## Unit 9

# SCIENCE EDUCATION IN GLOBAL PERSPECTIVE

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# CONTENTS

# INTRODUCTION

A Global Perspective is 'global' both in content and authorship. Its 17 chapters by an assemblage of seasoned and knowledgeable science educators from many parts of the world seek to bring to the fore current developments in science education and their implications. The book thus covers a wide range of topics in science education from various national and international perspectives. These include the nature of science, science and religion, evolution, curriculum and pedagogy, context-based teaching and learning, science and national development, socially-responsible science education, equitable access for women and girls in science and technology education, and the benefits of science education research. It ends on an optimistic note by looking at science education in 50 years' time with a recommendation, among others, for stakeholders to take the responsibility of preparing children towards a blossoming science education sector in an anticipated future world. This book is suitable for use by discerning researchers, teachers, undergraduate and postgraduate students in science education, and policy makers at all levels of education. Other educationalists and personnel in science and technology vocations will also find it interesting and useful as the reader-motivated approach has guided the presentation of ideas.

# OBJECTIVES

After reading this unit you will be able to**:**

1. Understand the concept of science education in developed and developing countries.
2. know about importance of science education in Pakistan.
3. aware about future trends in science education.

## 9.1. Science Education in the Developed Countries

In the past two decades, a consensus has emerged that science should be a compulsory school subject.However, whilst there is agreement that an education inscience is important for all school students, there hasbeen little debate about its nature and structure. Rather, curricula have simply evolved from pre-existing forms. Predominantly these curricula have been determined by Scientists who perceive school science as a basic preparation for a science degree – in short a route into science. Such curricula focus on the foundational knowledge of the three sciences – biology, chemistry and physics. However, our contention is that such an education does not meet the needs of the majority of students who require a broad overview of the major ideas that science offers, how it produces reliable knowledge and the limits to certainty. Second, both the content and pedagogy associated with such curricula are increasingly failing to engage young people with the further study of science. Indeed, there is a strong negative correlation between students' interest in science and their achievement in science tests. Much of the current concern about science education, expressed in reports such as *Europe Needs More Scientists* [1], concentrates solely on the supply of future scientists and engineers and rarely examines the demand. There is, for instance, a failure to recognize that science is a global activity where the evidence would suggest that there is no overall shortage at the doctoral level [2] although there may be local shortages of particular types of scientists and engineers, for example, pharmacologists in the UK. There may also be shortages at the technician and intermediate levels of scientific and technological work but better data is needed before making major policy decisions on science education. In such a context, encouraging or persuading young people to pursue careers in science without the evidence of demand would be morally questionable. In addition, transforming young people's attitudes to science is a long-term project. Even if it could be achieved readily, it would be at least a decade before any notable change in the supply would be noticed. Rather, the normative economic means of manipulating supply is through adjusting the financial remuneration offered to individuals. The problem with framing the discussion about school science in terms of the supply of the next generation of scientists is that it defines the primary goal of science education as a pipeline, albeit leaky. In so doing, it places a responsibility on school science education that no other curriculum subject shares. Our view is that a science education *for all* can only be justified if it offers something of universal value for *all* rather than the *minority* who will become future scientists. For these reasons, the goal of science education must be, first and foremost, to offer an education that develops students' understanding both of the canon of scientific knowledge and of how science functions. In short that school science offers an *education in science* and not a form of pre-professional training.

Most school science curricula do attempt to serve two goals – that of preparing a minority of students to be the next generation of scientists – and that of educating the majority in and about science, most of whom will follow non-scientific careers. For the future scientist, their education best begins with the fundamentals of the discipline. In this approach, only students who reach a relatively high level of education in science develop a sense Yet it is this latter understanding – good examples of which can be found in the better quality of popular science writing [3] – that everyone requires. Asking the school science curriculum and teachers of science to achieve both of these goals simultaneously places school science in tension where neither goal is served successfully. In addition, the standard school science education has consistently failed to develop anything other than a naïve understanding of the nature of science, commonly called Traditional curricula in school science suffer from a number of difficulties. Knowledge is usually presented in fragmented concepts where the overarching coherence is not even glimpsed let alone grasped – an experience which has been described as akin to being on a train with blacked-out windows – you know you are going somewhere but only the train driver knows where. In addition, there is a growing gulf between the focus of school science – commonly the achievements of the 19th and early 20th Centuries – and the science that is reported in the media, such as astrophysics, neuroscience and molecular genetics.

Moreover, there still remains an enduring problem with the proportion of girls entering physical sciences and engineering in many but not all EU countries. Research has shown that there is a significant disparity between the aspects of science that interest girls and those that interest boys inviting the question as to what extent extant curricula serve the interests of girls?

## 9.2. Science Education in Developing Countries

The authors herein offer the science education community perspective on several issues that influence the teaching and learning of science in developing countries. Moreover, they identify emerging priorities for science education in developing world contexts. Concomitantly, this issue ought to raise the consciousness of individuals in "First World nations" to the issues, concerns, and contextual realities associated with teaching and learning science. Ideally, this Theme Issue will advance a broader discourse toward cultural struggle, empowerment, and possibility. This Theme Issue challenges First World hegemony, while recognizing the need for global collaboration in an ever-increasing global community. In essence, this Theme Issue brings to light the issues and challenges that educators and learners in developing countries address on daily basis. While science educators in developing countries must strive to enhance the educational opportunities available to all students, their real educational mission is often more closely associated with central tenets of social justice. In seeking to create improved contexts for educating learners, it is reasonable to raise our collective consciousness to the science, technology, and societal issues that ought to be addressed by all educators in the decades to come, thereby acknowledging that teaching for social justice is indeed a viable science education goal. Teaching for Social Justice The totality of an education in science is equally as much oriented toward social justice, critical democracy, empowerment, action-taking, and investing in our future's intellectual capacity as it is about constructing conceptual understandings of the world. I recognize that there are individuals who state emphatically that this broader image is not what science education is all about. To such critics I offer the following imperatives: The essence of a learner's education in science must be linked to an understanding of the nature of science *and* learners must be afforded the opportunity to experience the meaning of "education" in science education. I assert that we must transform how we see science education so that it is congruent with both how we see science and how we see education.

Science is about knowing. However, all knowing (therefore all conceptual thought—all theory, concept, and belief) leads to contradictions. One of the most profound problems with "Reality" is that it is changing—constantly. In essence, scientists' search for knowledge is changing constantly as well. The search for knowledge—understanding the

world and the universe—is dynamic! In the context of this search for knowledge, scientists believe in an external world, simply because it is the task of scientists to observe the world "out there" so that conclusions about phenomenon may be drawn. Thus, the process of science is not a quest for absolute Truth or Reality; scientific knowledge is tentative and subject to change; and the practice of science rests upon a number of taken-for-granted metaphysical presuppositions about the external world.
How we see science is essential to how we construct our images of science education.

Education is about hope, dreams, aspirations, and struggle. Hope for a better life, dreams of what the world might be like, aspirations for future successes, and struggle over how to understand and overcome obstacles while searching for and achieving that better life. Education is about expanding upon the knowledge of lived experiences that learners bring to situations; it is about opening doors, opening minds, and opening possibilities. Education must be *for* something.

But what? Education ought to be for the purpose of fostering critical and participatory democracy, enabling students to recognize that the world that is being presented to them is in fact a world that is being made—it is changing constantly—thus, for this very reason, it can be changed, it can be transformed, and it can be reinvented. Education frees the mind to create the future. How we see education is equally as important to how we construct our images of science education. Life World Experiences and the Culture of Science How do these notions of science and education play out in society? As a result of an education in science, people in Western society are willing to accept what science "tells them" about the world and universe. Yet, they are also willing to accept that what is "known" can change, based upon future research and discoveries. Thus, people are willing to both accept what science "tells them" and at the same time they are equally willing to accept that what they have so easily accepted to be true may turn out to be false. How curious! Western popular culture today possesses images of science and scientists much like other cultures' perceptions of village elders, medicine men, and shamans (ironically, the hegemony of Western science fails to view indigenous people's knowledge of the natural world or their healing techniques as "science"). In the realm of Western popular culture, central tenets of science have become a belief system, people place their faith in science, they refer to the "miracles" and "wonders" of science, and they believe that the beliefs that scientists hold about the universe are true. Scientists are viewed as a source of wisdom. These notions of science and scientists are constructed in the context of the current K–12 science education experiences and life world experiences in Western society. Through these collective experiences, students and the general populace have no difficulty whatsoever constructing an image of "science knowledge" that often differs from knowledge used in their life world experiences.

Clearly, in the minds of the vast majority of the populace educated in Western society, the culture of science exists in the context of multiple subcultures and countercultures. Thus, I raise the following question: Have science educators been successful in their efforts to enable learners to construct scientific meaning in the context of the multiple subcultures in which they engage in life world experiences? I believe the simple answer to this question is "no." For this read-256 KYLE son, I believe that the issues and challenges among science educators in Western and non- Western cultures alike are more similar than different. Ultimately, we must seek answers to the following questions: How do we come to see science education in a context that will facilitate learners' conceptualization of an ever-changing world?, and How do we facilitate the conceptualization of meaningful scientific knowledge?

## Knowledge and Science Education

First, we must acknowledge that there exist inequities in our global community with respect to the social distribution of knowledge, as well as with respect to individual access to knowledge. Inequitable social distribution of knowledge and access to knowledge is not merely a phenomenon of non-Western cultures; such inequities exist within Western cultures as well.

The implication for science educators, however, is that the social construction and distribution of knowledge is plural; there is not a singular or universal knowledge. Rather, there are multiple knowledge's. Thus, while everybody thinks, not everyone has access to the same knowledge and not everyone constructs the same meanings in the context of his or her life world experiences. Further, within each culture there are distinctive ways of processing and transmitting knowledge. If we view knowledge as plural, then it is only reasonable that the education in science that learners experience ought to be dynamic, it ought to be linked to one's life world experiences, and it ought to focus upon the world and how we take action in the world. If the world is changing constantly, then an education in science ought to be focused upon the dynamics of change, the whole rather than the parts, and the ways in which individuals act in the world. Such an education in science would be very different from what learners experience today. Rather than focusing upon the whole, we have chosen to focus upon the parts; learners construct knowledge about the parts and never come to understand the whole or the ways in which highly specialized scientific knowledge is synthesized. Seldom does an education in science focus upon action, beliefs, or interactions, all in the context of striving to change, transform, and reinvent the world in an effort to create the future. The focus of an education in science ought to be upon an education that fosters learners' ability to work collectively toward a better society. Such a focus would be in stark contrast to the ways in which learners come to know science through their science education experiences today. The science education that most learners have experienced actually serves to disenfranchise learners from coming to know the world and the universe. The science education that most learners have experienced is bound by disciplines and offers the impression of a static world.

When we view knowledge as plural, then the issues, concerns, and contextual realities raised by authors in this Theme Issue become the starting point for addressing the question: How can we create an education in science that is meaningful to all learners? I suggest that an education in science that is grounded in the context of development and sustainability would foster the kinds of global communication and collaboration that will be imperative in the forthcoming century. Addressing Poverty, Development, and Sustainability Poverty is a worldwide phenomenon. Poverty serves as one of the primary contributors to the inequitable social distribution of knowledge and the inequitable access to knowledge. Of all factors that combine to degrade health, poverty stands out for its overwhelming role. The World Health Organization views poverty as the world's leading killer. Poverty affects health in its own EDITORIAL 257 right: Just being poor increases one's risk of ill health. Poverty also contributes to disease and death through its second-

order effects; poor people, for instance, are more likely to live in an unhealthy environment. The interactions of disease agents, individual susceptibility, behavior (which often reflects education), and local environmental conditions all bear heavily on health outcomes. Poverty—not insufficient global food production—is the root cause of malnutrition. Poor families lack the economic, environmental, or social resources to purchase or produce enough food. We can no longer separate efforts to build an environmentally sustainable economy from efforts to meet the needs of the world's poor. Understanding how poverty affects both the environment and health can enable policymakers and educators to identify new strategies for action. As we approach the forthcoming century, it is increasingly recognized both by governments and by corporations that there is a need for a new economic model—one that facilitates development and is environmentally sustainable. And, one that does not further exacerbate the widening gap between the "haves" and the "have knots." The defining feature of the 20th Century was growth grounded in the context of First World hegemony. In recent years, growth has become the de facto organizing principle for societies around the world. The place to begin a conversation on growth is with human population. In 1900 the world population was 1.6 billion. Total population reached 2 billion by 1930 and 3 billion by 1960. It only took 17 years to add another billion to the global population and a mere 12 years after that to reach a population of 5 billion in 1989. World population will surpass 6 billion this year. If population growth follows the United Nations world population projection, then we will add another 4.6 billion people in the forth coming century. There will be a key difference in the 21st Century growth. During the 20th Century, growth occurred in both industrial and developing countries; during the forthcoming century, almost all the population increase will take place in developing countries—and mainly in urban centers. The population of the present-day industrial world is expected to decline slightly The scientific and technological advances of the 20th Century can be described as phenomenal. The rapid pace of change can be seen in every field of human endeavor. Perhaps the defining economic development of the 20th Century is the harnessing of the energy in fossil fuels. In 1900, only a few thousand barrels of oil were used daily. By 1997, that figure had reached 72 million barrels per day. As we approach the 21st Century though, the key limits to sustainability are fresh water, forests, rangelands, oceanic fisheries, biological diversity, and the global atmosphere. In the forthcoming century we must recognize the natural limits of our behaviors and limit our environmental impact upon the world. An education in science must address the emerging issues of development and sustainability in a global context.
One of the goals of the June 1992 Earth Summit in Rio de Janeiro was to forge a historic North–South partnership to help the world's poorer countries make the transition to sustainable development. A key element of this new partnership was a pledge by industrial countries to increase their aid spending. Seven years later, little of the promised funding has materialized.

However, a shift has occurred since the Earth Summit that is influencing prospects for sustainable Development: international private investment in and lending to developing countries. While there are numerous environmental concerns related to such private investment (especially since studies suggest that industries are generally drawn to the developing world by the low-cost of labor, the availability of natural resources, or the strategic access to new markets) international investment may bring cutting-edge environmental technologies to enable developing Countries to leapfrog over damaging phases of the development path pioneered by the industrial world. Private capital is also moving into the developing world as foreign direct investment (FDI) by transnational corporations setting up local plants, often through joint ventures with lo- 258 KYLE cal companies. FDI is the international capital flow of greatest significance for development, as it is long-term and it has the added advantage of not contributing to a country's debt burden. People in developing countries lack access to many services crucial to a high quality of life. For instance, 1.2 billion people—Z\b of humanity—have no access to clean drinking water, 2 billion people have no electricity, and approximately 3 billion people do not have adequate sanitation services. An important goal of developing country governments is to provide these services to their citizens. Developing the infrastructure to supply services such as electricity, transportation, and sewage treatment often involves large construction projects that are costly both to national treasuries and to the health of the natural world. An education in science should enhance developing countries' future citizenry's capacity to find ways to provide these crucial services in ways that are environmentally sound, socially equitable, and economically affordable. Throughout the developing world there are numerous power projects now in the pipeline that potentially have grave implications for the future health of the planet—especially for the quality of the air and the stability of the climate. Over the next several decades, the bulk of new global investment in the power sector is projected to take place in developing countries. The world's ability to avert a catastrophic global warming over the next several decades will depend in no small measure on what kind of power plants are built. Traditional environmental laws and enforcement systems need to be strengthened in many developing countries. Innovations in national fiscal policy, such as reducing subsidies to environmentally harmful activities and taxing them instead, are necessary as well. Policy reforms that change incentive structures throughout national economies must be implemented, thereby tipping the balance away from environment- EDITORIAL 259.

## Table 1

*The 15 largest countries ranked according to population size: 1998, with projections for 2050*

| | 1998 | | 2050 | |
|---|---|---|---|---|
| Rank | Country | Population (million) | Country | Population (million) |
| 1 | China | 1,255 | India | 1,533 |
| 2 | India | 976 | China | 1,517 |
| 3 | United States | 274 | Pakistan | 357 |
| 4 | Indonesia | 207 | United States | 348 |
| 5 | Brazil | 165 | Nigeria | 339 |
| 6 | Russia | 148 | Indonesia | 318 |
| 7 | Pakistan | 147 | Brazil | 243 |
| 8 | Japan | 126 | Bangladesh | 218 |
| 9 | Bangladesh | 124 | Ethiopia | 213 |
| 10 | Nigeria | 122 | Iran | 170 |
| 11 | Mexico | 96 | The Congo | 165 |
| 12 | Germany | 82 | Mexico | 154 |
| 13 | Viet Nam | 78 | Philippines | 131 |
| 14 | Iran | 73 | Viet Nam | 130 |

15 Philippines 72 Egypt 115

*Note:* Population data are derived from the Population Division, Department for Economic and Social Information and Policy Analysis of the United Nations Secretariat. See, for example, Annual Populations 1950–2050 (The 1996 Revision), New York: United Nations (1996); part of World Population Prospects: The 1996 Revision, New York: United Nations (1997).

## 9.3. Science Education in Pakistan

Education plays a vital role in human capital formation. It raises the productivity and efficiency of individuals and thus produces skilled manpower that is capable of leading the economy towards the path of sustainable economic development. Like many other developing countries, the situation of the education sector in Pakistan is not very encouraging. The low enrolment rates at the primary level, wide disparities between regions and gender, lack of trained teachers, deficiency of proper teaching materials and poor physical infrastructure of schools indicate the poor performance of this sector.

Education provides the bedrock for reducing poverty and enhancing social development. An educational system of poor quality may be one of the most important reasons why poor countries do not grow. In Pakistan, the quality of education has a declining trend. It is realized that science education in particular is reaching lowest ebb and needs to be improved urgently. There is acute shortage of teachers. Laboratories are poor and ill equipped and curriculum has little relevance to present day needs. The schools generally are not doing well. Tracing causative factors responsible for the present state is a critical need. These include defective curricula, dual medium of instruction at secondary level, poor quality of teachers, cheating in the examinations and overcrowded classrooms (Economic Survey of Pakistan, 2002). In Pakistan efforts have been made to mould the curriculum in accordance with our ideological, moral and cultural values as well as our national requirements in the fields of science, technology, medicine, engineering and agriculture, etc. The rise in supply of educational infrastructure or removal of the supply side constraints can play an important role in raising literacy and education of the population. Development budget allocation for the social sector has been very low throughout and is evident from the budgetary allocation for education.

## 9.4. Future Trends in Science Education

The importance of science education at different levels has been stressed by educators and researchers as it plays multiple roles in enhancing citizen's scientific literacy, promoting the scientific and technological capacity of the workforce, and fostering next generation school science educators (NSF 1996; NRC 1997, 1999, 2000). Research in science education has been called to be conducted with an aim to critically "inform educational judgments and decisions in order to improve educational action" (Bassey 1995, p. 39) at different levels. It is critical not only to conduct relevant science education research to help science teachers improve their classroom practice and play better roles in enhancing scientific literacy, but also to understand what have been studied in the past in order to know what could be explored further in the future. This study applied automatic content analysis methods from scientometrics to investigate the development trends of science education research. In particular, we proposed a multi-stage clustering technique based on bibliographic coupling to examine with what topics, to what development trends, and from whose contributions that the scientific journal publications constructed as a science education research field.

## Curriculum Reforms and Science Education

The development of current research and curricular activities in science education can be traced back to the science education reforms in the late 1950's in the USA (de Jung 2007; Fensham 2004). In his review, de Jung (2007) indicated that the three main waves of science education reform in the 1950, 1980, and 2000's have shifted the foci of curriculum design and brought the evolution of science education research. The science education curriculum reform in the USA started with the recognition of the deficit of the nation in science and technology (de Jung 2007). The relatively low quality of science education was seen as the main cause of the nation's inferiority to the former Soviet Union, who launched the first man-made satellite (Sputnik) in 1957. Instead of memorizing scientific facts, the major science curriculum reform efforts after Sputnik emphasized the understanding of basic scientific concepts and the process in learning science.

The second science curriculum reform in the 1980's was brought by the alarming report, *A Nation at Risk* (National Commission on Excellence in Education 1983). The report warned that the USA had been falling behind in the international economic and industrial competitions because of the weaknesses in the educational system. As de Jong (2007) indicated, this wave of curriculum reform focused on turning the student's passive school learning into an active process and connecting the learning of scientific concepts to their application in daily lives. Researches during this reform also focused on science learning as a conceptual change process.

The understanding of conceptions in science teaching and learning seemed to be overly emphasized after the early 1980's. It was indicated that this approach may prevent students from linking their conceptual learning to the social and cultural context. The later evolution of constructivist views of learning has marked as the third wave of educational reform in the science education researches since late 1990's (de Jong 2007; Jenkins 2001). As a result, social and cultural dimensions and the science-technology-society (STS) issues were brought into the scene of science curricula and research. In addition, new technologies such as computer-assisted instruction and the use of Internet also gained attention (de Jong 2007).

## The Development of Science Education as a Research Field

Fensham (2004) used dimensions of structural, intra-research, and outcome in the judgment of the establishment of a discipline or a research field. In the structural dimension, Fensham (2004) indicated that a well established research field is: (1) to create the full professorial appointments to gain *academic recognition*; (2) to have *research journals* to publish quality research and report the research outcomes; (3) to found *professional associations*; (4) to hold *research conferences* periodically so that direct exchange and interaction among researchers can be made; (5) to establish *research centers*; and (6) to have *research training* plans to foster researchers.

For the dimension of professional association and research journals, studies have indicated that the USA was the first country to devote to science education research (Fensham 2004; Treagust 2006). For example, the first journal concentrating on research of science teaching and learning, *Science Education* (SE), was first published in 1916 in the USA. On the other hand, the worldwide acknowledged research association, the National Association for Research in Science Teaching (NARST), was founded in 1928 and still holds international conference annually. Sponsored by the NARST, the *Journal of Research in Science Teaching* (JRST) publishes 10 issues per year and has great impact on research in science education.

With the worldwide spread of journals on research of teaching and learning in science, science education as a distinctive field of research emerged and was developed internationally since mid-1900's (Fensham 2004). Examples of the prominent science education research journals include JRST, SE in North America, *International Journal of Science Education* (IJSE, initially the European Journal of Science Education) in Europe, and *Research in Science Education* (RISE) in Australasia (White 1997).

One developing trend in science education research is that a wider range of countries were participating in research publication activities (Lee et al. 2009; Treagust 2006), which can be evidenced in the country's level in the structural dimension (Fensham 2004). For example, as an active member in the international science education research community, it was not until the 1980's that Taiwan started founding academic science education organizations and research institutes. In the 1990's, publications from Taiwan researchers started to appear in the international English-language journals.

Although the importance of science education had been brought to educational policymakers' attention in the 1970's, it took more than 30 years of gradually development for science education, as seen in the structural dimension (Fensham 2004), to be regarded as a research field in the educational institutions. For example, sponsored by the Ministry of Education of Taiwan, the science education center was established at the National Taiwan Normal University (NTNU) in 1974. Later in 1986, the institute of science education (graduate school) was founded at the NTNU and more graduate schools of science education have been established at other universities since. In the meantime, during the mid-1980's, the Chinese association of science education (CASE) was founded and a CASE-sponsored science education conference was held annually. In 1993, sponsored by the CASE, the quarterly Chinese Journal of Science Education began to publish academic papers in the research of science education. It was then Taiwan's participation in international academic activities in science education started. For international research journals, it was not until 1993 that the science education scholars from Taiwan published in journals of SE and JRST.

## Research in Science Education

To understand how the research field has developed, researchers may investigate from a wide range of the structural perspectives such as educational reform movements (de Jung 2007) and the development level of the academic environment (Fen sham 2004) to delineate the scope of science education research. On the other hand, using content analysis approach on literature review was also usually conducted to gain a more detailed view of the development trends (e.g., de Jung 2007; Rennin 1998; Lee et al. 2009; Tsai and Win 2005; White 1997).

In comparing different editions of Handbook of Research on Teaching, White (1997) pointed out that research styles and research topics were two major changes in science education research since the second edition of the handbook published in 1973. In his study, a content analysis of journal articles was conducted to further examine the above observed changes. White (1997) used science education research articles in the Education Resources Information Center (ERIC) database and the journal RISE as sources of data. His analysis on research topics trends was done by counting the keywords of the articles from 1965 to 1995. The investigation of research style trends was across three decennial reference points of 1975, 1985, and 1995. The analysis concluded that science education research has shifted from laboratory-style experiments to observation and description of classroom practice while interviewing as research tool has become common.

With a focus on the quality of research, Rennin (1998) and Eye and Schmidt (2001) examined science education literature from the perspective of how to report research results and to improve research quality. After examining research articles published in the five journals of IJSE, JRST, RISE, SE, and *Research in Science and Technological Education* (RSTE) in 1996, Rennin (1998) illustrated and provided recommendations on how to present and improve the quality of quantitative research. Eye and Schmidt (2001) investigated the research trends in chemical education through a review of 81 studies published in the journals of JRST and IJSE from 1991 to 1997. As a result, quality criteria were suggested to include six categories: theory relatedness, quality of the research question, methods (for quantitative and qualitative studies), presentation and interpretation of results, implications for practice, and competence in chemistry.

In two time periods of 1998–2002 and 2003–2007, a series of content analysis comparing three major science education journals of IJSE, JRST, and SE were conducted (Lee et al. 2009; Tsai and Win 2005). In these studies, researchers' nationalities, research types, and topics were analyzed and the trends were compared. It was indicated that researchers from the English-speaking countries contributed to most of the research products during the two time periods although the researchers from non-English speaking countries had increasing number of research articles, especially during the period of 2003–2007. As revealed, empirical study was the major research type during the two time periods while most of the empirical articles employed qualitative method in 2003-2007. In the studies, the research topics were categorized by the adapted NARST conference strand categories. The analysis found that the topics of "Learning-Context" and "Teaching" were gaining more attention from 1998 to 2007 while the topics of "Learning Conceptions" and "Culture, Social and Gender" were in decline.

De Jog (2007) also adapted conference themes, from the NARST and European Science Education Research Association (ESERA), as a pre-set framework to analyze research topics trends of science education for the 2 years of 1995 and 2005 in three selected journals of JRST, IJSE, and SE. The analysis revealed that the researches were becoming small-scaled in research design while more qualitative data collection methods were used. The top three research topics in 1995 were "students' conceptions", "practical work", and "teachers' content knowledge." In 2005, "practical work" was still in top three research topics, but "students' conceptions" and "teachers' content knowledge" were replaced by the topics of "teachers' pedagogical content knowledge" and "STS and context-based issues."

### Scientometrics on Research Trends of Science Education

As seen from the above literature analysis, the reviews of science education research varied in purposes. There were researchers aiming to provide guidance for improving research quality (Eye and Schmidt 2001; Rennin 1998); while others focusing on identifying major features and contributors such as authors, topics, and research types (de Jog 2007; Lee et al. 2009; Tsai and Wen 2005; White 1997). In addition, attention was also paid to point out what have missed and might be done in future research (White 1997). Although various trends of science education research have been identified through literature reviews, variables such as researchers' personal interests, level of professional knowledge, and use of traditional narrative review method could have led the reviews to subjective interpretations. Further, by using a pre-set category structure as analysis framework, the research topic ranking would depend on the category that the researchers choose to use (de Jog 2007). That is, different category structures could generate different topic ranking results when analyzing the same data.

To present a comprehensive and longitudinal overview, this study used the scientometrics method (Braun 2007) to conduct a development trends analysis of science education research. A total number of 3,039 articles from four of major science education research journals, namely IJSE, SE, JRST, and RISE, during the period from 1990 to 2007 were analyzed. With the application of the automatic content analysis method, this study analyzed the structure of science education research by identifying the major study topics, the development of research threads, the countries and the leading authors, and the most cited references on which the research community was formulated.

Instead of matching the articles reviewed with a pre-set topic structure, the research topic categories in this study were developed inductively as emerging from the entire corpus of the four journals from 1990 to 2007. This grounded approach took root on the materials to provide educators, researchers, and policymakers of science education an overview of the structure and evolution of the field. It was expected that this study would help educators and researchers reflect on the trends and issues in science education research, advance their understanding in science education, and pursue further exploration and practice in research and teaching. This study would also report on how automatic content analysis technique was used to explain and interpret the trends of science education research to yield information useful for further application of scientometrics in science education research.