Chapter 13
Impacts of Citations on Conceptual Change Articles Between 1982 and 2011: From International and Regional Perspectives

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Abstract The purpose of this book chapter is to investigate the impacts of research articles on conceptual change field via the analysis of citations listed in a set of selected journal articles. According to our screening processes, we found 365 articles in the selected science education journals (*Journal of Research in Science Teaching, Science Education, International Journal of Science Education, Research in Science Education, International Journal of Mathematics and Science Education*) and 17,919 citations were included in the articles. Out of 365, there were 78 articles that had Asian scholars as either the first author or the corresponding persons. Among them, there were 3710 citations in these Asian studies. From the analyses, we found that Posner et al. (Sci Educ 66(2): 211–227, 1982) was the most cited article across the world, followed by Strike and Posner (Cognitive structure and conceptualchange. Academic Press, New York, pp. 211–231, 1992) and Pintrich et al. (RevEduc Res 63(2): 167–199, 1993). However, there were some differences of the orderings of the cited research articles in Asia except the first one, Posner et al. (SciEduc 66(2): 211–227, 1982). In terms of the authors, we found Driver as the most influential researcher in the area of conceptual change compared to others across the world. This holds true in Asia as well. However, the orderings of the cited authors were quite different between global and regional aspects. These findings might show specific preferences or impacts of research directions globally and locally. Detailed analyses and implications will be discussed.

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13.1 Introduction

There is quite a developed literature on conceptual change over the past 40 years. For this development, we can trace back to Kuhn's (1962) "normal science" or Lakatos's (1970) "theoretical hard core" that are considered as the central commitments for knowledge use on the one hand. On the other hand, conceptual change occurs when these central commitments require modifications and replacement. Kuhn terms this kind of conceptual change a "scientific revolution" whereas Lakatos called it research programs. Posner et al. (1982) believe there are analogous patterns of conceptual change in learning. Taking Piagetian terminologies, assimilation, and accommodation, as analogies, assimilation refers to the use of existing knowledge to cope with new knowledge, whereas accommodation refers to the replacement or reorganization of one's knowledge structure accordingly (Posner et al. 1982) which is considered as radical conceptual change. In addition to these scholars and theories, different researchers in the fields of cognitive science, cognitive psychology, or social psychology also developed important theories to describe the nature of conceptual change and what attributes to conceptual change. For instance, Stella Vosniadou, as a cognitive psychologist, considered conceptual change as related to learners' ontological and epistemological presupposition of a phenomenon that shapes one's conceptual understanding and internal representations (e.g., Vosniadou and Brewer 1994; Vosniadou et al. 2008). Micki Chi, as a cognitive scientist, proposed that conceptual change refers to moving one ontological concept from an ontological tree to the other (e.g., from Matter to Process categorical tree) (e.g., Chi et al. 1994; Chi 2008). She categorized conceptual change into three types, namely belief revision, mental model transformation, and categorical shift. All are dealt with the ontological categories of a concept. In science education, Posner et al. (1982) identified four conditions for conceptual change, namely, dissatisfaction, intelligibility, plausibility, and fruitfulness. Driver et al. (1994) defined learning as involving a process of conceptual change. Linn (2008) defined conceptual change as "the individual's lifelong trajectory of understanding of a given topic or discipline" (p. 694). Pintrich et al. (1993), Sinatra and Pintrich (2003) advocated contextualized learning and motivation factor that play influential roles in science learning. Even though different authors do not seem to share similar ideas or theories about what the nature and representation of knowledge is and how knowledge is constructed and reconstructed, the importance of understanding the theories and mechanism of conceptual change inform the use of the term within science education.

Chiu et al. (2016) investigated 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. A total of 383 articles in the international journals (including 26 English papers from researchers in Taiwan) were investigated.

The authors used an approach titled RAINBOW (Research and Instructional Based/Oriented Work, Chiu and Lin 2008) with six perspectives, namely,

development, epistemology, ontology, evolution, affection/social, and instruction, to analyze the types of the articles. They found that there were more empirical studies than nonempirical studies (82.5 % vs. 17.5 %). Among the empirical studies, 66.1 % of the articles adopted the epistemological approach and 61.1 % of the articles were based upon instructional perspective. Very limited percentages of articles were from the ontological perspective (6.0 %) and evolutionary approaches (0.5 %). Affective and developmental perspectives had about 8.6 %. It was understandable that there were more articles coming from the epistemological perspective because researchers in science education tend to understand how to help students learn scientific knowledge and phenomenon. From the analysis, the authors also found that the numbers of articles published in epistemological and ontological perspectives started to increase in 1993 while the number of affective perspective articles started to increase in 1998 for five years after Pintrich et al. (1993) published their influential article on "hot" conceptual change (Chiu et al. 2016). The authors also noticed that in addition to Posner, et al.'s articles on the conditions of conceptual change, some influential research articles were also published during the years between 1991 and 2000. Therefore, we intended to put one more step further to analyze the frequencies of citations in the selected five journals that Chiu et al. used in their study for investigating the impacts of the articles on conceptual change.

13.2 Research Questions

There are three research questions to be answered in this chapter.

Question 1: Which articles were ranked on the top of 25 most citable papers across the world during 1982–2011?

Question 2: Which articles were ranked on the top of 25 most citable papers in Asia during 1982–2011?

Question 3: Who were ranked on the top of 25 most citable researchers across the world during 1982–2011?

Question 4: Who were ranked on the top of 25 most citable researchers in Asia during 1982–2011?

13.3 Method

13.3.1 Identifying Papers for This Review

Journal articles published from 1982 to 2011 in the top five international science education journals [i.e., *Journal of Research in Science Teaching, Science Education, International Journal of Science Education (formerly entitled as European Journal of Science Education), Research in Science Education,* and

International Journal of Science and Mathematics Education] were searched with the keywords of "conceptual change." This process yielded 365 articles and 17,919 citations. Among them, there were 78 articles whose first author or corresponding author was Asian. There were 3710 citations from these Asian studies.

13.3.2 Data Analysis

For the international highest impact citations, we identified the most cited references among the 365 articles, and selected the top 25 articles. If the citation number was equal, we compared the published year of these articles or books and selected the newer ones for our list. For the highest impact citations in Asia, we looked for the most cited studies among the 78 Asian articles, and selected the top 25 citations as well.

Since a single author might have several important studies, we have also ranked the number of citation for each scholar to better reflect his/her contribution. For the highest impact international scholars, we counted the first author who was the most cited in the 365 articles, and selected the top 25 scholars. For the highest impact Asian scholars, our scope was changed to the 78 Asian articles, and the top 25 high-impact scholars in Asia were also selected.

13.3.2.1 Formation of an Analytical Framework

In this chapter, we used content analysis method to analyze the journal articles mentioned above. Figure 13.1 shows the dimensions of the framework for content analysis of this study.

13.3.3 Reliability of Data Source

The difficulty of this study was the accuracy of authors' citations. The same work might be cited as different information by different authors. For examples, Strauss's work (1998) might be cited as "Basics of qualitative research: Techniques and procedures for developing grounded theory" or "Basics of qualitative research:

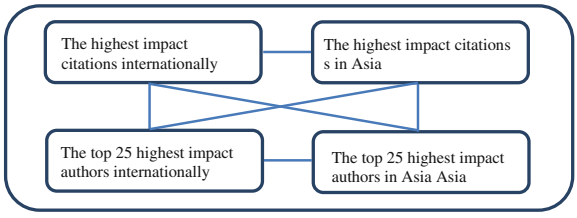

Fig. 13.1 The framework for content analysis of this study

Techniques and procedures for developing ground theory". These inconsistent citations might lead to different codings; therefore, the authors of the current study spent much effort to correct the information to enhance the reliability of this study. Once the data were verified and then the computer software would analyze them accordingly.

13.4 Results and Discussions

13.4.1 The Top 25 International Highest Impact Articles

To answer the first research question of this study, some descriptive statistics were conducted. Our analysis results are shown in Table 13.1. During 1982–2011, the top 25 articles that have major international impact on science education were published between 1962 and 1996 and the Time Cited count was ranged from 29 to 199. The top three influential articles are Posner et al. (1982), Strike and Posner's (1992), and Pintrich et al. (1993). Posner et al. were the first group that proposed the conceptual change model (CCM). They claimed four necessary conditions for students' conceptual change: dissatisfaction, intelligibility, plausibility, and fruitfulness. The second influential one, Strike and Posner's study, expanded the explanatory power of the CCM and used "conceptual ecology" to interpret student's science learning. Pintrich et al. reminded that the previous studies of conceptual change was too rational and highlighted the significance of students' motivational dimension (goals, values, self-efficacy, and control beliefs).

The rank 5 article, National Science Education Standards (NSES, National Research Council 1996) and the rank 18 article, Benchmarks for science literacy (American Association for the Advancement of Science 1993) are the most influential education documents. NSES are a set of guidelines for science education in primary and secondary schools in the United States. It is based heavily on constructivism, and emphasized scientific literacy (i.e., inquiry, history, and nature of science, personal and social perspectives of science, science, and technology). Programs that were defined according to these standards should be developmentally appropriate, interesting, and relevant to students' lives. As for Benchmarks for Science Literacy, it is not a curriculum framework or a curriculum plan. It simply provides educators with sequences of specific learning goals, and states what all students should know and be able to do in science, mathematics, and technology by the end of grades 2, 5, 8, and 12.

The rank 6 (Pfundt and Duit 1994), rank 13 (Driver and Easley 1978), rank 14 (Osborne and Freyberg 1985), rank 17 (Wandersee et al. 1994), rank 18 (Driver et al. 1994), and rank 22 (Osborne and Wittrock 1983) citations included a bibliography, three books and two review articles, which delicately collected and categorized various students' or teachers' alternative conceptions. It is worth mentioning that number six on the ranking was a bibliography by Pfundt and Duit. This bibliography was revised several times to reflect the rapid developments of science education

Table 13.1 The rank of the top 25 international highest impact citations (N = 365)

No.	Rank. Authors	Title	*n*	%
1	1. Posner et al. (1982)	Accommodation of a scientific conception: toward a theory of conceptual change	199	54.5
2	2. Strike and Posner (1992)	A revisionist theory of conceptual change	88	24.1
3	3. Pintrich et al. (1993)	Beyond cold conceptual change: the role of motivation beliefs and classroom contextual factors in the process of conceptual change	78	21.4
4	4. Carey (1985)	Conceptual change in childhood	54	14.8
5	5. NRC (1996)	National Science Education Standards	52	14.2
6	6. Pfundt and Duit (1994)	Bibliography of every day conceptions and science education	50	13.7
7	7. Hewson and Thorley (1989)	The conditions of conceptual change in the classroom	49	13.4
8	7. Kuhn (1962)	The structure of scientific revolutions	49	13.4
9	9. Chi et al. (1994)	From things to processes: a theory of conceptual change for learning science concepts	46	12.6
10	10. Chinn and Brewer (1993)	The role of anomalous data in knowledge acquisition: a theoretical framework and implications for science instruction	44	12.1
11	11. Vosniadou (1994)	Capturing and modeling the process of conceptual change	42	11.5
12	12. Hewson (1981)	A conceptual change approach to learning science	40	11.0
13	13. Driver and Easley (1978)	Pupils and paradigms: a review of literature related to concept development in adolescent science students	39	10.7
14	14. Osborne and Freyberg (1985)	Learning in science: the implications of children's science	37	10.1
15	15. Vosniadou and Brewer (1992)	Mental models of the earth: a study of conceptual change in childhood	34	9.3
16	15. Nussbaum and Novick (1982)	Alternative frameworks, conceptual conflict and accommodation: toward a principled teaching strategy	34	9.3
17	17. Wandersee et al. (1994)	Research on alternative conceptions in science	33	9.0
18	18. AAAS (1993)	Benchmarks for science literacy: a project 2061 report	32	8.8
19	18. Driver et al. (1994)	Constructing scientific knowledge in the classroom	32	8.8
20	20. Duschl and Gitomer (1991)	Epistemological perspectives on conceptual change—implications for educational practice	31	8.5
21	21. Strike and Posner (1985)	A conceptual change view of learning and understanding	30	8.2
22	22. diSessa (1993)	Toward an epistemology of physics	29	7.9
23	22. Osborne and Wittrock (1983)	Learning science: a generative process	29	7.9
24	22. Tyson et al. (1997)	A multidimensional framework for interpreting conceptual change events in the classroom	29	7.9
25	22. White and Gunstone (1989)	Metalearning and conceptual change	29	7.9

research. We counted them as the same literature despite the revisions. Its final version was named "Students' and Teachers' Conceptions and Science Education". However, its author, Duit (2009), decided to stop revising the bibliography since new powerful search means have become available. In summary, this bibliography was helpful for teaching and learning science from a constructivist perspective.

The fourth (Carey 1985), seventh (Hewson and Thorley 1989), 9th to 12th [Chi et al. (1994) followed by Chinn and Brewer (1993), Vosniadou (1994), Hewson (1981)], and 15th to 22nd [Vosniadou and Brewer 1992 followed by Duschl and Gitomer (1991), Strike and Posner (1985), Tyson et al. (1997), diSessa (1993) and White and Gunstone (1989)] dealt with theories of conceptual change. It seems that there are two peaks among these fundamental theories.

The first peak, Carey's work on children's understanding, was a coherent and consistent account for biology. It finally enabled us to understand the classical Piagetian work on animism and how it fitted with the later work on children's concepts of living things. She also differentiated degrees of conceptual change into weak and strong. The former only dealt with addition and/or deletion while the latter dealt with the restructuring of knowledge. Hewson's study could be seen as the pioneering work for CCM. It investigated how a student holding a set of conceptions of natural phenomena would respond when confronted by new experiences. Hewson and Thorley further showed that the four conditions for conceptual change have been used to analyze interview data and plan instruction but not to interpret interactions in the classroom via literature review. Their analysis of the ways in which students can and do produce evidence of meeting conditions shows that this only happens when they are able to monitor and comment on the scientific content of their conceptions. Chi et al. interpreted students' learning difficulties in science from the ontological perspective. She argued that students tended to use matter ontology rather than emergent process ontology to explain complex natural phenomenon due to their lack of the emergent process schema. The contribution of Chinn and Brewer is to propose students' seven responses to anomalous data. "Peripheral theory change" and "theory change" are the only two responses from the seven that could reach conceptual change. Vosniadou (1994), Vosniadou and Brewer (1992) proposed the "framework theory" and explained that all kinds of students' mental models are limited by "specific theories" from different cultures and nature observations. Furthermore, these specific theories are constrained by ontology and epistemology.

For the second peak of these important theories, there were Duschl and Gitomer who used "portfolio culture" to advance a piecemeal model of the character and mechanism of restructuring. The essential characteristic of this culture is that it creates opportunities for students to develop their scientific understanding and equip them with the tools necessary to take responsibility for their own restructuring. Strike and Posner (1985) examined the criticisms of the original CCM and provided empirical evidences to revise it. Tyson et al. (1997) analyzed the various usages of "conceptual change," and developed a multidimensional framework (i.e., epistemological, ontological, and social/affective perspectives) for conceptual changes in the classroom. They asserted that effective changes in students' knowledge structures should be considered from this multidimensional framework.

In contrast to Vosniadou's framework theory (Vosniadou 1994), diSessa (1993) investigated the intuitive sense of mechanism and proposed a p-prim theory and coordination theory to explain how intuitive ideas influence school physics learning. He claimed that the intuitive sense of mechanism contains various simple elements (p-prim), which were originally relatively problematic, and the system is weakly organized. White and Gunstone (1989) claimed the promotion of a new belief is relatively easy, but it is difficult to get students to abandon their former beliefs. They argued that the resolution of conflicting beliefs requires elements of metalearning (i.e., conscious control over one's learning). These theoretical articles and the top 3 highest impact studies possess 2.26 times cited more than the other studies, and displayed various vital perspectives explaining students' conceptual change.

The publication of Kuhn's work (ranked 7) was a landmark event in the history, philosophy, and sociology of scientific knowledge and triggered the development of CCM. "The structure of scientific revolutions" was also the only publication from science philosopher's perspective. Nussbaum and Novick's study (rank 15) presented a case study on a sequence of two lessons about the particle model and provided an analysis of the phases of the instructional strategy (alternative frameworks-conceptual conflict-accommodation) employed for cognitive accommodation. This study only focused on particle model unlike other books or review articles on our high-impact list, which documented various students' alternative conceptions.

13.4.2 The Top 25 Highest Impact Articles in Asia

To answer the second research question of this study, some descriptive statistics were conducted. The top 25 highest impact articles in Asia are shown in Table 13.2. During 1982–2011, the top 25 articles which have major impact on science education were published between 1962 and 2003 and the Time Cited count was ranged from 7 to 37. The top three influential articles are Posner et al. (1982), Pintrich et al. (1993) studies and Chi et al.'s (1994) ontology theory. The comparison of the high-impact articles between the Asia and International lists showed the studies of Chinn and Brewer (1998), White and Gunstone (1992), Chi (1992), Dreyfus et al. (1990), and Shepardson and Moje (1999), She (2004), Pintrich (1999) and Clement (1982) were only on the Asia list. Conversely, the studies of Hewson and Thorley (1989), Hewson (1981), Vosniadou and Brewer (1992), Benchmarks for science literacy (AAAS 1993), Duschl and Gitomer (1991), Strike and Posner (1985), diSessa (1993), White and Gunstone (1989), and Osborne and Wittrock (1983) were only on the International list.

The following studies are related to teaching strategies or teaching models. Chinn and Brewer (1993) first proposed a taxonomy of seven responses to anomalous data (ranked 7). In 1998, they revised the taxonomy and added the

Table 13.2 The rank of the top 25 highest impact articles in Asia (N = 78)

No.	Rank. Authors	Title	*n*	%
1	1. Posner et al. (1982)	Accommodation of a scientific conception: toward a theory of conceptual change	37	47.4
2	2. Pintrich et al. (1993)	Beyond cold conceptual change: the role of motivation beliefs and classroom contextual factors in the process of conceptual change	22	28.2
3	3. Chi et al. (1994)	From things to processes: a theory of conceptual change for learning science concepts	18	23.1
4	4. Strike and Posner (1992)	A revisionist theory of conceptual change	15	19.2
5	5. Kuhn (1962)	The structure of scientific revolutions	14	17.9
6	6. Chinn and Brewer (1998)	An empirical test of a taxonomy of responses to anomalous data in science	12	15.4
7	7. Chinn and Brewer (1993)	The role of anomalous data in knowledge acquisition: a theoretical framework and implications for science instruction	11	14.1
8	7. Vosniadou (1994)	Capturing and modeling the process of conceptual change	11	14.1
9	7. White and Gunstone (1992)	Probing understanding	11	14.1
10	10. Pfundt and Duit (1994)	Bibliography of every day conceptions and science education	10	12.8
11	10. Wandersee et al. (1994)	Research on alternative conceptions in science	10	12.8
12	12. Chi (1992)	Conceptual change within and across ontological categories: examples from learning and discovery in science	9	11.5
13	12. Driver et al. (1994)	Constructing scientific knowledge in the classroom	9	11.5
14	12. NRC (1996)	National Science Education Standards	9	11.5
15	12. Osborne and Freyberg (1985)	Learning in science: the implications of children's science	9	11.5
16	12. Tyson et al. (1997)	A multidimensional framework for interpreting conceptual change events in the classroom	9	11.5
17	17. Carey (1985)	Conceptual change in childhood	8	10.3
18	17. Dreyfus et al. (1990)	Applying the cognitive conflict strategy for conceptual change—some implications, difficulties and problems	8	10.3
19	17. Driver et al. (1985)	Children's ideas in science	8	10.3
20	17. Duit and Treagust (2003)	Conceptual change: a powerful framework for improving science teaching and learning	8	10.3
21	17. Shepardson and Moje (1999)	The role of anomalous data in restructuring fourth graders' frameworks for understanding electric circuits	8	10.3
22	23. Clement (1982)	Students' preconceptions in introductory mechanics	7	9.0
23	23. Gilbert et al. (1982)	Children's science and its consequence for teaching	7	9.0
24	23. Pintrich (1999)	Motivational beliefs as resources for and constraints on conceptual change	7	9.0
25	23. She (2004)	Fostering "radical" conceptual change through dual situated learning model	7	9.0

eighth response, "holding the data in abeyance" (Chinn and Brewer 1998, rank 6). They claimed that the taxonomy could help science teachers to anticipate students' reactions to anomalous data and it could also be used to lead students' discussion regarding the nature of scientific rationality. Shepardson and Moje's (1999) study was also related to students' response to anomalous data (rank 17). They studied the nature of fourth graders' understandings of electric circuits and showed how they used it as frameworks for interpreting data derived from the observation and manipulation of electric circuits. In White and Gunstone's (1992) study (rank 7), they attempted to provide several practical teaching methods for teachers to probe students' understanding. In Dreyfus and his colleagues' (1990) study (rank 17), researchers discussed how the three main stages of conceptual change (i.e., awareness, disequilibrium, and reformulating) influenced misconceptions of 10th graders. She (2004) developed the dual situated learning model to promote students' radical conceptual change (rank 23). Summarizing these studies, it appears that the researchers in Asia (73.2 %) valued teaching methods or teaching models more than international scholars (12.1 %).

There were two studies about children's ideas that were not on the international list. Clement's (1982) study was focused on students' alternative conceptions in force and acceleration. The source of this qualitative misunderstanding could be a result of a preconception that hinders the full understanding of Newton's first and second laws. Clement proposed that new concepts must displace or be remolded from an existing concept. Gilbert et al. (1982) argued that what children bring with them to science lessons are logical and coherent to them, and that these views have considerable influence on how and what children learn from their classroom experiences.

Chi's ontology theory was initially introduced in 1992. This chapter was also the study that was not on our analysis of the international list (Table 13.1). In this chapter, she firstly introduced the conceptual change that occurs within an ontological category and that necessitates a change between ontological categories to discriminate conceptual learning and development. It seems that researchers in Asia placed more emphasis on ontological perspective than international researchers (34.6 % vs. 12.6 %). The other significant perspective in Asia was Pintrich's (Pintrich 1999; Pintrich et al. 1993) motivation in conceptual change theory (37.2 % vs. 21.4 %). Pintrich et al. (1993) have emphasized that the conceptual change processes are influenced by affective, motivational, and social factors. In Pintrich's (1999) study, he further analyzed the impact of different goal orientations, epistemological beliefs, personal interests, self-efficacy, and the influence of control beliefs on conceptual change. He argued that intrinsically motivated learners with a mastery orientation, who focus on the understanding and mastering the subject matter, are more likely to be engaged in deeper cognitive processing and, thus, show more conceptual change than extrinsically motivated learners with a performance orientation, who focus on external rewards, good grades, and besting others.

13.4.3 The Top 25 Highest Impact Researchers Internationally

To answer the third research question of this study, we conducted some analysis and the results are shown in Table 13.3. Table 13.3 reveals the first authors who were ranked the top 25 highest influential researchers on conceptual change. During the period of 1982–2011, the most cited article was written by Rosaline Driver. In other words, all her publications during the period were cited more than once in all 365 articles. Following Driver, 85.8 % of the articles cited papers published by Stella Vosniadou and 83.3 % of the articles cited Peter W. Hewson's studies. Although George J. Posner's article on CCM published in 1982 was cited the most (Table 13.1), 60 % of his publications were cited and followed by Reinders Duit

Table 13.3 The rank of the top 25 highest impact authors internationally

Rank	Scholar	Country	Total	% (n = 365)	Aligned authors with publications in Table 13.1
1	Driver, R.	UK	366	100.3	13, 19
2	Vosniadou, S.	Greece	313	85.8	11, 15
3	Hewson, P.W.	USA	304	83.3	1, 7, 12
4	Posner, G.J.	USA	228	62.5	1, 2, 21
5	Duit, R.	USA	195	53.4	6
6	Osborne, R.J.	UK	171	46.8	14, 25
7	diSessa, A.A.	USA	161	44.1	22
8	Chi, M.T.H.	USA	153	41.9	9
9	Strike, K.A.	USA	142	38.9	1, 2, 21
10	Pintrich, P.R.	USA	135	37.0	3
11	Novak, J.D.	USA	134	36.7	x
12	Carey, S.	USA	126	34.5	4
13	Lawson, A.E.	USA	124	34.0	x
14	Clement, J.	USA	124	34.0	x
15	Piaget, J.	USA	117	32.1	x
16	Gilbert, J.K.	UK	109	29.9	x
17	Nussbaum, J.	UK	107	29.3	16
18	Roth, W.-M.	Canada	99	27.1	x
19	Chinn, C.A.	USA	98	26.8	10
20	White, R. T.	Australia	97	26.6	24
21	Gunstone, R.F.	Australia	92	25.2	x
22	Duschl, R.A.	USA	85	23.3	20
23	Tobin, K.G.	USA	77	21.1	x
24	Kuhn, T.S.	USA	72	19.7	8
25	Kuhn, D.	USA	72	19.7	x

Note x stands for not included in the internationally list

with 50 % on his publications. In sum, nearly 20 % of the articles had cited works written by the top 25 researchers.

According to Tables 13.1 and 13.3, we found 16 out of 25 researchers in Table 13.3 had their publications listed on the top 25 most cited papers. Among them, Rosaline Driver had two influential articles (Driver and Easley 1978; Driver et al. 1994) ranked as 13 and 19 as shown in Table 13.1; Stella Vosniadou was ranked second and with two articles ranked as the 11th and 15th; (Vosniadou 1994; Vosniadou and Brewer 1992); Peter Hewson and Greg Posner were also recognized as the third and the fourth with three articles ranked highly in international community.

Finally, as shown in Table 13.3, we also found that about 70 % (N = 17) of the research was from the US, followed by 16 % (N = 4) from the UK, 8 % (N = 2) from Australia, and 4 % (N = 1) each from Canada and Greece, respectively.

13.4.4 The Top 25 Highest Impact Researchers in Asia

Table 13.4 revealed that the top 25 highest impact researchers in Asia on conceptual change were also cited the most in publications by Asian scholars. The first one was Rosaline Driver again as shown in Table 13.3. There were 82.1 % of the articles that cited her publications. Following Driver, there were 66.7 % of articles that cited Tsai's research work and then Vosniadou, Lawson, and Pintrich with more than 50 % of the articles citing them.

As compared to Table 13.2, we found that the works citing Driver's publications by Asian scholars were slightly different from non-Asian works that also cited Driver (such as Driver et al., 1985; Driver et al., 1994).

Finally, as shown in Table 13.4, we also found that about 60 % (N = 15) of the research was from the USA, followed by 12 % (N = 3) from Taiwan in Asia, 12 % (N = 3) from UK, 8 % (N = 2) from Australia, 4 % (N = 1) from Germany and Greece, respectively. The ones from Taiwan were works by Chiu et al. (2002), Chiu and Lin (2005), She (2002, 2004), and Tsai (1999, 2000, 2002, 2003), Tsai and Wen (2005), respectively.

13.4.4.1 Researchers Listed Among the Top 25 in the World and in Asia

We found that 20 out of 25 researchers were present in both of our analyses for international and Asian citations. Among them, Driver was ranked first either in the world ranking or in the Asian ranking. If we took the top 10 into consideration for both the international and the Asian rankings, we found that the frequencies of citations of works by several scholars (e.g., Chi, Duit, Osborne, Pintrich, Posner, and Vosniadou) were consistently high. In other words, Asian scholars were able to catch the main trend of research on conceptual change and cited relevant studies in the field.

Table 13.4 The ranking of the top 25 highest impact authors in Asia

Rank	Scholar	Country	Total	% (n = 78)	Aligned authors with publications in Table 13.2
1	Driver, R.	UK	64	82.1	13, 19
2	Tsai, C.C.	Taiwan	52	66.7	x
3	Vosniadou, S.	Greece	44	56.4	8
4	Lawson, A.	USA	42	53.8	x
5	Pintrich, P.	USA	41	52.6	23
6	Chi, M.T.H.	USA	38	48.7	3
7	Posner, G.	USA	37	47.4	1
8	Osborne, R.J.	UK	29	37.2	15
9	She, H.C.	Taiwan	29	37.2	22
10	Duit, R	Germany	29	37.2	20
11	Hewson, P.W	USA	25	32.1	1
12	Strike, K.	USA	25	32.1	1, 4
13	Chinn, C.A.	USA	23	29.5	6, 7
14	Nussbaum, J.	UK	23	29.5	x
15	White, R.T.	Australia	23	29.5	9
16	Clement, J.	USA	22	28.2	24
17	Novak, J.D	USA	21	26.9	x
18	Piaget, J.	USA	18	23.1	x
19	Chiu, M.H.	Taiwan	17	21.8	x
20	Carey, S.	USA	17	21.8	17
21	Tobin, K.	USA	16	20.5	x
22	Treagust, D	Australia	16	20.5	20
23	diSessa, A	USA	15	19.2	x
24	Kuhn, D.	USA	15	19.2	x
25	Linn, M.C.	USA	15	19.2	x

Note x standards for not included in the Asian list

However, we also noticed that there were some researchers who were listed in the top 25 persons internationally, but not in Asia (such as Duschl, Gilbert, Gunstone, Kuhn, T., and Roth). Similarly, there were some researchers listed as the top 25 scholars on conceptual change in Asia, but not listed on the international list (such as Chiu, Linn, She, Treagust, and Tsai). However, they did make their contribution on conceptual change research in Asia.

13.5 Conclusions and Implications

Based upon our analysis of the identified articles both from international scholars and Asian scholars, we have the following claims to make.

Claim 1: Both of the international and the Asian scholars valued conceptual change model and motivation most, but Asian scholars valued other theories more equally

This study found that the top three high-impact theoretical perspectives in international research were CCM (111.2 %) (i.e., Hewson 1981; Posner et al. 1982; Strike and Posner 1992), Pintrich's motivation beliefs (21.4 %), and Vosniadou's framework theory (20.8 %). On the other hand, the order in Asian research was CCM (66.6 %), Pintrich's motivation beliefs (37.2 %) and Chi's ontology theory (34.6 %). The focuses in common were the research of CCM and motivation beliefs. Although international studies respected the importance of theory, they put much attention on CCM, while the Asian studies valued various conceptual change theories more equally. Among these theories, Pintrich's motivation beliefs (Asian: 37.2 % vs. International 21.4 %), Chi's ontology theory (Asian: 34.6 % vs. International: 12.6 %), and multidimensional framework for interpreting conceptual change events (Asian: 21.8 % vs. 7.9 %) were some perspectives that caught more attention among Asian scholars than international scholars. Conversely, Vosniadou's framework theory got less attention in Asia (international: 20.8 % vs. 14.1: 0 %), and diSessa's (1993) p-prime (international: 7.9 % vs. Asian: 0 %) and White and Gunstone's (1989) metalearning element (international: 7.9 % vs. Asian: 0 %) were missing on the Asian list.

Claim 2: Reciprocal effects between international conceptual change research and educational policy

There were reciprocal effects between international conceptual change research and educational policy. On the one hand, the authors of the U.S. national standards documents (AAAS 1993; National Research Council 1996) consulted conceptual change research findings in writing content benchmarks (Anderson 2007). On the other hand, *National Science Education Standards* (NRC 1996) and *Benchmarks for Science Literacy: A project 2061 Report* (AAAS 1993) were also the fifth and the eighteenth high-impact document on the international list and guided several conceptual change researches. In addition, *National Science Education Standards* was also the fourteenth high-impact document on the Asia list.

Claim 3: The distributions of authors' countries were slightly different between the international and Asian citations

The analyses of citations in international and Asian studies were slightly different. For the international analysis, 96 % of the citations were from English speaking countries. Meanwhile, in Asia, there was relatively more diversity in terms of the countries that the authors are from, For example, while 80 % of the first authors of the citations in the Asian analysis were from English speaking countries, the percentage of the citations from Germany, Greece, and Taiwan was also relatively high (20 %).

Claim 4: Asian research focused more on teaching strategies

This study further categorized the top 25 international and Asian studies into theory (international: 226.2 % vs. Asian: 202.5 %), instruction (international: 12.1 % vs. Asian: 73.2 %), and the investigation of alternative conceptions (international: 69.5 % vs. Asian: 76.9 %), respectively, and found the Asian research more focused on conceptual change teaching strategies than international research. Among these studies, cognitive conflict was the most popular teaching strategy. This finding echoes Chiu et al.'s (2016) study that more studies were related to epistemology and instruction compared to other perspectives (e.g., ontology, motivation). Although their study compared International and Taiwanese studies, Taiwanese studies on conceptual change possess the largest part in Asia, their result could explain the similar situation in this study.

Suggestion 1: Strengthening the effort on developing theoretical frameworks for informing conceptual change research for local or global needs

Most Asian researchers were devoted to designing appropriate teaching strategies for promoting students' conceptual change in science. It might be a good approach for Asian researchers in the early stage of developing research in the area of conceptual change because it helps them understand different students' characteristics and effect of various teaching strategies from empirical studies in order to evolve new theories (or paradigm) on conceptual change. However, as the research has been investigated for more than 20 years, it is the time to reflect on what has been done and what has not been conducted and needed more knowledge and effort to be put in. Researchers in this field have accumulated considerable results from these empirical studies in Asia. The next step is to synthesize these results and increase the number of theoretical studies for renewing or reconstructing conceptual change theories for local or global needs.

Suggestion 2: Welcoming divergent research paradigms to shed light of cultural and societal impact on science learning

To expand impacts of research, to provide sustainable development of the research on conceptual change in science, and to influence school teaching and teachers' perceptions for conceptual change, we need to provide a wide range of instructional paradigms that are evidence based to support school teaching. Also, as science educators, we need to take individual differences (e.g., students' background, prior knowledge about science, gender) on understanding sciences into account and provide distinct and effective approaches that should be explored in research before implementing them in the school system. Therefore, research has to take cultural, societal, and students' characteristics into consideration for the sake of equality and quality science education. Although Asia started research on conceptual change later than other regions did, we believed researchers in Asia not only recognized the main research trend on conceptual change globally but also extended their research with contextualized elements in their studies. Researchers across the

world should accept divergent research theories to shed light of cultural and societal impact on science learning is still the future work.

Suggestion 3: Outcomes of conceptual change research in Asia should inform education policies

The international conceptual change research had a substantial influence on educational policy. Many textbooks now include lists of common misconceptions in their teacher's editions (Anderson 2007). The conceptual change research in Asia was also influenced by ⟨National Science Education Standards⟩ (NRC 1996). However, the conceptual change research in Asia has accumulated considerable studies. In particular, teaching strategy was the major focus in Asian conceptual change research. There were more research results to inform local teaching practice and education policy.

Suggestion 4: Increasing the interaction between local scholars and international scholars to increase impacts of regional studies in Asia with its special characteristics on cultural and contextual aspects

Contextual and cultural factors have been investigated to show their impacts on students' learning in science. With some historical background and tradition of research on science education, some preferences of research topics might be influenced by specific needs or trends among the research communities in Asia or other areas. By comparing the local and international research results, the culture and society factors could be manifest. Based upon the results, linking local research with the international research community should be emphasized. We believe Asian researchers have expertise and experiences in conducting research locally and publishing in international journals. The interactions between different cultures and ideas could foster new ideas to enhance the impact of the theoretical and empirical research on conceptual change.

Suggestion 5: Identifying the most influential citations and authors for guiding research paradigm and even go beyond their territories

From the analysis shown in this chapter, several researchers and their work were highly cited which could shed some light of conducting research and even put more steps further to enrich in specific areas. However, we also need to broaden our view and then pay attention to other researchers or articles that have potential to lead insightful research topics, directions, or methodology that have not been well received and recognized by the research communities.

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