineering
Politics, Sociology, and International Relations	Health Service Management	Cardiovascular and Respiratory Research	Internal Medicine	Urban Studies

5. CONCLUSION

There are eleven main research themes featured in this study that can be used as a base for an evaluation of existing research themes in UI and the development of future research. Those main research themes are: 1) *Infectious Disease*, 2) *Business and Management*, 3) *Nano Science and Technology*, 4) *Management of Technology and Innovation*, 5) *Electrochemistry*, 6) *Maternal and Child Health*, 7) *Politics, Sociology, and International Relations*, 8) *Health Service Management*, 9) *Internal Medicine*, 10) *Cardiovascular and Respiratory Research*, and 11) *Urban Studies*. Most of those themes have been set by DRPM as UI research themes. However, from the results of this study, it was found that more specialized and unique themes occurred as main research areas, such as *Infectious Disease*, *Business and Management*, *Internal Medicine* and *Electrochemistry*. For further research, *text Data Mining Classification Method* with a basic dictionary of knowledge from various disciplines that can be applied to avoid manually grouping keywords in the data pre-processing. By using this method, the grouping of keywords will be more accurate and faster.

6. ACKNOWLEDGEMENT

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