Chapter 2
Research Projects on Science Education Funded by the National Science Council in Taiwan from 1982 to 2012: A Historical Review

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Abstract The National Science Council (NSC) in Taiwan supports research in science education and is a major funding agency for such research. The major themes and trends of science education research projects funded by the Department of Science Education (DSE) of the NSC from 1982 to 2012 are reviewed in this chapter. This review includes official documents from the NSC, such as Calls for Proposals and Annual Reports, which include information about the goals of science education research, research strategies implemented, number of projects funded annually, and the distribution of the funded research projects across the evolving scheme for categorizing research in science education. Special emphasized research topics that occurred from time to time are also highlighted. NSC research projects are granted financial support based on a well-developed evaluation system. Specific features of the evaluation system, their impact on the research community, and additional measures to promote science education research are also described in this chapter. Certain objective data are used to illustrate the outcomes and achievements of the NSC-funded projects. Since the principal investigators are the direct and key participants involved in the DSE funding process, a questionnaire was developed to better understand their experiences and viewpoints regarding the impact of the DSE-funded research projects. The implications from this review and the survey results are discussed in terms of improving the funding process and policies, and informing future directions in science education research.

2.1 Introduction

Research in science education plays an important role in better understanding how students learn science and how teachers can teach science more effectively. In order to prepare scientifically literate citizens and ensure countries can use science to solve

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problems and advance their quality of life, both science education and research in it are considered integral parts of numerous nations' plans for development in science and technology. For Taiwan, a small island with limited natural resources, the importance of national development in science and technology has been widely recognized as witnessed by the establishment of the National Science Council (NSC) in 1959 and the publication of a series of national White Papers on Science and Technology. With the formal establishment of the Department of Science Education (DSE) in 1982, the NSC began to provide strong support and leadership for research in science education.

Since then, research in science education in Taiwan has flourished. In recent years, research from Taiwan has even risen in prominence in the international science education community (Chang 2012). Whether this success is the result of long-term coordinated efforts or coincidence, and whether the heyday of research in science education in Taiwan has just begun or is doomed to soon pass remain unanswered questions. In addition, we must ask what lessons can be learned from the past in order to inform the DSE and the Taiwanese research community so that Taiwan continues to contribute to the field of science education locally, nationally, and internationally. Only by answering these questions can we ensure future generations will be well prepared for the worldwide socio-scientific challenges that lay ahead.

2.1.1 The Purpose of this Chapter

A good understanding of the background and growth of research in science education in Taiwan can identify the effectiveness and limitations of the DSE-funding policies and practices and offer insight into future possibilities. With this in mind, the purpose of this chapter is to provide a historical account pertaining to the following questions:

- What were the aims of the DSE for funding research projects on science education?
- What were the funding policies, funding schemes, evaluation criteria, and practices regarding research ethics and how did they evolve in time?
- What kinds of research projects were funded and what were their trends over the years?
- Who were the participants involved in these research efforts? What were the products, outcomes, and impacts of these research projects?
- What lessons were learned from such a historical review?

2.1.2 Contextual Background of Science Education Research in Taiwan

To provide background for international readers, this section gives a brief account of the status of research on science education in Taiwan. First, most parents and

the general public alike tend to consider school education, in general, and science teaching and learning, in particular, as important. Most parents and teachers have high expectations for their children and students in terms of their behavior, attitude, and academic performance. Following elementary school, students compete fervently to enter prestigious high schools and colleges/universities. It is a common phenomenon for teachers and their students to be willing to participate in research studies if they believe such participation could help the students get higher test scores. However, this is not true at grades 9 and 12 when it is generally very difficult to negotiate or persuade schools and teachers to allow 9th- and 12th-grade students to take part in research studies. The main reason for this difference is that teachers are busy preparing their students at these grades to take tests that essentially will decide which high schools or universities the students may enroll in. In addition, extraneous factors that could confound research results must be considered since many Taiwanese students from grades 1 through 12 attend a wide variety of enrichment classes and academic activities after school. Aiming at helping students get higher test scores, it is a common practice for teachers at so-called "cram schools" to emphasize improving students' knowledge and skills via memorization and contrived drill-and-practice problems instead of putting emphasis on meaningful conceptual understanding and application of core concepts and basic principles.

Although the students participating in a study funded by the DES may include kindergarten to university students and the general public, typically most studies focus on science education at the elementary, junior high-, and senior high school levels. For these studies, it is easy to invite teachers, school administrators, and principals to participate in a research study if they have finished their degrees at, or are currently enrolled in a professional development program offered by the home institution of the primary investigators and associated researchers. Of course, there are ethical and pragmatic pros and cons of such a practice, and one has to be careful in interpreting and generalizing the research results so obtained.

Science education researchers in Taiwan come from a number of institutional sources, including normal universities (referring to universities training students to be teachers), colleges and universities of education, colleges and universities offering educational courses and professional development programs, science museums, etc. Since preparing science teachers is part of science education researchers' professional responsibility, faculty members in the teacher preparation institutions have the advantage of combining teaching and research. They are also in close contact with schools and teachers and generally in a better position to invite teachers, school administrators, and principals to participate in a research study. There are some, but relatively less, principal investigators and researchers who teach science, mathematics, and other interdisciplinary courses at the college and university level. Principal investigators for research projects on science education funded by the DSE are mostly PhD degree holders majoring in science education (including mathematics education, etc.), or in science, mathematics, technology, information science, medical science, cognitive science and other related fields. While many cross-disciplinary projects may involve associated researchers majoring in education, the humanities, and other related fields, faculty members who major in these

areas are less likely to be principal investigators on research projects in science education. For those investigators and researchers who come from higher education institutions and government-supported science museums, conducting research studies and publishing the results is an essential part of their professional activity and helps them to develop professionally and move toward the upper ends of the academic and administrative ladders.

Since the first establishment of the DSE at the NSC in 1982, science education research and related research activities have flourished in Taiwan as evidenced by the increasing number of junior faculty members going abroad to do their advanced studies in science education, the number of returning PhD and EdD degree holders majoring in science education, the initiation of master's and PhD degree programs in science education in Taiwan since 1987, the establishment of the Chinese Science Education Association in 1988, and the publication of the first issue of the *Chinese Journal of Science Education* in 1993. Concurrent with the implementation of a series of educational reform initiatives since the mid-1980s, science educators/researchers in Taiwan have produced a wide range of research results that significantly impacted science teacher education and professional development and resulted in better understanding of students' learning in science and mathematics, the improvement of science/mathematics teaching and assessment, and the development of more effective teaching materials and strategies. Meanwhile, science education researchers in Taiwan actively participate in international conferences and publish the results of their studies in well-known international journals on science, mathematics, technology education, and so on. Many internationally well-known science educators and scholars from Taiwan have been invited to participate and speak at workshops, seminars, and conferences. Currently, a number of Taiwanese science education researchers actively participate in the science education community internationally, including for instance, Chang, C. Y. (editorial board, *Journal of Research in Science Teaching*, JRST; associate editor, *International Journal of Science and Mathematics Education*, IJSME), Chiu, M. H. (associate editor, JRST; editorial board, IJSME), Lin, J. W. (editorial board, JRST), Tuan, H. L. (former associate editor, JRST; editorial board, IJSME), Lin, H. S. (editor-in-chief, IJSME), Tsai, C. C. (editor-in-chief, *Computers and Education*; former associate editor, IJSME), and Wu, H. K. (editorial board, *Science Education*).

Across a span of a few decades, research on science education in Taiwan has grown tremendously. It is a collective effort to which the government and many individuals have made significant contributions. From the 1980s onward, the establishment of national policies on science and technology was a major concern of the central government. This resulted in continued interest and support for research in science education during a period of economic growth. As a result, there was improvement in the national infrastructure, the transformation of nine normal schools into normal colleges, a substantial increase in the number of higher education institutions, and a series of educational reforms including reforms in science education. All these wider contextual events are important factors influencing the development of science education research in Taiwan.

2.1.3 The Scope, Limitations, Methods, and Implications

The DSE provides funds, on a competitive basis, for researchers to do research in a range of fields, including primarily mathematics, biology, chemistry, and physics. However, substantial funds are also available for educational research in other closely related fields such as technology, information science, engineering, environmental science, medical studies, public science, and so on. It is therefore worthwhile pointing out that, unless explicitly mentioned, the term "science education" is used in the broadest sense so that it refers to educational studies in disciplinary areas including science, technology, environment, mathematics, and other closely related fields.

As with other fields in education, science education can be taken as a policy–practice–research triad occurring in a context influenced by personal, social, educational, cultural, economic, and political factors. It is a complex system within which the constituent parts, their interrelationships, and the system boundaries are changing over time in a way which may not be easily identified, predicted, and/or explained. A systematic study of the system unavoidably will include close examination into the inputs, the contents, the contexts, the processes, and the products and their mutual relationships at different levels of investigation, or "grain sizes." Realizing the complex nature of the science education enterprise, we shall focus our attention primarily on the aspects that are directly related to research in science education, while only briefly touching upon the aspects concerned with practice and policy in science education. Our historical review focuses on characteristics of the DSE funding policies and practices and the outcomes and impacts of funded projects at the collective level, and no attempts are made in this study to evaluate the performance and effectiveness of an individual research grant, a specific funding scheme, a particular research field, or the DSE as a funding agency.

In essence, no attempt is made to answer questions such as: Was the time and money spent on the funded project worthwhile and what were the reasons for the success/failure of the funded program? Certainly, these kinds of evaluative and cause-and-effect questions are proper and important, and in fact a major concern of many reports and publications (Cressman et al. 2009; National Academy of Sciences 2011; Reinhardt and Milzow 2012). However, realizing that valid and justified answers to these questions would require much more rigorous methodologies and efforts than what we can afford to do in the present chapter, the authors chose a primarily qualitative and descriptive approach to answer the set of questions mentioned at the beginning of this chapter.

In this study, we shall look at the mission and role of the DSE at the NSC, closely examine its funding policies and funding schemes, together with the evaluation criteria and practices on research ethics, and see how it uses the resources available to help the science education research community in Taiwan rise in prominence internationally. The approach taken is similar to the Case Study Evaluation Model described by Stufflebeam (2001), especially since the case study approach is characterized as a context-bound questions/methods-oriented approach rather than an

improvement/accountability approach. Aiming at presenting a historical review of the research projects on science education funded by the NSC in Taiwan from 1982 to 2012, the authors echoed the "attempt to systematically recapture the complex nuances, the people, meanings, events, and even ideas of the past that have influenced and shaped the present" (Berg and Lure 2012, p. 305).

Official documents from the NSC and the DSE, such as White Papers on Science and Technology, Yearbook of Science and Technology, NSC Review, National Science and Technology Development Plans, DSE Calls for Proposals and self-evaluation reports, and additional special reports were reviewed. Some of these documents are available in English, often in abridged versions. For instance, a series of official documents concerning national policies on science and technology can be found online at the NSC website: http://web1.nsc.gov.tw/ct.aspx?xItem=9257&CtNode=1000&mp=7. A set of science and technology yearbooks from 2002 to 2012 are available in English at the NSC website: http://yearbook.stpi.org.tw/englishpdf.html, while the Chinese version, originally in hard copy, can be traced back to 1983. These reports include important information such as the number of projects funded, the research funds spent, the number of researchers involved, important research activities and results, the total number of papers published, and other research products and outcomes. Following general guidelines of historical research (Berg and Lune 2012), the authors paid special attention to the selection, organization, and analysis of the most pertinent collected evidence. Data from the official documents were cross-checked to verify the authenticity and accuracy of source materials.

In addition to the aforementioned tangible measures, there are other important effects that are less obvious, take time to build up, and are hard to measure quantitatively. As the authors have played a range of roles at different stages , including principal investigators, coordinators/leaders of large-scale research projects, primary and secondary reviewers, consultants to the DSE, and director of the DSE (the first author), we are able to assess and judge the validity and accuracy of the information presented in various official documents collected in this study, to assess the effectiveness of the DSE funding policies and practices, and to make qualitative assessments of the outcomes and impacts of the DSE-funded projects, based not only on our experiences but also on reflections of our own career paths and the observations of the professional trajectories of many science education researchers in Taiwan. However, in order to downplay the roles of our subjective opinions, we developed a short questionnaire to uncover principal investigators' perceptions on these matters.

In principle, research results obtained from the DSE-funded projects have implications for policymakers, researchers in the science education community, science education practitioners, students, parents, and the general public. It is beyond the scope of the current study to carry out a comprehensive survey on such a wide range of stakeholders regarding their viewpoints on the impact of DSE-funded research projects. Since the principal investigators are the most direct and key participants involved in DSE-funded research projects, a 25-item questionnaire was developed in this study, using a four-point Likert scale, to find out their viewpoints on the impact of DSE-funded research projects. The data obtained from the questionnaire

were used to substantiate our assessments and comments on the impact of DSE-funded projects.

Through our historical review, we hope that international and domestic science educators and researchers will have a more holistic understanding of what the science education research community in Taiwan has done, what we have achieved so far, what remains to be done, and continue to pursue success and excellence in doing science education research. However, because of differences in educational, cultural, social, and historical backgrounds among different countries or geometrical areas, what seems to work in Taiwan may or may not work elsewhere. Therefore, for the interests of the international readers of this book, we hope to share our experiences as a case and leave readers to figure out what lessons are of interest or use to them.

2.2 Overview of the Funding of Science Education Research by the NSC

2.2.1 Historical and Organizational Background

The NSC, established in 1959, plays a significant role in supporting university faculty members' research in a wide range of fields, not explicitly including science education in the beginning. The burgeoning of science education research in Taiwan can be traced back to the official establishment of the DSE at the NSC in 1982. Since then, the DSE has been charged with the special mission, among others, to plan and promote research and development of science education. Of course, this does not imply that there are no other government funding organizations for research and development in science education, nor does it mean that research and development of science education were nonexistent in Taiwan prior to 1982. In fact, at the government level, both the Ministry of Education and the NSC had initiated important programs related to the research and development of science education as far back as the 1950s. Concurrent with science education reforms worldwide, initial efforts on science education at that time focused mainly on the development of science curriculum, teacher professional development, and evaluation of students' achievement in mathematics and science. By the early 1970s, there were a handful of professors, including Chin-Chi Chao at the National Taiwan Normal University, who began to advocate the importance of research in science education. However, prior to 1982, the number of government-funded research studies, the researchers involved, and the research budgets spent on science education research were limited.

Concerning the promotion of research and development in science education, the NSC and the Ministry of Education reached a consensus in 1985 that the NSC would be responsible for basic research and exploratory developmental studies, while the latter would be responsible for the implementation and application of

more practically oriented studies. Such a consensus has been honored throughout the years, although there are clearly the cases in which both parties worked collaboratively. Representative examples of such collaborative works include the joint efforts of the two governmental agencies on the improvement of assessment of students' learning in science and mathematics in the 1980s, and the participation of Taiwanese students in Trends in International Mathematics and Science Study (TIMSS) and Program for International Student Assessment (PISA) in recent years.

As a subordinate unit of the NSC, the missions and strategies to plan and promote the research and development of science education at the DSE follow the goals and visions on science and technology determined by the NSC and the Executive Yuan. A useful official document—Yearbook of Science and Technology Republic of China—provides a comprehensive description of the national policies, strategies, and progress in science and technology and is compiled annually by the NSC since 1983. Online versions in English have been available since 2002 (http://yearbook.stpi.org.tw/englishpdf.html). As can be seen from a glimpse at these yearbooks, the development of a population literate in science and technology continues to be a major national concern, and development of science education is part of the entire design. In fact, each yearbook contains a summary of the number of sponsored projects, the population of researchers, and the number of topics funded by the NSC each year.

According to the NSC Charter, the DSE is responsible for the following (also see http://www.nsc.gov.tw/sci/ct.asp?xItem=5233&CtNode=1347):

- To plan and promote the research and development of science education.
- To review and approve funding for research projects in science education.
- To research, guide, and expand popular science education.
- To publish scientific journals.

Officially, a department director is appointed to take charge of the DSE, which comprises a dozen or so staff members. Compared to other governmental organizations, a distinct feature of the NSC concerning personnel affairs is that it operates under a more flexible system of rules and regulations. For example, the director of the DES, typically an active and experienced science education educator/researcher, is chosen from the research community to serve at the NSC for a term of 2 years. It can be renewed for an additional term. The staff members working at the DES are also hired and promoted through a channel emphasizing research competencies rather than administrative knowledge and skills. In addition, a number of panels and ad hoc committees composed of members of the university research communities help the DES function at its best and provide needed advice.

According to a special report (in Chinese) celebrating the 30th anniversary of the NSC, the DSE, back in 1984, commissioned a group of six professors, including Cheng-Hsia Wang, to come up with a preliminary report delineating the future direction of science education research. The report displayed a three-dimensional structure of science education in terms of subject matter disciplines, substantial elements, and organizations. It also specified the levels, categories, and subjects of research in science education. In addition, research areas and important research

topics were illustrated. In 1986, the DSE recommissioned a wider group of science and mathematics educators/researchers to prepare position papers for the four major disciplines that are included in the elementary and high school curriculum, namely, mathematics, physics, chemistry, and biology. Important research domains and topics within each of these disciplines were delineated in these documents, providing a useful reference for the DSE to prepare the annual Call for Proposals and for researchers to choose research topics. Of course, with time, suggestions and recommendations from these earlier documents were revised or replaced with more relevant ones, in response to various internal and external changes.

In order to meet the demands of mid- to long-term plans on national progress and development, the Ministry of Education and the NSC jointly held the First National Conference on Science Education during December 20–21 in 2002. The DSE played an important role in preparing a first draft of the White Paper on Science Education in 2001 and initiated six public hearings prior to the conference, in which a wide range of scholars, government officials, as well as opinion leaders from the general public were invited to participate. The consensus and conclusions reached at the 2002 conference resulted in the publication of the White Paper on Science Education in December 2003 by the Ministry of Education. A Chinese version of the White Paper is available online (MOE 2004). In addition to setting out the visions, goals, and implementation strategies, the importance of research in science education and research focus and priorities was emphasized. Calls for establishing adequate science education policy and environment were also included. The White Paper on Science Education has served as an important guide for research in science education for the past 10 years.

2.2.2 Evolving Funding Policies and Practices

Just like other government offices, the annual budget for the DSE has to go through a standard review procedure that takes into account both the DSE's prior performance and proposed plans for the future. Once the annual proposal and the required budget are formally approved, the DES is responsible for carrying out its assigned missions, including most importantly the planning and promotion of science education research. Following broad guidelines from the NSC, the DES assumes the responsibility for developing pertinent funding policies and implementation strategies, generally with input from a number of ad hoc committees. With this input, the DES announces a Call for Proposals each year, delineating the important research themes and topics that the DES wants to encourage researchers to work on. In response to various external and internal influences, the research focuses and priorities as revealed in the annual Call for Proposals evolve and change over time. In addition to the annually announced Call for Proposals, the DSE also puts forward mission-oriented research programs from time to time, either autonomously or jointly with other government funding organizations, and invites researchers to apply for available grants.

Since the submitted proposals are awarded on a competitive basis, application forms and criteria for evaluation are also included in the Call for Proposals. The submitted proposals are evaluated through a unique review process that consists of two stages—a preliminary formative stage and a final decision stage. At first, each proposal is individually peer-reviewed by two referees. According to the policies and practices emphasized in the Call for Proposals, evaluation forms and guidelines to the reviewers have been developed and revised from time to time. The evolving evaluation criteria adopted in the first-stage review typically include categories such as the significance and quality of the proposal, research outcomes and impacts from previous research projects, the publication records and other bibliographic measures, the competencies of the principal investigator, and so on. In the early 1980s, submitting a research report may be considered as having fulfilled the criteria of producing research outcomes and impacts from previous research projects. Good publication records were taken into account since the early 1990s, and comprehensive schemes were developed to provide quantitative measures for this category. Since then, research articles published in *Social Science Citation Index* (SSCI), *Science Citation Index* (SCI), and *Engineering Index* (EI) journals with high impact factors and a few domestic science education journals were assigned higher credits, as compared to other journals, books published, and papers presented in seminars and conferences. However, the reviewers are also requested to evaluate the quality of the published papers and the potential contributions and impacts of the research outcomes.

As an example, the preliminary stage review form for a great majority of research proposals submitted to the DSE for the 2013 school year mainly consists of the following four categories: (1) alignment with the Call for Proposals (10%), (2) contribution to science education and novelty (20%), (3) contents of the proposal, that is, whether the proposal is well prepared (30%), and (4) principal investigator's previous research outcomes and competencies (40%). Besides these, the reviewers are also requested to provide a summary of evaluation, make suggestions for financial supports, check whether adequate approvals are provided in case the research involves human subjects in biomedical and behavioral studies, and a list of overall comments to be forwarded to the DSE and reviewers at the secondary stage.

The above example serves to illustrate that the evaluation criteria adopted by the DSE are designed to help increase research involvement in selected research areas and improve the quality and impacts of research outcomes. As major research granting agencies, the NSC and the DSE also pay particular attention to issues related to research ethics. Especially in recent years, research projects that involve human subjects in biomedical and behavioral research are required to obtain permissions from Institutional Review Board (IRB). Particular attention is paid to issues on intellectual property rights and research misconducts such as fabrication, falsification, and plagiarism in proposing, performing, or reviewing research, or in reporting research results. Within the NSC, there are guidelines for dealing with cases on research misconducts, the latest version (in Chinese) being updated in February 2013.

As mentioned above, the referees at the first stage are required to write detailed comments and suggestions about the proposal. These written comments and

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