Chapter 5
Content Analysis of Conceptual Change Research and Practice in Science Education: From Localization to Globalization

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Abstract This chapter reviews the current research on conceptual change in science education. The review includes research located in the DoRise system (Database of Research in Science Education) in Taiwan and articles published in selected international science education journals *(Journal of Research in Science Teaching, Science Education, International Journal of Science Education, Research in Science Education, and International Journal of Science and Mathematics Education)* between 1982 and 2012. Three hundred and eighty-three articles in the international journals (including 26 English papers from researchers in Taiwan) and eighty-six articles from Taiwan were analyzed (60 and 26 articles from Taiwanese and international journals, respectively). There are five major findings. First, most of the research follows the empirical approach, regardless of it being an international or national article. Second, physics was the main discipline examined both in the international and national studies. Third, about two thirds of the studies from outside of Taiwan used epistemological perspective to frame and present their study. A similar percentage of articles investigated the instructional perspective whereas nearly two thirds of the Taiwanese articles investigated the instructional perspective and only 28% followed the epistemological perspective. Fourth, as for the research method, we found that qualitative data analysis was ranked first among all the methods we investigated whereas Taiwan appeared to integrate both quantitative and qualitative methods. Fifth, as expected, high percentages of published researchers were from English-speaking countries (i.e., the USA, Australia, and the UK). Taiwan was ranked third out of 31 countries with respect to the number of publications in this study from 1982 to 2012 but was the first non-English-speaking country. Recommendations for researchers and educators are provided.

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5.1 Introduction

For the past three decades, there have been studies investigating learners' pre-instruction conceptions and their impact on learners' understanding of scientific phenomenon. Consistent findings regarding the difficulties involved in changing conceptions that learners hold prior to and even after formal instruction were revealed across genders, grades, and cultures. This research showed that learners tend to hold their intuitive knowledge across years and tend to revert to original conceptions even after formal instruction. The robust nature of prior knowledge is believed to be the result of the difficulties inherent in developing true scientific knowledge. Scientific concepts are often abstract, complex, and counterintuitive, and as a result are commonly perceived as not aligned with learners' daily life experiences. To face this challenge, science education researchers proposed different frameworks and theories on conceptual change to explain why naïve conceptions are difficult to refine, restructure, or even remove. The most cited reference on conceptual change is Posner et al. (1982) who advocated that a learner has to feel dissatisfied and conflicted about one's conception before one can accept the scientific concept. They provided conditions that must be met during instruction to successfully promote conceptual change in science learning. These include (1) dissatisfaction with existing conceptions, (2) new conception must be intelligible, (3) new conception must appear plausible, and (4) new conception should suggest the possibility of a fruitful program. This theory on changing learners' intuitive conceptions to scientific concepts has been challenged (Gunstone 1990; West and Pines 1983) for its view of learning as a merely rational activity. It has also been modified to take into account the interaction between scientific conceptions and misconceptions, learners' motivation, and social interaction among learners (Strike and Posner 1992).

The research field on conceptual change is inspiring and pioneer work gradually received the attention of researchers from various fields. To conduct this study, we searched "conceptual change" as a keyword on Web of Science (WOS) (http://www.isi-thomsonreuters.org/), and we found 1788 articles from 1970 to 2013 (through 10 October 2013). In other words, as far as the WOS list is concerned, we found that the earliest article was dated 1970. According to the results from the WOS, there was a dramatic increase in the number of articles in the area of conceptual change published from 1992, about 10 years after Posner et al. (1982) published their pioneer work and then continuously increased (see Fig. 5.1).

As a tribute to the 30th anniversary of Posner and his colleague's influential article on conceptual change in science education, being first published in 1982 (Posner et al. 1982), we selected 1982 as the starting year for our literature review, going on till 2013. Figure 5.2 shows the gradual growth in the number of publications on conceptual change. Dramatic increases are not evidenced during the first 10 years following Posner et al.'s seminal publication. The three years, 1998, 2007, and 2010, represent peaks in the number of publications.

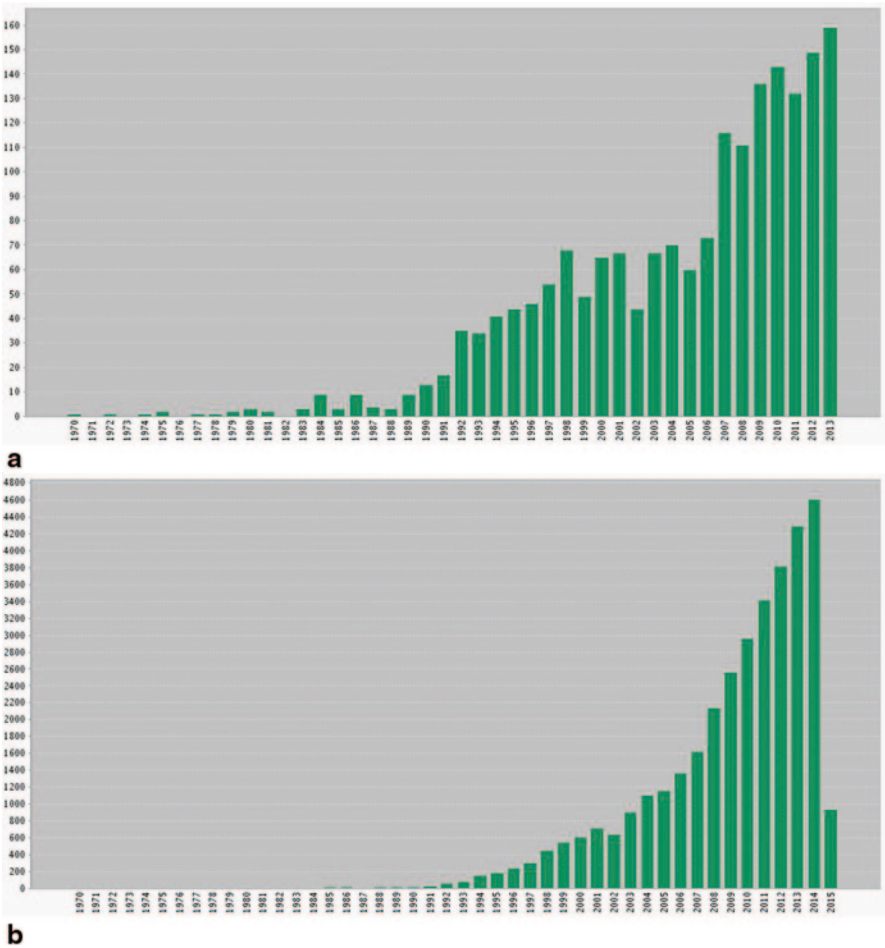

Fig. 5.1 Number of publications and citations in the area of conceptual change **a** published articles with conceptual change as a keyword from 1970 to 2013, **b** published articles on conceptual change cited from 1970 to 2013

While investigating articles published in Chinese in Taiwan, the earliest article appeared in 1992, 10 years after the Posner et al. (1982) article. This number continued to increase with peaks in 2000 and 2005. With the only exception being 1994, every year between 1992 and 2012 saw at least one article on conceptual change being published by Taiwanese scholars.

Although there is a great deal of research in the area of conceptual change, there is little consensus as to the definition of conceptual change. Some of the more widely used definitions involve: (a) reassignment of a concept to a different (within or across) ontological category or generation of a new distinct ontological category (Chi 2008), (b) additions or deletions from an existing network or the radical shift

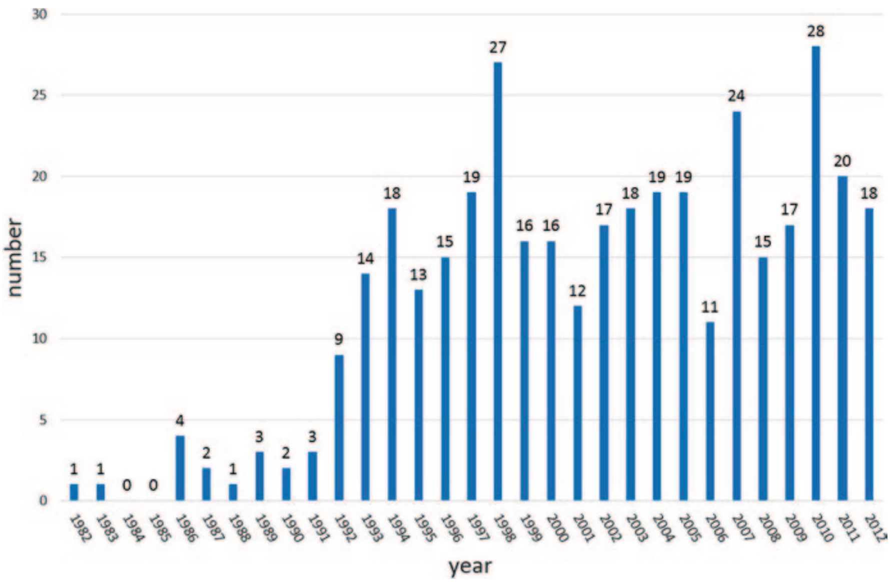

Fig. 5.2 Number of published articles per year in international journals from 1982 to 2012

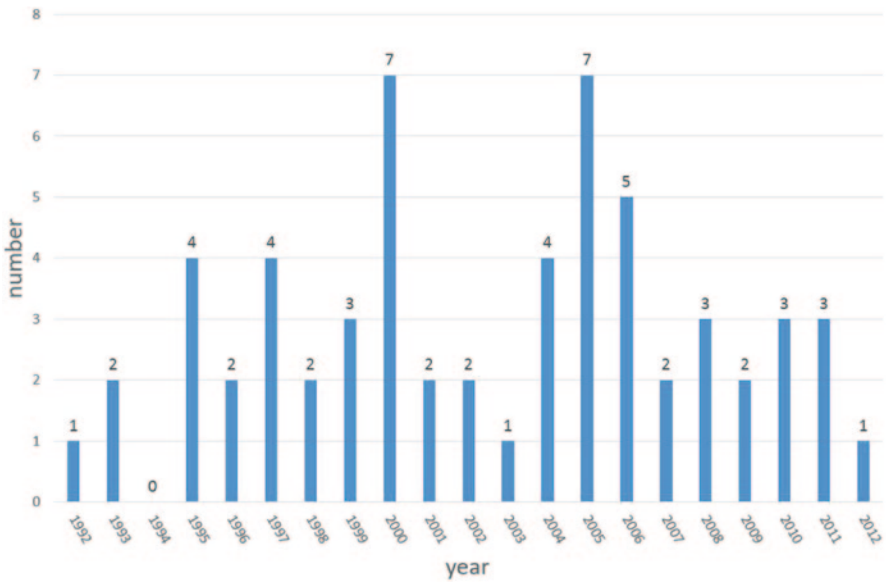

Fig. 5.3 Articles on conceptual change published each year in local journals in Taiwan (1992–2012)

to different branches or trees, (c) change in the ontological and epistemological presupposition of the learner's internally coherent explanatory system, (d) "individual's lifelong trajectory of understanding of a given topic or discipline" (Linn 2008, p. 694), or (e) "knowledge-in-pieces" involving incoherent and inconsistent structures that gradually develop into coordinator structure (diSessa 2008). In the three special handbooks on conceptual change (Schnotz et al. 1999; Vosniadou 2008, 2013), there seems to be no consensus about the nature of knowledge structures that a learner owns, namely, consistent or inconsistent, coherent or piecemeal, and mental models or p-prims (e.g., Vosniadou 1994, 2008; diSessa 1993, 2008). Researchers continue to debate over the universal definition of each of these elements.

The multiple frameworks that attempt to explain how conceptual change occurs and the research for investigating conceptual change have their origins in science education (i.e., Chiu 2007; Chiu and Lin 2008; Duit and Treagust 2003; Treagust and Duit 2008). These evolutions of conceptual change theories move research from a singular perspective to a multi-perspective paradigm that provides powerful interpretations and predictions of conceptual change.

The authors of this chapter have been long engaged in research on conceptual change involving different science topics and adopted a conceptual framework more recently via the use of the research and instructional based/oriented work (RAINBOW) framework that the first author developed to investigate issues related to science learning (see Chiu 2007; Chiu and Lin 2008). The RAINBOW framework includes multiple perspectives, namely ontological, epistemological, developmental, evolutionary, instructional, affective/social, and integrative approaches, to describe how conceptual change might be investigated. We published several articles related to each of these perspectives, namely, ontological (Chiu et al. 2002; Chiu and Chung 2013), epistemological (Chiu et al. 2002; Chiu and Lin 2005; Wang et al. 2013), developmental (Chiu and Chung 2013; Chiu and Wu 2013; Liang et al. 2011), evolutionary (Lin 2008; Lin and Chiu 2009; Chiu and Wu 2013), instructional (Chiu et al. 2002; Chiu and Chung 2013; Chiu and Lin 2005), affective/social (Chiu and Chung 2013), and integrative (Chiu and Lin 2008; Chiu et al. 2002; Chiu and Lin 2005; Chiu and Chung 2013) approaches to describe students' performance in learning different topics in sciences.

Conceptual change has guided much science education research over the past 30+years. Taiwan also showed its interest in conceptual change. The first article to come out of Taiwan that involved conceptual change was published in a local journal in 1992 (Hsu, 1992) in which the article discussed more about the nature and evaluation modes in measuring hypotheses and process skills in inquiry practice. Little was dealt with contemporary conceptual change theories or empirical work. The first article to discuss Posner et al. (1982)'s four conditions of conceptual change model was by Chiu (1993) in which introduced the nature of CCM, Chi's ontological categories of scientific concepts in conceptual change, and the relation between conceptual change and textbooks for meaningful learning. An article introducing researchers in the area of conceptual change including Chi, Vosniadou, Thagard, and Nersessian was published in Taiwan in 2000 (Chiu 2000) and was selected as one of the eight most cited papers between 1993 and 2002. In this review chapter, we would like to explore the rankings of countries that contributed to the field of conceptual change as well. It will show the efforts the researchers in Taiwan and other countries invested.

Possible influences on the research on conceptual change in Taiwan were the presentations provided by leading researchers in the area of conceptual change who were invited to give lectures at workshops or/and conferences, including Michelene T.H. Chi, Reinders Duit, Dedre Gentner, Ken Forbus, John Gilbert, Peter Hewson, David Treagust, and Stella Vosniadou. But other researchers in this field (such as Paul Thagard and Nancy Nersessian) also influenced the research trend on conceptual change in other ways. These researchers, as well as others, provided a valuable foundation to the theories of cognitive learning and inspired interactions between local and international science educators conducting research on conceptual change in science education.

With long-term research interest and experience in the area of conceptual change, in this chapter, we analyze the contents of local and international articles on conceptual change to uncover the journey that many researchers took over the past 30 years and then provide some evidence-based pedagogical suggestions for future research in science education.

5.1.1 Research Purposes and Questions

This chapter fulfills two purposes. First, it shows the research trends in conceptual change in science education over the past 30 years. Second, it compares the similarities and differences between national and international publications on conceptual change.

The following research questions are answered in this chapter:

1. How many empirical and nonempirical studies on conceptual change were published from 1982 to 2012?
2. What were the theoretical perspectives presented in the literature on conceptual change from 1982 to 2012?
3. What were the science disciplines examined in these studies?
4. What were the research methods and instruments used in these studies?
5. What were the teaching strategies used to investigate conceptual change in these studies?
6. What were the rankings of countries that contributed to the field of conceptual change from 1982 to 2012?

5.2 Method

5.2.1 Identifying Papers for This Review

Identification of journal articles included two parts. Journal articles published from 1982 through 2012 in the top five international science education journals (i.e., *Journal of Research in Science Teaching, Science Education, International Journal of Science Education (European Journal of Science Education), Research in Science Education, and International Journal of Science and Mathematics Education*) were searched for the keywords “conceptual change.” This process yielded 383 articles. Among them, there were 26 articles whose first author or corresponding author was from Taiwan. For the Taiwanese articles, the authors used the index to Taiwan periodical literature system (http://readopac.ncl.edu.tw/nclJournal/) to identify conceptual change related journal articles. This free database contained an exhaustive list of article citations of Chinese and Western language periodicals published in Taiwan (including some in Hong Kong and Macau) since 1970. This database was searched using the same keyword, i.e., conceptual change, and 70 articles were displayed. However, this included some nonacademic journal articles. As a result, we performed a second search on the DoRise (Database of Research in Science Education, http://w1.dorise.info/JCSE/) database to cross check and delete nonacademic journals from our search. This database was supported by the National Science Council and was the most representative database of research in science education in Taiwan. Of the original 70 Taiwanese articles, 60 were from academic journals and these 60 were selected for inclusion in our analyses.

5.2.2 Formation of an Analytical Framework

In this chapter, to provide support for implementation and make policies for promoting scientific literacy and support educational reform, we used the content analysis method to analyze the selected journal articles with special interest in the following topics: research theoretical framework, methodological issues, research intervention, and authorship (See Fig. 5.4).

Based on the framework and our previous research, we constructed a preliminary coding scheme for analyzing the selected articles. As for the categories of teaching strategies, they were expanded from another collaborative study (Chiu 2012) that had a panel of 12 experts with different background knowledge and experiences in science education. Sixteen out of 60 Taiwanese journal articles were systematically selected to pilot the feasibility of the analytical framework. The final coding scheme is shown in Table 5.1.

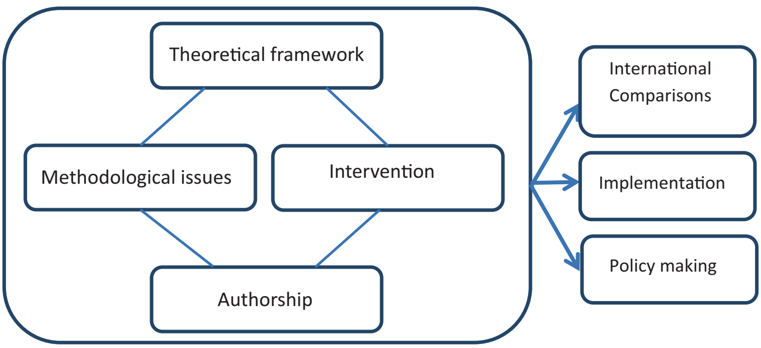

Fig. 5.4 The framework for content analysis of this study

Table 5.1 Coding scheme of the study

Research question	Category	Subcategory
RQ 1	Empirical and nonempirical	1. Empirical 2. Nonempirical
RQ 2	Theoretical perspectives	1. Epistemology 2. Ontology 3. Affection/social 4. Development 5. Evolution 6. Instruction 7. Multiple dimensions 8. Others
RQ 3	Discipline	1. Physics 2. Chemistry 3. Biology 4. Earth science 5. Cross-domain 6. Others (such as decision-making, modeling) 7. NA (such as nature of science, motivation)
RQ 4	Research methods	1. Qualitative 2. Quantitative 3. Mixed methods 4. Quantify qualitative data analysis
	Instruments	1. Paper-and-pencil test 2. Interview 3. Drawing 4. Online data 5. Questionnaire 6. Online questionnaire 7. Rubric or coding sheet of classroom observation 8. Biological data 9. Others
RQ 5	Teaching strategies	1. Analogy, model, and modeling 2. Multimedia 3. Conceptual conflict 4. Inquiry 5. Cooperative learning 6. Experiment 7. Text 8. Multiple representations 9. Argumentation 10. Concept map 11. Science history 12. Metacognitive approach 13. Constructivist approach 14. Self-explanation 15. Others

Table 5.1 (continued)

Research question	Category	Subcategory
RQ 6	The nationality of authors	1. The first author or corresponding author was from Taiwan 2. At least one author was from Taiwan but not the first author or corresponding author 3. No scholars from Taiwan involved
	The nationality of participants	–

NA Not applicable

5.2.3 Data Analysis

Each of the 443 studies (383 in English and 60 in Chinese) was analyzed based on the coding scheme in Table 5.1. At first, 383 international articles and 60 Chinese articles were ordered by year and author names, respectively. And then, all Chinese journal articles were coded by one of the authors of this article and then double-checked by a second person to validate the feasibility of the coding rubric. Once all the consistencies were confirmed and possible queries solved, 16 Chinese journal articles were systematically selected for coding exercises and establishing the preliminary inter-rater reliability. The inter-rater reliability was 87.5 %, and following training, the rest of the articles were independently coded by the three authors. Due to the large number of international journal articles, 70 international journal articles were selected (one out of every 5–7 articles) for double-checking and calculating the inter-rater reliability. The inter-rater reliability was 70.0 %. Due to the difficulty associated with extrapolating the theoretical background of some of the studies, inter-rater reliability excluding the theoretical background category increased to 74.3 %. Disagreements between the two examiners were resolved by revisiting and discussing specific segments of the article or by adding opinions of a third member. Details of categorical comparisons between articles written by Taiwanese scholars in international journals (TIJ) and in Taiwanese journals (TJ) are listed in the appendices.

5.3 Results and Discussions

The results start with the analysis of the articles on conceptual change from international scholars ($n = 383$, including 26 articles from Taiwan as a whole) and articles from scholars in Taiwan ($n = 86$; 60 articles in national and 26 in international journals), separately. Then comparisons are drawn between the articles from national and international researchers to show trends in the research on conceptual change in science learning. To refer to the articles from different sources, we categorized them as follows. For the 383 articles from international journals, we used the code

IJ. In other words, it appeared in an international journal regardless of the scholar's country of origin. For the 60 articles published in Taiwanese journals, we used the code TJ. For the 26 articles written by Taiwanese scholars but published in international journals, we used the code TIJ. The total articles published by scholars in Taiwan (TJ + TIJ = 86) was coded as T. The detailed statistics from the analyses are presented in the appendices.

5.3.1 RQ1: Empirical and Nonempirical Studies

The 10 years after Posner et al. (1982) proposed the first conceptual change model (CCM) served as an induction period with few studies published on the topic. During this period (1982–1992), about 40 % of the published studies both inside and outside of Taiwan (10 out of 26) were nonempirical. These studies mainly supported the philosophy of conceptual change in science (e.g., Stenhouse 1986; Terry and Jones 1986) and suggested other factors of conceptual change. For example, Stenhouse suggested Wittgenstein's concept of the "language-game," and Hewson and Thorley (1989) added the idea of conceptual ecology. During the years 1993–1997, studies of conceptual change grew rapidly and this trend continues today. The number of nonempirical studies ($n = 22$, 5.7 % of the total) was also the highest at this stage. However, after this stage, the number decreased by year. In other words, there were more empirical studies accepted for publication in international journals, whereas fewer and fewer nonempirical studies (such as position articles) that described the issues surrounding conceptual change were published.

As for the TJ ($n = 60$) articles published in Taiwan, the first conceptual change study appeared in 1992. This article was an empirical study that explained the relationship between formulating hypotheses and conceptual change (Hsu 1992). However, the first one introduced contemporary theories of conceptual change (such as Chi, Duit, Hewson, Treagust, and Vosniadou) was by Chiu (1993). In the early stages, nonempirical studies outnumbered empirical studies from 1988 to 1997. These studies mainly introduced the trend of cognitive psychology and theories of knowledge restructuring to Taiwanese researchers. After 1997, the number of empirical studies increased abruptly, and some Taiwanese articles on conceptual change began to be published in international journals. All of the articles written by Taiwanese scholars and published in the international journals were empirical studies. The first TIJ ($n = 26$) appeared in the *International Journal of Science and Education* in 1999. This study mainly examined the effects of a problem-solving-based instructional model on earth science students' alternative frameworks and achievement (Chang and Barufaldi 1999). From 1998 to date, the publication rate for Taiwanese authors stabilized, and the research came to focus on the application of conceptual change theories on science education research (i.e., Chiu et al. 2002; Tsai 2000). There were five articles published in TJ on average per year.

Generally speaking, the growth of conceptual change studies in Taiwan fell behind the international trend starting around 5–10 years. The research in Taiwan on conceptual change was started by introducing important conceptual change theories to the science education research community. Therefore, the nonempirical studies outnumbered the empirical studies between 1993 and 1997. The biggest growth period in Taiwan was between 1998 and 2002. During this period, there were many empirical studies published. After 2002, the number of conceptual change research stabilized. However, the number of articles published in TIJ increased whereas TJ decreased (Table 5.2).

5.3.2 RQ 2: Theoretical Framework

We used the RAINBOW (Chiu 2007; Chiu and Lin 2008) approach to analyze each article. The order of the perspectives from most frequent to least frequent were epistemology, instruction, other (including self-naming theories), affection/social interaction, development, ontology, multiple dimensions, and evolution. Among these, 66.1 % of epistemology and 61.1 % of instruction perspectives were revealed in the international journals. The ontology (6.0 %, such as Chiu et al. 2002), multiple dimensions (3.1 %, such as Chiu and Lin 2005), and evolution (0.5 %, such as Alzate and Puig 2007) approaches were quite low. Affection and development (i.e., Margel et al. 2008) were ranked in the middle. However, the order of the approaches was instruction, epistemology, multiple dimensions, ontology, other (including self-naming theories), development, affection/social, and evolution, for the international and national journals in Taiwan. Among them, about 70 % of the articles were related to the instructional perspective and 33.7 % were related to the epistemological perspective which differed from the international studies. Because science educators try to understand how students construct their knowledge and then how they use explanations of scientific phenomena (Vosniadou and Ioannides 1998), it was understandable that relatively high percentages of studies in the area of epistemological approach occurred.

In addition, we found that the number of articles published in epistemology and ontology perspectives started to increase in 1993 whereas the number of articles published in the affection perspective started to increase in 1998 after Pintrich et al. (1993) published their influential article on “hot” conceptual change for 5 years. With some reflections on the possible explanations for these trends found in Table 5.3, we notice that, other than Posner’s influential 1982 article, several other theories on conceptual change, such as Chi (1992), Thagard (1992), and Vosniadou and Brewer (1992), emerged in 1992. The 1992 theories might have also influenced the development of research in this area.

In addition, we found more studies investigating the impact of affection on conceptual change in the international journals as opposed to studies by Taiwanese scholars. However, there were more studies related to ontological issues by Tai-

Table 5.2 The distribution of empirical and nonempirical publications during 1982–2012

	Time interval	1982–1987		1988–1992		1993–1997		1998–2002		2003–2007		2008–2012		Subtotal	
International $n=383$	1. Empirical	5	(1.3)	11	(2.9)	57	(14.9)	75	(19.6)	78	(20.4)	90	(23.5)	316	(82.5)
	2. Nonempirical	3	(0.8)	7	(1.8)	22	(5.7)	14	(3.7)	13	(3.4)	8	(2.1)	67	(17.5)
	Total	8	(2.1)	18	(4.7)	79	(20.6)	89	(23.2)	91	(23.8)	98	(25.6)	383	(100.0)
Taiwan $n=86$	1. Empirical	0	(0.0)	1	(1.2)	5	(5.8)	19	(22.1)	24	(27.9)	20	(23.3)	69	(80.2)
	2. Nonempirical	0	(0.0)	0	(0.0)	7	(8.1)	4	(4.7)	3	(3.5)	3	(3.5)	17	(19.8)
	Total	0	(0.0)	1	(1.2)	12	(14.0)	23	(26.7)	27	(31.4)	23	(26.7)	86	(100.0)

Table 5.3 The distribution of conceptual framework of articles from 1982 to 2012

	Time interval	1982–1987		1988–1992		1993–1997		1998–2002		2003–2007		2008–2012		Subtotal	
International $n=383$	1. Epistemology	8	(2.1)	15	(3.9)	56	(14.6)	66	(17.2)	52	(13.6)	56	(14.6)	253	(66.1)
	2. Ontology	0	(0.0)	0	(0.0)	4	(1.0)	9	(2.3)	6	(1.6)	4	(1.0)	23	(6.0)
	3. Affection/social	1	(0.3)	0	(0.0)	4	(1.0)	10	(2.6)	10	(2.6)	8	(2.1)	33	(8.6)
	4. Development	0	(0.0)	3	(0.8)	5	(1.3)	6	(1.6)	7	(1.8)	12	(3.1)	33	(8.6)
	5. Evolution	0	(0.0)	0	(0.0)	0	(0.0)	1	(0.3)	1	(0.3)	0	(0.0)	2	(0.5)
	6. Instruction	5	(1.3)	14	(3.7)	46	(12.0)	52	(13.6)	65	(17.0)	52	(13.6)	234	(61.1)
	7. Multiple dimensions	0	(0.0)	2	(0.5)	3	(0.8)	2	(0.5)	2	(0.5)	3	(0.8)	12	(3.1)
	8. Others	1	(0.3)	2	(0.5)	6	(1.6)	8	(2.1)	17	(4.4)	19	(5.0)	53	(13.8)
	Subtotal	15	(3.9)	36	(9.4)	124	(32.4)	154	(40.2)	160	(41.8)	154	(40.2)		
Taiwan $n=86$	1. Epistemology			1	(1.2)	6	(7.0)	6	(7.0)	8	(9.3)	8	(9.3)	29	(33.7)
	2. Ontology			0	(0.0)	1	(1.2)	3	(3.5)	3	(3.5)	2	(2.3)	9	(10.5)
	3. Affection/social			0	(0.0)	0	(0.0)	1	(1.2)	1	(1.2)	1	(1.2)	3	(3.5)
	4. Development			0	(0.0)	0	(0.0)	2	(2.3)	1	(1.2)	1	(1.2)	4	(4.7)
	5. Evolution			0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	1	(1.2)	1	(1.2)
	6. Instruction			0	(0.0)	8	(9.3)	20	(23.3)	16	(18.6)	16	(18.6)	60	(69.8)
	7. Multiple dimensions			0	(0.0)	1	(1.2)	2	(2.3)	1	(1.2)	0	(0.0)	4	(4.7)
	8. Others			0	(0.0)	2	(2.3)	0	(0.0)	4	(4.7)	2	(2.3)	8	(9.3)
	Subtotal			1	(1.2)	18	(20.9)	34	(39.5)	34	(39.5)	31	(36.0)		

wanese scholars compared to the international scholars. More effort for a diverse approach to face difficulties of learning scientific concepts is needed.

5.3.3 RQ 3: Science Disciplines

During the period 1982–2012, we found that among the four science disciplines the highest percentage of research was completed in physics (29.2 %), followed by biology (18.8 %) and then chemistry (15.9 %) in the international journals. The publications in the area of earth science had the lowest percentage (8.6 %) among the four subjects. In general, physics is considered a difficult science discipline to be learned in elementary and secondary school because it involves a lot of abstract and complex concepts. Because this subject causes students a great deal of difficulty, many researchers in science education chose physics as their research topic to investigate students' alternative conceptions about physics (Akerson et al. 2000; Chiu and Lin 2005; Hewson and Hewson 1983; Tsai 2003; Zembal-Saul et al. 2002).

A similar finding resulted from the publications by Taiwanese authors with the highest percentage of studies involving physics (34.9 %), followed by chemistry (17.4 %; see Table 5.4). Internationally, studies in the area of conceptual change have grown rapidly in 1993. However, the growth in publishing of articles by Taiwanese authors in international journals was not evident until 1998.

From the results, it is evident that physics was the top science discipline to be explored and examined among all the science disciplines (see Table 5.4). From the analysis of the trend every 5 years, we found that publications by Taiwanese researchers mirrored the trend of international journals except for biology and earth science. According to our analysis, biology education researchers did not publish any international articles on conceptual change. However, there were many earth science conceptual change articles and there were more international articles on conceptual change in chemistry than in physics from Taiwan.

5.3.4 RQ 4: Methodology

5.3.4.1 Research Methods

As for the method of data analysis, namely quantitative, qualitative, both methods, or quantifying qualitative data, we found that over the past 31 years, one third of the articles were qualitative (e.g., Venville et al. 2012), followed by integration of quantitative and qualitative (19.8 %; e.g., Tsui and Treagust 2010), and quantifying qualitative data (19.8 %; e.g., Beerenwinkel et al. 2011) in the international journals. Also, we found that there was an increasing rate of publications emphasizing qualitative data analysis, up from 0.3 % in the first period of 1982–1987 to 11.5 % in the last period of 2008–2012.

Table 5.4 Science disciplines represented in the published articles on conceptual change from 1982 to 2012

	Time interval	1982–1987		1988–1992		1993–1997		1998–2002		2003–2007		2008–2012		Subtotal	
International $n=383$	1. Physics	5	(1.3)	8	(2.1)	25	(6.5)	19	(5.0)	29	(7.6)	26	(6.8)	112	(29.2)
	2. Chemistry	0	(0.0)	1	(0.3)	11	(2.9)	15	(3.9)	14	(3.7)	20	(5.2)	61	(15.9)
	3. Biology	0	(0.0)	4	(1.0)	17	(4.4)	18	(4.7)	17	(4.4)	16	(4.2)	72	(18.8)
	4. Earth science	0	(0.0)	0	(0.0)	1	(0.3)	11	(2.9)	7	(1.8)	14	(3.7)	33	(8.6)
	5. Cross-domain	0	(0.0)	0	(0.0)	4	(1.0)	4	(1.0)	5	(1.3)	1	(0.3)	14	(3.7)
	6. Other	0	(0.0)	2	(0.5)	11	(2.9)	19	(5.0)	16	(4.2)	18	(4.7)	66	(17.2)
	7. NA	3	(0.8)	3	(0.8)	12	(3.1)	5	(1.3)	5	(1.3)	3	(0.8)	31	(8.1)
	Subtotal	8	(2.1)	18	(4.7)	81	(21.1)	91	(23.8)	93	(24.3)	98	(25.6)		
Taiwan $n=86$	1. Physics			0	(0.0)	4	(4.7)	8	(9.3)	8	(9.3)	10	(11.6)	30	(34.9)
	2. Chemistry			0	(0.0)	0	(0.0)	2	(2.3)	8	(9.3)	5	(5.8)	15	(17.4)
	3. Biology			0	(0.0)	0	(0.0)	3	(3.5)	2	(2.3)	1	(1.2)	6	(7.0)
	4. Earth science			0	(0.0)	3	(3.5)	4	(4.7)	3	(3.5)	3	(3.5)	13	(15.1)
	5. Cross-domain			0	(0.0)	0	(0.0)	1	(1.2)	2	(2.3)	0	(0.0)	3	(3.5)
	6. Other			0	(0.0)	0	(0.0)	4	(4.7)	4	(4.7)	4	(4.7)	12	(14.0)
	7. NA			1	(1.2)	5	(5.8)	3	(3.5)	0	(0.0)	0	(0.0)	9	(10.5)
	Subtotal			1	(1.2)	12	(14.0)	25	(29.1)	27	(31.4)	23	(26.7)		

However, as for research done by scholars from Taiwan, 34.9 % of the articles contained both qualitative and quantitative data methods. This was followed by the quantitative approach (23.3 %). This trend kept steady over the past two decades even though the total number of articles in the area of conceptual change decreased by scholars from Taiwan. When we took into account the articles published by Taiwanese scholars in the international journals (see Table 5.5), the highest percentage was still on the integration of quantitative and qualitative research methods (34.9 %), followed by the quantitative approach (17.4 %).

In sum, compared to the international articles, we found that Taiwanese scholars tended to make good use of quantitative and qualitative research methods more than the either research method alone. Also, Taiwanese scholars tended to have more quantitative research articles than qualitative research articles as shown in Table 5.5.

5.3.4.2 Research Instruments

There were nine categories for analyzing the research instruments, namely paper-and-pencil test, interview, drawing, online data collection, paper-and-pencil and online questionnaires, classroom observation rubric, biological data, and others. Among these categories, 51.2 % of the articles used interviews to collect data, and 41.3 % of the articles used paper-and-pencil tests to assess students' and teachers' performance on their conceptual change. In addition, although 83 articles (21.7 %) were considered empirical studies, they did not use the instruments discussed above to collect data. Based upon Table 5.6, to our surprise, there was only one paper that used an online questionnaire to investigate conceptual change. Also, there was only one paper that used biological data to investigate conceptual change. It is likely that these types of research have been published in other research journals which fit much better than the journals we selected for analysis.

Both paper-and-pencil tests (53.5 %) and interviews (54.7 %) were the most commonly used instruments in the studies conducted in Taiwan. Taking the papers published in the international journals by science researchers from Taiwan into account (TIJ), we found similar trends in the use of paper-and-pencil tests and interviews for data collection. For the rest of the methods, very low percentages of papers used them to collect research data.

The data collection methods varied in the articles between IJ and TIJ. Although articles in the areas of conceptual change tended to use the first two types of instruments to conduct conceptual change research, we found that articles in the international journals tended to have a wider range of research instruments, in particular, drawing, questionnaires, online data, and the observation rubric, which were regularly used. Taking into account the papers published in international journals by scholars from Taiwan (TIJ), the majority of research collected data either by paper-and-pencil tests or interview techniques.

Table 5.5 The distribution of research methods of articles from 1982 to 2012

	Time interval	1982–1987		1988–1992		1993–1997		1998–2002		2003–2007		2008–2012		Subtotal	
International $n=383$	1. Qualitative	1	(0.3)	5	(1.3)	18	(4.7)	34	(8.9)	42	(11.0)	44	(11.5)	144	(37.6)
	2. Quantitative	1	(0.3)	3	(0.8)	17	(4.4)	12	(3.1)	15	(3.9)	18	(4.7)	66	(17.2)
	3. Both (1) & (2)	2	(0.5)	3	(0.8)	13	(3.4)	21	(5.5)	16	(4.2)	21	(5.5)	76	(19.8)
	4. Quantifying the qualitative data	1	(0.3)	4	(1.0)	14	(3.7)	15	(3.9)	18	(4.7)	24	(6.3)	76	(19.8)
	5. NA[a]	3	(0.8)	7	(1.8)	22	(5.7)	14	(3.7)	13	(3.4)	8	(2.1)	67	(17.5)
	Subtotal	8	(2.1)	22	(5.7)	84	(21.9)	96	(25.1)	104	(27.2)	115	(30.0)		
Taiwan $n=86$	1. Qualitative			0	(0.0)	1	(1.2)	5	(5.8)	5	(5.8)	4	(4.7)	15	(17.4)
	2. Quantitative			1	(1.2)	0	(0.0)	7	(8.1)	8	(9.3)	4	(4.7)	20	(23.3)
	3. Both (1) & (2)			0	(0.0)	4	(4.7)	7	(8.1)	10	(11.6)	9	(10.5)	30	(34.9)
	4. Quantifying the qualitative data			0	(0.0)	1	(1.2)	0	(0.0)	8	(9.3)	7	(8.1)	16	(18.6)
	5. NA[a]			0	(0.0)	7	(8.1)	4	(4.7)	3	(3.5)	3	(3.5)	17	(19.8)
	Subtotal			1	(1.2)	13	(15.1)	23	(26.7)	34	(39.5)	27	(31.4)		

[a] *NA* stands for nonempirical studies for coding methods

Table 5.6 The distribution of data collection methods of articles from 1982 to 2012

	Time interval	1982–1987		1988–1992		1993–1997		1998–2002		2003–2007		2008–2012		Subtotal	
International $n = 383$	1. Paper and pencil test	3	(0.8)	7	(1.8)	29	(7.6)	35	(9.1)	34	(8.9)	50	(13.1)	158	(41.3)
	2. Interview	4	(1.0)	6	(1.6)	32	(8.4)	44	(11.5)	58	(15.1)	52	(13.6)	196	(51.2)
	3. Drawing	0	(0.0)	1	(0.3)	6	(1.6)	9	(2.3)	8	(2.1)	13	(3.4)	37	(9.7)
	4. Online data	0	(0.0)	0	(0.0)	3	(0.8)	1	(0.3)	3	(0.8)	2	(0.5)	9	(2.3)
	5. Questionnaire	0	(0.0)	0	(0.0)	1	(0.3)	8	(2.1)	3	(0.8)	4	(1.0)	16	(4.2)
	6. Online questionnaire	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	1	(0.3)	1	(0.3)
	7. Rubric or coding sheet of classroom observation	0	(0.0)	1	(0.3)	0	(0.0)	3	(0.8)	3	(0.8)	3	(0.8)	10	(2.6)
	8. Biological data	0	(0.0)	0	(0.0)	0	(0.0)	1	(0.3)	0	(0.0)	0	(0.0)	1	(0.3)
	9. Other	1	(0.3)	3	(0.8)	17	(4.4)	25	(6.5)	16	(4.2)	21	(5.5)	83	(21.7)
	10. NA	3	(0.8)	7	(1.8)	22	(5.7)	14	(3.7)	13	(3.4)	8	(2.1)	67	(17.5)
	Subtotal	11	(2.9)	25	(6.5)	109	(28.5)	140	(36.6)	138	(36.0)	154	(40.2)		
Taiwan $n = 86$	1. Paper and pencil test			1	(1.2)	4	(4.7)	12	(14.0)	17	(19.8)	12	(14.0)	46	(53.5)
	2. Interview			0	(0.0)	4	(4.7)	11	(12.8)	20	(23.3)	12	(14.0)	47	(54.7)
	3. Drawing			0	(0.0)	0	(0.0)	1	(1.2)	1	(1.2)	3	(3.5)	5	(5.8)
	4. Online data			0	(0.0)	0	(0.0)	1	(1.2)	1	(1.2)	1	(1.2)	3	(3.5)
	5. Questionnaire			0	(0.0)	0	(0.0)	1	(1.2)	0	(0.0)	0	(0.0)	1	(1.2)
	6. Online questionnaire			0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	1	(1.2)	1	(1.2)
	7. Rubric or coding sheet of classroom observation			0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	8. Biological data			0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	9. Other			0	(0.0)	1	(1.2)	5	(5.8)	4	(4.7)	6	(7.0)	16	(18.6)
	10. NA			0	(0.0)	7	(8.1)	4	(4.7)	3	(3.5)	3	(3.5)	17	(19.8)
	Subtotal			1	(1.2)	16	(18.6)	35	(40.7)	46	(53.5)	38	(44.2)		

In row number 9, Others refers to documents, content analysis of literature, or videotapes, etc.
NA Not applicable

5.3.5 RQ 5: Teaching Strategies

For the international part, from the 383 articles, 240 articles were related to conceptual change teaching strategies (62.7 %). From the TJ, 58 articles (67.4 %, excluding articles that were not applicable) out of total 86 were related to conceptual change teaching strategies (67.4 %). It seems that science educators in Taiwan focus more on the application of teaching strategies (Table 5.7).

From 1982 to 1992, the teaching strategy of conceptual conflict was the top method researchers adopted in IJ. The percentages were 1.3 and 2.1 % in total, respectively. Without doubt, Posner et al.'s (1982) study was the first article to apply the teaching strategy of conceptual conflict. Besides, they also integrated experiments and group discussion to foster students' science learning. However, from 1993 to 2002, the top strategy changed to "analogy, model and modeling." The percentages were 5.0 and 5.0 %, respectively. Actually, the first article about this teaching strategy appeared in 1992. Brown (1992) questioned the effectiveness of a traditional teaching-by-example technique, and presented several principles to design effective analogies in a constructive way. After this article, this strategy increased abruptly. There were various teaching strategies related to "analogy, model and modeling," such as bridging analogies (Brown 1994, Bryce and MacMillan 2005), multiple analogies (Chiu and Lin 2005), transformative modeling (Shen and Confrey 2007), and so on. Recently (2003–2012), the instruction of multimedia became the mainstream to help students overcome their alternative conceptions. The percentages were 5.4 (2003–2007) and 4.6 % (2008–2012), respectively. However, early in 1986, Zietsman and Hewson had already adopted microcomputer simulations to diagnose and remediate an alternative conception of velocity. With regard to the whole sample, the most popular methods were analogy, model/modeling (19.6 %), followed by multimedia (16.3 %) and conceptual conflict (15.8 %). The trend in conceptual change instruction was from conceptual conflict to analogy, model/modeling, and then to instruction of multimedia.

As for the TJ, on the whole, "multimedia" (20.7 %), "conceptual conflict" (20.7 %), "analogy, model/modeling" (15.5 %), "inquiry" (12.1 %), and "concept map" (10.3 %) were the teaching strategies most adopted. In the initiation stage (1982–1997), there were fewer journal articles related to teaching strategies. In the years 1993–1997, text was the most popular teaching strategy (3.4 %). Then, the teaching strategies of multimedia, conceptual conflict, and concept map (6.9, 6.9, 6.9 %, respectively) became popular between 1998 and 2002. At the last stage, teaching strategy of multimedia (10.3 %) was the most popular teaching method between 2008 and 2012.

The researchers in Taiwan invested more effort than international researchers in developing teaching strategies using multimedia (Taiwan: International = 20.7 %: 16.3 %) and improving the strategy of conceptual conflict (Taiwan: International = 20.7 %: 15.8 %). The importance of these two instructional strategies is still evident. Unlike the trend of the changes of teaching strategies across the globe, there was no obvious trend of changing in Taiwan. Besides, the total percentage showed Taiwanese researchers (125.9 %) adopted more multiple teaching strategies in a study than international researchers (117.1 %) (see Table 5.8).

Table 5.7 The distribution of teaching or nonteaching studies from 1982 to 2012

	Time interval	1982–1987		1988–1992		1993–1997		1998–2002		2003–2007		2008–2012		Subtotal	
International $n=383$	Articles related to teaching	4	(1.0)	10	(2.6)	46	(12.0)	56	(14.6)	63	(16.4)	61	(15.9)	240	(62.7)
	NA	4	(1.0)	8	(2.1)	33	(8.6)	33	(8.6)	28	(7.3)	37	(9.7)	143	(37.3)
	Total	8	(2.1)	18	(4.7)	79	(20.6)	89	(23.2)	91	(23)	98	(25.6)	383	(100.0)
Taiwan $n=86$	Articles related to teaching	0	(0.0)	0	(0.0)	2	(2.3)	19	(22.1)	22	(25.6)	15	(17.4)	58	(67.4)
	NA	0	(0.0)	1	(1.2)	8	(9.3)	6	(7.0)	5	(5.8)	8	(9.3)	28	(32.6)
	Total	0	(0.0)	1	(1.2)	10	(11.6)	25	(29.1)	27	(31.4)	23	(26.7)	86	(100.0)

NA not applicable, articles are not related to teaching

Table 5.8 The distribution of teaching strategies between 1982 and 2012

	Time interval	1982–1987		1988–1992		1993–1997		1998–2002		2003–2007		2008–2012		Subtotal	
International $n=240$	1. Analogy, model and modeling	0	(0.0)	1	(0.4)	12	(5.0)	12	(5.0)	13	(5.4)	9	(3.8)	47	(19.6)
	2. Multimedia	1	(0.4)	0	(0.0)	6	(2.5)	8	(3.3)	13	(5.4)	11	(4.6)	39	(16.3)
	3. Conceptual conflict	3	(1.3)	5	(2.1)	7	(2.9)	6	(2.5)	9	(3.8)	8	(3.3)	38	(15.8)
	4. Inquiry	0	(0.0)	0	(0.0)	2	(0.8)	4	(1.7)	9	(3.8)	8	(3.3)	23	(9.6)
	5. Cooperative learning	1	(0.4)	0	(0.0)	2	(0.8)	4	(1.7)	6	(2.5)	2	(0.8)	15	(6.3)
	6. Experiment	1	(0.4)	0	(0.0)	1	(0.4)	3	(1.3)	3	(1.3)	4	(1.7)	12	(5.0)
	7. Text	0	(0.0)	0	(0.0)	5	(2.1)	1	(0.4)	4	(1.7)	1	(0.4)	11	(4.6)
	8. Multiple representation	0	(0.0)	0	(0.0)	1	(0.4)	2	(0.8)	3	(1.3)	3	(1.3)	9	(3.8)
	9. Argumentation	0	(0.0)	0	(0.0)	1	(0.4)	1	(0.4)	0	(0.0)	3	(1.3)	5	(2.1)
	10. Concept map	0	(0.0)	1	(0.4)	3	(1.3)	0	(0.0)	1	(0.4)	0	(0.0)	5	(2.1)
	11. Science history	0	(0.0)	1	(0.4)	1	(0.4)	0	(0.0)	2	(0.8)	0	(0.0)	4	(1.7)
	12. Metacognitive approach	0	(0.0)	0	(0.0)	0	(0.0)	2	(0.8)	0	(0.0)	2	(0.8)	4	(1.7)
	13. Constructivist approach	0	(0.0)	1	(0.4)	1	(0.4)	0	(0.0)	1	(0.4)	0	(0.0)	3	(1.3)
	14. Self-explanation	0	(0.0)	0	(0.0)	1	(0.4)	2	(0.8)	0	(0.0)	0	(0.0)	3	(1.3)
	15. Other	1	(0.4)	1	(0.4)	9	(3.4)	18	(7.5)	13	(5.4)	21	(8.8)	63	(26.3)
	Total	7	(2.9)	10	(4.2)	52	(21.7)	63	(26.3)	77	(32.1)	72	(30.0)	281	(117.1)

Table 5.8 (continued)

	Time interval	1982–1987		1988–1992		1993–1997		1998–2002		2003–2007		2008–2012		Subtotal	
Taiwan $n=58$	1. Analogy, model and modeling	0	(0.0)	0	(0.0)	1	(1.7)	3	(5.2)	3	(5.2)	2	(3.4)	9	(15.5)
	2. Multimedia	0	(0.0)	0	(0.0)	0	(0.0)	4	(6.9)	2	(3.4)	6	(10.3)	12	(20.7)
	3. Conceptual conflict	0	(0.0)	0	(0.0)	0	(0.0)	4	(6.9)	6	(10.3)	2	(1.7)	12	(20.7)
	4. Inquiry	0	(0.0)	0	(0.0)	0	(0.0)	2	(3.4)	4	(6.9)	1	(1.7)	7	(12.1)
	5. Cooperative learning	0	(0.0)	0	(0.0)	0	(0.0)	1	(1.7)	1	(1.7)	0	(0.0)	2	(3.4)
	6. Experiment	0	(0.0)	0	(0.0)	0	(0.0)	1	(1.7)	2	(3.4)	0	(0.0)	3	(5.2)
	7. Text	0	(0.0)	0	(0.0)	2	(3.4)	0	(0.0)	0	(0.0)	0	(0.0)	2	(3.4)
	8. Multiple representation	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	9. Argumentation	0	(0.0)	0	(0.0)	0	(0.0)	2	(3.4)	0	(0.0)	0	(0.0)	2	(3.4)
	10. Concept map	0	(0.0)	0	(0.0)	0	(0.0)	4	(6.9)	1	(1.7)	1	(1.7)	6	(10.3)
	11. Science history	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	2	(3.4)	2	(3.4)
	12. Metacognitive approach	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	13. Constructivist approach	0	(0.0)	0	(0.0)	0	(0.0)	1	(1.7)	0	(0.0)	0	(0.0)	1	(1.7)
	14. Self-explanation	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	15. Other	0	(0.0)	0	(0.0)	1	(1.7)	4	(6.9)	7	(12.1)	4	(6.9)	16	(27.6)
	Total	0	(0.0)	0	(0.0)	4	(6.9)	26	(44.8)	26	(44.8)	17	(29.3)	73	(125.9)

5.3.6 RQ 6: Authorship and Participants

5.3.6.1 Authorship

Among the 383 articles published in the international journals from 1982 to 2012, we found that 38.1% ($n=146$) of the authors were from the USA, followed by 9.9% ($n=38$) from Australia (see Table 5.9). The first two countries were mainly English-speaking countries with a population of 320 and 24 million, respectively (World Population Review 2014). Taiwan, with 6.8% ($n=26$), was ranked third; Taiwan is the first non-English-speaking country in the list and has a population of 23 million only. In particular, the papers published by scholars in Taiwan were only during the last 15 years (1998–2012) unlike the USA, Australia, and the UK who started publishing as early as the 1980s. As a non-English-speaking country, this provides evidence that the efforts of researchers in Taiwan contributed to the conceptual change community worldwide. In addition to this, we also noted that South Korea (with a population of 50 million), Turkey (with a population of 76 million), and Germany (with a population of 80 million) showed their active involvement in publishing research papers during the period 2003–2012. In addition, we found that several countries had started publishing papers in the five major science education journals during the period 1998–2002. Although this phenomenon was not foreseen and it is difficult to attribute causes for the increase, we hypothesized that the international trend of research on students' understanding of science switched from the alternative conception paradigm, which accumulated a great number of research results, to the conceptual change paradigm to improve school science learning, which may have been a factor. A great number of studies have been produced that address the difficulties of learning science at different levels, by different genders, and within different cultures. The results of these studies have guided science education researchers to consider possible meaningful strategies for promoting students' knowledge reconstruction of scientific phenomenon. Therefore, after Posner et al. (1982) and other researchers published conceptual change articles, this area gained more attention from science educators and researchers. We also noticed that the number of articles from the USA started to increase in 1993. Several other countries also showed their interest in conducting research on conceptual change (e.g., Australia, the UK, Israel, Canada, and Spain) whereas Taiwan joined the research trend in 1999 and stably increased its visibility. As for Turkey, it was quite impressive to see eight international articles published from 2008 to 2012, putting Turkey at number four among the 32 countries.

5.3.6.2 Participating Countries

An analysis was conducted on the participating countries, and we found that 34.2% ($n=131$) of the articles were published in the USA, and that this dropped dramatically to 7.8% ($n=30$) in Australia, 6.0% ($n=23$) in Taiwan, and then 3.9% ($n=15$) each from the UK and Israel. Also, there were five articles that involved

Table 5.9 The distribution of the first or correspondence authors' countries from 1982 to 2012

			1982–1987		1988–1992		1993–1997		1998–2002		2003–2007		2008–2012		Subtotal	
International $n=383$	1.	USA	2	(0.5)	9	(2.3)	41	(10.7)	45	(11.7)	20	(5.2)	29	(7.6)	146	(38.1)
	2.	Australia	1	(0.3)	3	(0.8)	7	(1.8)	5	(1.3)	12	(3.1)	10	(2.6)	38	(9.9)
	3.	Taiwan	0	(0.0)	0	(0.0)	0	(0.0)	7	(1.8)	8	(2.1)	11	(2.9)	26	(6.8)
	4.	UK	1	(0.3)	0	(0.0)	5	(1.3)	4	(1.0)	8	(2.1)	3	(0.8)	21	(5.5)
	5.	Israel	1	(0.3)	2	(0.5)	5	(1.3)	3	(0.8)	3	(0.8)	3	(0.8)	17	(4.4)
	6.	Canada	0	(0.0)	1	(0.3)	5	(1.3)	4	(1.0)	3	(0.8)	2	(0.5)	15	(3.9)
	7.	Spain	0	(0.0)	1	(0.3)	3	(0.8)	4	(1.0)	6	(1.6)	0	(0.0)	14	(3.7)
	8.	Korea	0	(0.0)	0	(0.0)	0	(0.0)	1	(0.3)	6	(1.6)	4	(1.0)	11	(2.9)
	9.	Turkey	0	(0.0)	0	(0.0)	0	(0.0)	1	(0.3)	1	(0.3)	8	(2.1)	10	(2.6)
	10.	Germany	0	(0.0)	0	(0.0)	0	(0.0)	1	(0.3)	4	(1.0)	4	(1.0)	9	(2.3)
	11.	Greece	0	(0.0)	0	(0.0)	0	(0.0)	2	(0.5)	2	(0.5)	4	(1.0)	8	(2.1)
	12.	South Africa	2	(0.5)	0	(0.0)	4	(1.0)	1	(0.3)	0	(0.0)	1	(0.3)	8	(2.1)
	13.	China	0	(0.0)	0	(0.0)	0	(0.0)	5	(1.3)	1	(0.3)	0	(0.0)	6	(1.6)
	14.	France	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	4	(1.0)	2	(0.5)	6	(1.6)
	15.	Sweden	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	2	(0.5)	4	(1.0)	6	(1.6)
	16.	Brazil	0	(0.0)	1	(0.3)	0	(0.0)	1	(0.3)	1	(0.3)	2	(0.5)	5	(1.3)
	17.	The Netherlands	0	(0.0)	1	(0.3)	1	(0.3)	2	(0.5)	1	(0.3)	0	(0.0)	5	(1.3)
	18.	Finland	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	2	(0.5)	2	(0.5)	4	(1.0)
	19.	Italy	0	(0.0)	0	(0.0)	4	(1.0)	0	(0.0)	0	(0.0)	0	(0.0)	4	(1.0)
	20.	Lebanon	0	(0.0)	0	(0.0)	1	(0.3)	0	(0.0)	0	(0.0)	3	(0.8)	4	(1.0)
	21.	Venezuela	0	(0.0)	0	(0.0)	1	(0.3)	2	(0.5)	0	(0.0)	1	(0.3)	4	(1.0)
	22.	Cyprus	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	2	(0.5)	1	(0.3)	3	(0.8)
	23.	New Zealand	1	(0.3)	0	(0.0)	0	(0.0)	0	(0.0)	1	(0.3)	0	(0.0)	2	(0.5)
	24.	Nigeria	0	(0.0)	0	(0.0)	1	(0.3)	0	(0.0)	1	(0.3)	0	(0.0)	2	(0.5)

Table 5.9 (continued)

		1982–1987		1988–1992		1993–1997		1998–2002		2003–2007		2008–2012		Subtotal	
25.	Singapore	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	1	(0.3)	1	(0.3)	2	(0.5)
26.	Argentina	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	1	(0.3)	0	(0.0)	1	(0.3)
27.	Bangladesh	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	1	(0.3)	1	(0.3)
28.	Northern Ireland	0	(0.0)	0	(0.0)	1	(0.3)	0	(0.0)	0	(0.0)	0	(0.0)	1	(0.3)
29.	Norway	0	(0.0)	0	(0.0)	0	(0.0)	1	(0.3)	0	(0.0)	0	(0.0)	1	(0.3)
30.	Scotland	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	1	(0.3)	0	(0.0)	1	(0.3)
31.	Switzerland	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	1	(0.3)	1	(0.3)
	Subtotal	8	(2.1)	18	(4.7)	79	(20.6)	89	(23.2)	91	(23.8)	98	(25.6)	383	(100.0)

collaboration between countries, namely, one article involving Australia and Korea, one involving Australia and the USA, two with New Zealand and China, and one for Spain and the UK (see Table 5.10).

5.4 Concluding Remarks

Based upon our careful analysis of the contents of the identified articles both from international and national journals, we have the following claims to make.

5.4.1 *Claim 1: Studies on Conceptual Change in International Journals Are at a Reasonable Stable Status but in TJ the Numbers Appear to Be Limited*

Conceptual change is important for science education, and its importance is still being unraveled. In our analysis, most of the studies follow the empirical approach to explore this domain whether it is an international or a national article. This is supported by the trend that publications on conceptual change in international journals are at a reasonably stable status (see Figs. 5.2 and 5.3). The research on conceptual change in Taiwan fell behind the international trend around 5–10 years back, but it has since risen and the number of published studies now rival Western countries. However, the rate of publication on conceptual change in Taiwan seems to be leveling off. The research trend of science education in Taiwan recently is quite consistent with the international research trend in three main science education journals *(Journal of Research in Science Teaching, Science Education, and International Journal of Science Education)*. That is, the context of students' learning replaced students' conceptual learning, which was the most published research topic from 1998 to 2002 (Lin et al. 2014). We speculate this might be the reason for the limited number of Taiwanese conceptual change studies lately.

5.4.2 *Claim 2: Most of the Published Research on Conceptual Change Investigated the Effectiveness of Instructional Strategies and Materials*

Based upon our analysis, we found that more studies were related to epistemology and instruction compared to other perspectives (See Table 5.3). Since most of instructions originated from epistemological perspective, it is not surprising to have high percentages of publications in these two areas. However, Taiwan tended to solve the problems in school practice by conducting more studies on designing instructional materials to improve science teaching, therefore, a high percent-

Table 5.10 The distribution of participants by country from 1982 to 2012

	Country	n	%
1.	USA	131	34.2
2.	Australia	30	7.8
3.	Taiwan	23	6.0
4.	UK	15	3.9
5.	Israel	15	3.9
6.	Canada	11	2.9
7.	Spain	11	2.9
8.	Korea	11	2.9
9.	Germany	9	2.3
10.	France	6	1.6
11.	Greece	6	1.6
12.	Sweden	6	1.6
13.	Turkey	6	1.6
14.	China	5	1.3
15.	South Africa	5	1.3
16.	Brazil	4	1.0
17.	Lebanon	4	1.0
18.	The Netherlands	4	1.0
19.	Finland	3	0.8
20.	Italy	3	0.8
21.	Venezuela	3	0.8
22.	Cyprus	2	0.5
23.	Nigeria	2	0.5
24.	Singapore	2	0.5
25.	Argentina	1	0.3
26.	India	1	0.3
27.	Latin America	1	0.3
28.	Maldives	1	0.3
29.	Northern Ireland	1	0.3
30.	Scotland	1	0.3
31.	Thailand	1	0.3
32.	Uganda	1	0.3
	Dual	5	1.3
	Australia & Korea	1	0.3
	Australia & USA	1	0.3
	New Zealand & China	2	0.5
	Spain and UK	1	0.3
	NA	53	13.8
	Total (n)	383	100.0

age of instructional studies in Taiwan compared to the international studies that emphasized more on the epistemological perspective on teaching and learning. We also found the low percentage of the amount of research on evolutionary perspective. We speculate one of the possible explanations is the difficulty of conducting long duration research in schools due to the pressure to cover a large number of science topics for the sake of high school and university entrance examinations. Furthermore, compared to international articles, it was found that Taiwan has more articles on the ontology perspective and a lower number of articles on affection/social. As researchers in this area advocated multiple-dimension approaches in uncovering the challenges of conceptual change in teachers' and students' beliefs and conceptions about science, this result shed some light on the research outcomes and directions for empowerment.

5.4.3 Claim 3: More Research on Conceptual Change Is in the Area of Physics Compared to Chemistry, Biology, and Earth Science

Not surprisingly, there were more studies completed in the area of physics compared to the other science disciplines because of its long history in science education research and the complex, counterintuitive, and abstract nature of its concepts. However, as one of the major science disciplines in elementary and secondary schools, relatively low percentage of studies were carried out for improving school biology instruction and developing teachers' expertise in knowing students' knowledge of biology in Taiwan which might need more attention from science educators (See Table 5.4). In addition, we noticed that there seems to be more physics education researchers than researchers of any other subjects. Although we do not have the exact number of researchers in physics education, we suspect that there are many current research investigating students' misconceptions and developing instructional materials and assessment items for physics (such as mechanics, light, and electricity), so the results can be easily compared across different cultures and countries. That might be one of the possible reasons why we found research in physics education dominating science education research.

5.4.4 Claim 4: Most Published Studies on Conceptual Change Relied on Multiple Data Collection Methods for Triangulation Purposes

As expected, most of the research used paper-and-pencil and interview methods to collect research data from 1982 to 2012 regardless of where the research took place. We also found that higher percentages of qualitative studies appeared in the international journals whereas higher percentages of studies using both qualitative and quantitative methods were found in the articles by Taiwanese authors. The use of the triangulation approach allows researchers to provide better quality, more richness, and fuller explanations of students' complex learning processes than is afforded by single methods alone (Cohen and Manion 2000).

5.4.5 Claim 5: Major Teaching Strategy Changes from Conceptual Conflict, Analogy to Multimedia

The change of the trend of teaching strategy in international journals is obvious. Conceptual conflict was the main teaching strategy early on, and it changed to "analogy, model and modeling," and then to multimedia. The trend in Taiwan was not as clear. It seems that researchers in Taiwan preferred the teaching methods of conceptual conflict and multimedia. One of the reasons might be that the Taiwanese government continuously allocated a considerable budget to support the development of e-learning via both scholarly and industrial research (Chang et al. 2009). There also appeared to be ample evidence from numerous studies that conceptual change instruction was more efficient than traditional instruction (Duit and Treagust 2012). However, is any teaching strategy more efficient than the other? Why is the trend of teaching strategy in Taiwan different from the international trend? These questions should be further examined by considering the nature of learners' conceptions, the theoretical backgrounds adopted, and cultural differences. Large-scale programs for improving the quality of science instruction should also be implemented in the near future.

5.4.6 Claim 6: Continuous Effort on Research on Conceptual Change in Science Learning

As a non-English-speaking country, Taiwan outperformed other countries in terms of research produced and published on conceptual change. Researchers in Taiwan should be continuously making contributions to this field and not only investigating theoretical frameworks but also taking sociocultural perspectives into account when conducting research in Taiwan. As Chiu and Duit (2011) pointed out, globalization is not a new movement. However, there is the danger of just exchanging local (indigenous) ideas for science conceptions; as a result, one may lose one's cultural identity and become alienated from one's indigenous culture. On the one hand, we concur that the perspective of globalization provides new insights into how science should be taught and what should be emphasized (Chiu and Duit 2011). On the other hand, we present the caveat that cultural and historical perspectives, which have not been taken into account in general thus far, should be considered as a way to guide us to conduct and implement the studies into practices.

5.4.7 Claim 7: Two Stages of Conceptual Change Research Trend

Based on our analysis of international and national articles on conceptual change, two stages of conceptual change research were identified: Stage 1 is *incubation* and Stage 2 is *development* in terms of quantity of publications during a specific period of time. For international articles, the period of Stage 1 was from 1982 to 1992 and Stage 2 from 1993 to 2012. For articles from science education researchers in Taiwan, the period of Stage 1 was from 1992 to 1997 and Stage 2 from 1998 to 2012. Taiwan started research on conceptual change 10 years later than the international research trend. However, starting in 1999, researchers in Taiwan generated quality publications that showed a high interest in this area. The special issue in *International Journal of Science Education* (Chiu et al. 2007) described the background and the process that the researchers in Taiwan spend our time, effort, and human and financial resources to conduct the National Science Concept Learning Study to catch up with the international studies on conceptual change.

5.5 Implications for Science Education Research on Conceptual Change

It was not a surprise to find the disparities of distributions of research types to be in favor of empirical studies that were published internationally and nationally. Due to the major findings shown above, we have the following suggestions for research on conceptual change.

5.5.1 Suggestion 1: Increasing Nonempirical Studies for Informing Conceptual Change Theory

After a period of the first 10 years (1982–1992), the percentage of nonempirical studies became less and less starting from 1993 to 1997 and then stayed low afterwards. Most researchers conducted empirical studies, in particular in the innovation of teaching strategies. It might be that science education researchers tried to accumulate more findings from empirical studies to evolve new theories (or paradigm) on conceptual change. Although the early Taiwanese conceptual change studies focused more on the nonempirical studies, they mainly introduced other scholars' important conceptual change theories for the Taiwanese science education community. In other words, no matter whether it is from the global perspective or the local perspective, science educators paid less attention to the formation or supplementation of conceptual change theories. We have accumulated considerable results from these empirical studies. The next step is to synthesize these results and increase the number of nonempirical studies for renewing or reconstructing conceptual change theories for global or local needs. In particular, Taiwan's educational system has its own unique culture (such as high-stakes testing) that may shed light on the conceptual change research challenges and the emerging need for developing local learning theories.

5.5.2 Suggestion 2: Encouraging More Research in Diverse and Cross-Science Disciplines

The imparity of distribution of studies in science disciplines shows an emerging need for putting more effort across different subjects. Although we did not analyze what topics in physics were investigated, our speculation is that topics in the area of electric circuits, light, mechanics, and weight and density are the most commonly found in the articles. Therefore, spreading out the research interests to other science disciplines and new scientific concepts (such as nanotechnology) would be valuable to explore.

5.5.3 Suggestion 3: Strengthening the Implementation of Multiple Perspectives of Approaches for Research

As early as 1997, Tyson et al. had already proposed the multidimensional approach for conceptual change studies; other researchers (Chiu 2007; Chiu and Lin 2008; Duit and Treagust 2003, Treagust and Duit 2008) have advocated for the multiple perspectives approach. Table 5.3 shows that besides epistemological perspectives, instructional perspectives received relatively more attention by researchers than the others. The other perspectives, individual or joint, need to be explored in the future. There is still room to improve our use of multiple approaches to answer crucial questions that remain in the area of conceptual change.

5.5.4 Suggestion 4: Using Multiple Research Methods to Increase Reliability of Studies as Evidence-Based Sources for Educational Reforms

Science education researchers need to seriously consider how to increase the reliability of their research methods, outcomes, and implications via multiple sources of data collection. Such evidence is necessary for making reliable and relevant judgments, conclusive claims, and convincing implications. It is the challenge before us to develop new research methods that can open new avenues to effective research on conceptual change in science learning. In addition, with advanced research methods, profound theories of students' construction and change of their epistemological beliefs will likely be developed. More importantly, it is evident that research outcomes currently have very little impact on science educational reform (such as science curriculum standards). By increasing the reliability of research outcomes, decisions made for science educational reforms can be more trustworthy, and as a result, more influential in school science practice reform policy-making.

5.5.5 Suggestion 5: Strengthening the Relationships Among Science Disciplines, Multimedia, and Instructional Theory, Followed by Conveying Them to School Teachers to Promote Quality Teaching in School Science Practice

From this literature review, we found the teaching strategy of multimedia is the most mainstream. In particular, Taiwan showed its advantage in terms of technology, science educators in Taiwan dominate in the development of innovative strategy with multimedia. However, multimedia is only a tool. We must strengthen the relationships among disciplines, multimedia, and conceptual change theory to change the teaching materials and then implement them in schools. Of course, teachers should be well informed about the innovative teaching opportunities and change their pedagogical content knowledge on science accordingly to provide higher quality instruction.

5.5.6 Suggestion 6: Increasing the Interaction Between Local Scholars and International Scholars

The research published in international journals and collaborated with international scholars should serve the following functions:

- To share research findings and experiences with the global community.
- To increase the researchers' awareness of the current trends in theoretical framework and methodological issues in different contexts.
- To show the uniqueness of cultural and social impacts on science learning.
- To build a culture of sharing and to cultivate research competence.

Based upon our results, linking local research with the international research community should be emphasized. Not only do local researchers have expertise and experiences in conducting research locally and publishing in international journals, but Taiwan researchers also have the obligation to increase international scholars' awareness of the cultural and historical impact of non-English-speaking countries on science as a human enterprise. More importantly, we should link research with school practice not only to change school teaching but also to promote quality professional development for preservice and in-service teachers.

5.5.7 Suggestion 7: Advocating New and Revolutionary Theories and Research Methods on Conceptual Change for Promoting Research Quality and Quantity to the Next Stage

Without insightful theories, empirical research cannot be easily developed or designed. Analyses of the current chapter showed that empirical studies, especially those with instructional design, dominated the field. To strengthen the impact of research on conceptual change in school science practice, revolutionary theories, innovative research methods, and systematic assessment tools on conceptual change in science education should be further developed and advanced. We concur that the "Acquisition of a paradigm and of the more esoteric type of research it permits is a sign of maturity in the development of any given scientific field" (Kuhn 1970, p. 55). The spirit of research maturity might also be applied to research on conceptual change in learning science.

Appendices

Appendix A. The distribution of empirical and nonempirical international and national publications by science education researchers in Taiwan from 1982 to 2012

		1982–1987		1988–1992		1993–1997		1998–2002		2003–2007		2008–2012		Total	
TIJ ($n=26$)	Empirical	0	(0.0)	0	(0.0)	0	(0.0)	7	(26.9)	8	(30.8)	11	(42.3)	26	(100.0)
	Nonempirical	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
TJ ($n=60$)	Empirical	0	(0.0)	1	(1.7)	5	(8.3)	12	(20.0)	16	(26.7)	9	(15.0)	43	(71.7)
	Nonempirical	0	(0.0)	0	(0.0)	7	(11.7)	4	(6.7)	3	(5.0)	3	(5.0)	17	(28.3)
Total ($n=86$)	Empirical	0	(0.0)	1	(1.2)	5	(5.8)	19	(22.1)	24	(27.9)	20	(23.3)	69	(80.2)
	Nonempirical	0	(0.0)	0	(0.0)	7	(8.1)	4	(4.7)	3	(3.5)	3	(3.5)	17	(19.8)

Appendix B. The distribution of science disciplines of articles by science education researchers in Taiwan from 1982 to 2012

	Time interval	1982–1987		1988–1992		1993–1997		1998–2002		2003–2007		2008–2012		Subtotal	
TIJ ($n=26$)	1. Physics							1	(3.8)	3	(11.5)	2	(7.7)	6	(23.1)
	2. Chemistry							1	(3.8)	3	(11.5)	5	(19.2)	9	(34.6)
	3. Biology							0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	4. Earth science							2	(7.7)	0	(0.0)	2	(7.7)	4	(15.4)
	5. Cross-domain							1	(3.8)	0	(0.0)	0	(0.0)	1	(3.8)
	6. Others							2	(7.7)	2	(7.7)	2	(7.7)	6	(23.1)
	7. NA							0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	Subtotal							7	(26.9)	8	(30.8)	11	(42.3)		

	Time interval	1982–1987		1988–1992		1993–1997		1998–2002		2003–2007		2008–2012		Subtotal	
TJ ($n=60$)	1. Physics			0	(0.0)	4	(6.7)	7	(11.7)	5	(8.3)	8	(13.3)	24	(40.0)
	2. Chemistry			0	(0.0)	0	(0.0)	1	(1.7)	5	(8.3)	0	(0.0)	6	(10.0)
	3. Biology			0	(0.0)	0	(0.0)	3	(5.0)	2	(3.3)	1	(1.7)	6	(10.0)
	4. Earth science			0	(0.0)	3	(5.0)	2	(3.3)	3	(5.0)	1	(1.7)	9	(15.0)
	5. Cross-domain			0	(0.0)	0	(0.0)	0	(0.0)	2	(3.3)	0	(0.0)	2	(3.3)
	6. Others			0	(0.0)	0	(0.0)	2	(3.3)	2	(3.3)	2	(3.3)	6	(10.0)
	7. NA			1	(1.7)	5	(8.3)	3	(5.0)	0	(0.0)	0	(0.0)	9	(15.0)
	Subtotal			1	(1.7)	12	(20.0)	18	(30.0)	19	(31.7)	12	(20.0)		

Appendix C. The distribution of conceptual framework of articles by science education researchers in Taiwan from 1982 to 2012

	Time Interval	1982–1987		1988–1992		1993–1997		1998–2002		2003–2007		2008–2012		Subtotal	
TIJ ($n=26$)	1. Epistemology							3	(11.5)	3	(11.5)	5	(19.2)	11	(42.3)
	2. Ontology							3	(11.5)	0	(0.0)	1	(3.8)	4	(15.4)
	3. Affection/social							0	(0.0)	1	(3.8)	1	(3.8)	2	(7.7)
	4. Development							0	(0.0)	0	(0.0)	1	(3.8)	1	(3.8)
	5. Evolution							0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	6. Instruction							6	(23.1)	4	(15.4)	7	(26.9)	17	(65.4)
	7. Multiple dimensions							0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	8. Others							0	(0.0)	3	(11.5)	1	(3.8)	4	(15.4)
	Subtotal							12	(46.2)	11	(42.3)	16	(61.5)		

	Time Interval	1982–1987		1988–1992		1993–1997		1998–2002		2003–2007		2008–2012		Subtotal	
TJ ($n=60$)	1. Epistemology			1	(1.7)	6	(10.0)	3	(5.0)	5	(8.3)	3	(5.0)	18	(30.0)
	2. Ontology			0	(0.0)	1	(1.7)	0	(0.0)	3	(5.0)	1	(1.7)	5	(8.3)
	3. Affection/social			0	(0.0)	0	(0.0)	1	(1.7)	0	(0.0)	0	(0.0)	1	(1.7)
	4. Development			0	(0.0)	0	(0.0)	2	(3.3)	1	(1.7)	0	(0.0)	3	(5.0)
	5. Evolution			0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	1	(1.7)	1	(1.7)
	6. Instruction			0	(0.0)	8	(13.3)	14	(23.3)	12	(20.0)	9	(15.0)	43	(71.7)
	7. Multiple dimensions			0	(0.0)	1	(1.7)	2	(3.3)	1	(1.7)	0	(0.0)	4	(6.7)
	8. Others			0	(0.0)	2	(3.3)	0	(0.0)	1	(1.7)	1	(1.7)	4	(6.7)
	Subtotal			1	(1.7)	18	(30.0)	22	(36.7)	23	(38.3)	15	(25.0)		

Appendix D. The distribution of data collection methods of articles by science education researchers from 1982 to 2012

	Time interval	1982–1987		1988–1992		1993–1997		1998–2002		2003–2007		2008–2012		Subtotal	
TIJ ($n=26$)	1. Qualitative							0	(0.0)	2	(7.7)	3	(11.5)	5	(19.2)
	2. Quantitative							3	(11.5)	2	(7.7)	3	(11.5)	8	(30.8)
	3. Both (1) and (2)							4	(15.4)	2	(7.7)	2	(7.7)	8	(30.8)
	4. Quantifying the qualitative data							0	(0.0)	3	(11.5)	5	(19.2)	8	(30.8)
	5. NA							0	(0.0)	0	(0.0)	1	(3.8)	1	(3.8)
	Subtotal							7	(26.9)	9	(34.6)	14	(53.8)		

	Time interval	1982–1987		1988–1992		1993–1997		1998–2002		2003–2007		2008–2012		Subtotal	
TJ ($n=60$)	1. Qualitative			0	(0.0)	1	(1.7)	5	(8.3)	3	(5.0)	1	(1.7)	10	(16.7)
	2. Quantitative			1	(1.7)	0	(0.0)	4	(6.7)	6	(10.0)	1	(1.7)	12	(20.0)
	3. Both (1) and (2)			0	(0.0)	4	(6.7)	3	(5.0)	8	(13.3)	7	(11.7)	22	(36.7)
	4. Quantifying the qualitative data			0	(0.0)	1	(1.7)	0	(0.0)	5	(8.3)	2	(3.3)	8	(13.3)
	5. NA			0	(0.0)	7	(11.7)	4	(6.7)	3	(5.0)	2	(3.3)	16	(26.7)
	Subtotal			1	(1.7)	13	(21.7)	16	(26.7)	25	(41.7)	13	(21.7)		

Appendix E. The distribution of data collection methods of articles by science education researchers from 1982 to 2012

	Time interval	1982–1987		1988–1992		1993–1997		1998–2002		2003–2007		2008–2012		Subtotal	
TIJ ($n=26$)	1. Paper and pencil test							5	(19.2)	4	(15.4)	4	(15.4)	13	(50.0)
	2. Interview							5	(19.2)	5	(19.2)	6	(23.1)	16	(61.5)
	3. Drawing							1	(3.8)	0	(0.0)	1	(3.8)	2	(7.7)
	4. Online data							0	(0.0)	0	(0.0)	1	(3.8)	1	(3.8)
	5. Questionnaire							0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	6. Online questionnaire							0	(0.0)	0	(0.0)	1	(3.8)	1	(3.8)
	7. Rubric or coding sheet of classroom observation							0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	8. Biological data							0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	9. Others							3	(11.5)	2	(7.7)	4	(15.4)	9	(34.6)
	10. NA							0	(0.0)	0	(0.0)	1	(3.8)	1	(3.8)
	Subtotal							14	(53.8)	11	(42.3)	18	(69.2)		

	Time interval	1982–1987		1988–1992		1993–1997		1998–2002		2003–2007		2008–2012		Subtotal	
TJ (*n*=60)	1. Paper and pencil test			1	(1.7)	4	(6.7)	7	(11.7)	13	(21.7)	8	(13.3)	33	(55.0)
	2. Interview			0	(0.0)	4	(6.7)	6	(10.0)	15	(25.0)	6	(10.0)	31	(51.7)
	3. Drawing			0	(0.0)	0	(0.0)	0	(0.0)	1	(1.7)	2	(3.3)	3	(5.0)
	4. Online data			0	(0.0)	0	(0.0)	1	(1.7)	1	(1.7)	0	(0.0)	2	(3.3)
	5. Questionnaire			0	(0.0)	0	(0.0)	1	(1.7)	0	(0.0)	0	(0.0)	1	(1.7)
	6. Online questionnaire			0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	7. Rubric or coding sheet of classroom observation			0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	8. Biological data			0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	9. Others			0	(0.0)	1	(1.7)	2	(3.3)	2	(3.3)	2	(3.3)	7	(11.7)
	10. NA			0	(0.0)	7	(11.7)	4	(6.7)	3	(5.0)	2	(3.3)	16	(26.7)
	Subtotal			1	(1.7)	16	(26.7)	21	(35.0)	35	(58.3)	20	(33.3)		

Appendix F. The distribution of teaching or nonteaching studies by science education researchers in Taiwan from 1982 to 2012

	Time interval	1982–1987		1988–1992		1993–1997		1998–2002		2003–2007		2008–2012		Subtotal	
TIJ (*n*=26)	Articles related to teaching	0	(0.0)	0	(0.0)	0	(0.0)	6	(23.1)	6	(23.1)	7	(26.9)	19	(73.1)
	NA	0	(0.0)	0	(0.0)	0	(0.0)	1	(3.8)	2	(7.7)	4	(15.4)	7	(26.9)
	Total	0	(0.0)	0	(0.0)	0	(0.0)	7	(26.9)	8	(30.8)	11	(42.3)	26	(100.0)
TJ (*n*=60)	Articles related to teaching	0	(0.0)	0	(0.0)	2	(3.3)	13	(21.7)	16	(26.7)	8	(13.3)	39	(65.0)
	NA	0	(0.0)	1	(1.7)	8	(13.3)	5	(8.3)	3	(5.0)	4	(6.7)	21	(35.0)
	Total	0	(0.0)	1	(1.7)	10	(16.7)	18	(30.0)	19	(31.7)	12	(20.0)	60	(100.0)

Appendix G. The distribution of teaching strategies of articles by science education researchers in Taiwan from 1982 to 2012

	Time interval	1982–1987		1988–1992		1993–1997		1998–2002		2003–2007		2008–2012		Subtotal	
TIJ ($n=19$)	1. Analogy, model and modeling	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	1	(5.3)	1	(5.3)	2	(10.5)
	2. Multimedia	0	(0.0)	0	(0.0)	0	(0.0)	1	(5.3)	0	(0.0)	5	(26.3)	6	(31.6)
	3. Conceptual conflict	0	(0.0)	0	(0.0)	0	(0.0)	2	(10.5)	3	(15.8)	2	(10.5)	7	(36.8)
	4. Inquiry	0	(0.0)	0	(0.0)	0	(0.0)	1	(5.3)	1	(5.3)	0	(0.0)	2	(10.5)
	5. Cooperative learning	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	6. Experiment	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	1	(5.3)	0	(0.0)	1	(5.3)
	7. Text	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	8. Multiple representation	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	9. Argumentation	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	10. Concept map	0	(0.0)	0	(0.0)	0	(0.0)	1	(5.3)	0	(0.0)	0	(0.0)	1	(0.0)
	11. Science history	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	12. Metacognitive approach	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	13. Writing	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	14. Constructivist approach	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	15. Self-explanation	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	16. Motivation	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	1	(5.3)	1	(5.3)
	17. Others	0	(0.0)	0	(0.0)	0	(0.0)	2	(10.5)	0	(0.0)	1	(5.3)	3	(15.8)
	Total	0	(0.0)	0	(0.0)	0	(0.0)	7	(36.8)	6	(31.6)	10	(52.6)	23	(121.1)

	Time interval	1982–1987		1988–1992		1993–1997		1998–2002		2003–2007		2008–2012		Subtotal	
TJ ($n=39$)	1. Analogy, model and modeling	0	(0.0)	0	(0.0)	1	(2.6)	3	(7.7)	2	(5.1)	1	(2.6)	7	(17.9)
	2. Multimedia	0	(0.0)	0	(0.0)	0	(0.0)	3	(7.7)	2	(5.1)	1	(2.6)	6	(15.4)
	3. Conceptual conflict	0	(0.0)	0	(0.0)	0	(0.0)	2	(5.1)	3	(7.7)	0	(0.0)	5	(12.8)
	4. Inquiry	0	(0.0)	0	(0.0)	0	(0.0)	1	(2.6)	3	(7.7)	1	(0.0)	5	(12.8)
	5. Cooperative learning	0	(0.0)	0	(0.0)	0	(0.0)	1	(2.6)	1	(2.6)	0	(0.0)	2	(5.1)
	6. Experiment	0	(0.0)	0	(0.0)	0	(0.0)	1	(2.6)	1	(2.6)	0	(0.0)	2	(5.1)
	7. Text	0	(0.0)	0	(0.0)	2	(5.1)	0	(0.0)	0	(0.0)	0	(0.0)	2	(5.1)
	8. Multiple representation	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	9. Argumentation	0	(0.0)	0	(0.0)	0	(0.0)	2	(5.1)	0	(0.0)	0	(0.0)	2	(5.1)
	10. Concept map	0	(0.0)	0	(0.0)	0	(0.0)	3	(7.7)	1	(2.6)	1	(2.6)	5	(12.8)
	11. Science history	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	2	(5.1)	2	(5.1)
	12. Metacognitive approach	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	13. Writing	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	14. Constructivist approach	0	(0.0)	0	(0.0)	0	(0.0)	1	(2.6)	0	(0.0)	0	(0.0)	1	(2.6)
	15. Self-explanation	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	16. Motivation	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	17. Others	0	(0.0)	0	(0.0)	1	(2.6)	2	(5.1)	7	(17.9)	2	(5.1)	12	(30.8)
	Total	0	(0.0)	0	(0.0)	4	(10.3)	19	(48.7)	20	(51.3)	8	(20.5)	51	(130.8)

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