Design of a social constructivism-based curriculum for primary science education in Confucian heritage culture

Ngô Vũ Thu Hằng

Design of a Social Constructivism-based Curriculum for Primary Science Education in Confucian Heritage Culture/ Ngô Vũ Thu Hằng – Utrecht: Freudenthal Institute for Science and Mathematics Education, Faculty of Science, Utrecht University / FIsme Scientific Library (formerly published as CD-β Scientific Library), no. 82, 2014.

Dissertation Utrecht University. With references. Met een samenvatting in het Nederlands.
ISBN: 978-90-70786-23-6
Keywords: design, social constructivist perspective, curriculum, primary science education, Confucian heritage culture, scientific argumentation
Cover design: Vormgeving Faculteit Bètawetenschappen
Printed by: Ipskamp, Enschede

Design of a Social Constructivism-based Curriculum for Primary Science Education in Confucian Heritage Culture

Een Sociaal Constructivistisch Curriculum Ontwerp voor Primair Onderwijs in de Natuurwetenschappen in een Confuciaanse Cultuur

(met een samenvatting in het Nederlands)

Proefschrift
ter verkrijging van de graad van doctor aan de Universiteit Utrecht
op gezag van de rector magnificus, prof. dr. G.J. van der Zwaan,
ingevolge het besluit van het college voor promoties
in het openbaar te verdedigen
op maandag 17 februari 2014 des middags te 12.45 uur

door

Ngô Vũ Thu Hằng

geboren op 10 september 1981
te Bacninh, Vietnam

Promotor: Prof.dr. A. Pilot

Co-promotor: dr.ir. A.M.W. Bulte

This thesis is financed by NUFFIC, the Dutch organisation for international cooperation in higher education, through the cooperation between the Netherlands and Vietnam.

Table of contents

Từ hai điểm lẻ loi và khác biệt
Nối vào nhau ta có một con đường

There is always a path between two distant gardens.

Er is altijd een pad tussen twee ver uit elkaar gelegen tuinen

CHAPTER 1 Introduction and Research Overview

Introduction

Social constructivist ideas have gained increasing attention from various researchers and educators over the past three decades. A social constructivist approach is thought to create a learning community, giving students the strong social and emotional support that enables them to take risks and develop ownership (Beck & Kosnik, 2006). It can thereby help students develop not only knowledge but also critical thinking (Totten, Sills, Digby, & Russ, 1991) and communicative skills (Confrey, 1985). At the level of primary science education, a social constructivist perspective has been increasingly applied in many countries connected to Western cultural traditions through the predominance of inquiry-based approaches (Anderson 2007) and the emphasis on the 'nature of science' education (Abd-El-Khalick & Lederman, 2000).

With widespread acceptance, social constructivist approaches are thought to create a paradigm change in science education (Coll & Taylor, 2012). Many studies show that a social constructivist perspective has come into focus for primary science education in Confucian heritage cultures through school reforms taken place in the last decade. Nevertheless, there is insufficient in-depth knowledge about the implementation of a social constructivist perspective in primary science education in Confucian heritage culture. Furthermore, there is also a lack of studies about how Confucian heritage culture influences the implementation of a social constructivist perspective in primary science education. Such studies are needed because the culture, with its distinct characteristics, is a crucial factor that strongly influences teaching and learning (Hofstede, 1986).

Teaching and learning in Confucian heritage culture have been dominated by a teacher-centred, book-centred method and an emphasis on rote memory (Liu & Littlewood, 1997) with little emphasis on critical thinking (Couchman, 1997). Teaching influenced by Confucian heritage culture is primarily one-sided in a one-way process: what the teacher announces is right and the students are not entitled to ask about sense and purpose, to require reasons, or to question the content (Chan, 1999). Such teaching and learning approaches are unsuitable for facilitating students to acquire necessary skills and attitudes toward science. However, not only scientific knowledge but also scientific skills and appropriate attitudes toward science have been increasingly stressed for students to learn science (Bybee, McCrae, & Laurie, 2009).

It is asserted to be difficult to apply a constructivist approach for a community where students had been passive of receiving data (Neuman & Bekerman, 2000). There is a need to take cultural resources (Neuman & Bekerman, 2000) and local experiences (Coll & Taylor, 2012) into consideration in order to avoid a "false universalism" (Nguyen, Elliott, Terlouw, & Pilot, 2009) and to reduce practical difficulties when applying Western educational theories to education in Non-Western contexts. However, there has been little evidence so far to show that social constructivist curricula have been designed and developed with a concern for distinct characteristics of Confucian heritage culture.

Therefore, it is necessary and essential to have a design for a social constructivism-based curriculum that is appropriate for characteristics of Confucian heritage culture in order to improve primary science education. This is suitable given the trend in the development of the science curriculum, and the local situation and context of primary science education in Confucian heritage countries.

Research Questions

This research has been carried out to address the aforementioned problems of applying a social constructivist perspective to primary science education in Confucian heritage culture. It aims to answer the main research question:

What curriculum design for primary science education has social constructivist characteristics and is appropriate for Confucian heritage culture?

To answer the above research question, the research focuses on answering the following sub-questions:

1. *To what extent is a social constructivist perspective implemented in primary science education in Confucian heritage culture?*
2. *How can this implementation be explained from a Confucian cultural perspective and what cultural factors are fostering and hindering the implementation?*

3. *What formal curriculum design for primary science education has social constructivist characteristics and is appropriate for Confucian heritage culture?*
4. *In a programme of professional development, how do Confucian heritage teachers interact with a primary science curriculum that is based on a social constructivist perspective and made appropriate for Confucian heritage culture?*
5. *To what extent does a unit of the curriculum design for primary science education in Confucian heritage culture meet social constructivist expectations in classroom practice?*
6. *To what extent does a unit of the adjusted design of the social constructivism-based curriculum for primary science education in Confucian heritage culture support students in practicing scientific argumentation in a science lesson?*
7. *To what extent does a unit of the adjusted design of the social constructivism-based curriculum for primary science education in Confucian heritage culture support students in attaining consensually agreed knowledge on scientific subject-matter?*

By answering the above sub-questions, this study contributes to the development of a knowledge base for designing a social constructivism-based curriculum for primary science education in Confucian heritage culture. Specifically, it can provide a social constructivism-based curriculum that can be applied to improve science education in Confucian heritage culture, and probably also in other cultures.

Overview of the Theoretical Perspectives in the Research

A social constructivist perspective

A social constructivist perspective is an outcome of a growing number of critiques against approaches in science education that tend to overemphasise the individual's learning process and neglect social issues in knowledge-construction processes (Duit & Treagust, 1998). In a social constructivist approach, students are considered to be active in constructing knowledge of science through their social interactions with their teacher and peers, providing, in this way, plausible answers and solutions to problems. According to Beck and Kosnik (2006), key features of a social constructivist perspective on learning are: 1) Learning is social; 2) Knowledge is experience based; 3) Knowledge is constructed by learners; 4) All aspects of a person are connected; and 5) Learning communities should be inclusive and equitable.

At the level of primary science education, a social constructivist perspective has been increasingly applied in many countries connected to Western cultural traditions through the predominance of inquiry-based approaches with the emphasis on the "nature of science" education that values process skills (Abd-El-Khalick and Lederman 2000). This is because "what is called inquiry learning is very similar to what others call constructivist learning" and "as with inquiry, the constructivist label can be applied to the nature of science, learning and teaching" (R.D. Anderson 2007, p.809). Recently, the historical, tentative, empirical, logical, and well-substantiated nature of scientific claims and the value of open communication and the interaction between personal, societal, and cultural beliefs in the generation of scientific knowledge are considered as the "nature of science" education (Abd-El-Khalick & Lederman, 2000).

Reform efforts in science education have called for new designs of curricula that can improve science teaching and learning, thereby enhancing learning outcomes. Many science curricula have been developed so far. According to McGee (cited from Coll & Taylor, 2012), curriculum development and implementation in most countries have involved the centre-periphery model. Traditional science curricula were applied up until about the 1980s (Coll & Taylor, 2012). The 1980s and 1990s witnessed "explosive" curriculum reforms worldwide, including in non-Western countries. Arguably the most commonly shared attributes of these curricula were their constructivist origins and learner-centred education, with its origins in constructivism, and variants of constructivism became something of "a mantra" (Coll & Taylor, 2012, p.773).

Confucian heritage culture

Confucian heritage culture refers to settings influenced by Confucianism. This is an ethical and philosophical system developed from the teachings of the Chinese philosopher Confucius. Countries strongly influenced by Confucianism include Greater China, Taiwan, Korea, Japan, Vietnam, and Singapore. The following features briefly characterise Confucian heritage culture (Berthrong & Berthrong, 2000; Đạm, 1994; Thêm, 1997).

a. The collectivist root. Confucian heritage countries share characteristics of a collectivist society with an agriculture-rooted culture that requires individuals to live a settled life with a fixed residence and value collectivity.

b. The harmony and stability preference as a cultural and human value. Confucian heritage individuals prefer to remain stable and in harmony with natural and social environments.

c. The virtue focus. The cultivation of virtue is emphasised with the aim that the individual be *a good person*. Benevolence, righteousness, civility, knowledge, and loyalty are strongly stressed in Confucian heritage culture.

d. The support of hierarchical order. Confucian heritage culture supports hierarchical relationships between people with the emphasis on mutual and complementary obligations: junior partners owe seniors respect and obedience; seniors owe junior partners protection and consideration.

e. The family value. Individuals are required to keep the family at the centre of their lives.

f. The emphasis on theoretical knowledge. Knowledge is considered as one of the complementary aspects of the ideal person.

Primary science education in Vietnam

This research was carried out in Vietnam. Primary science education in Vietnam is integrated into primary education that emphasises the mission of training students to be future labourers who have the necessary knowledge, skills, and attitudes to cope with the rapid changes of modern times and to contribute to the industrialisation of the country (Hoan, 2002). The conventional primary science curriculum in Vietnam is centralised and authorised by the Ministry of Education and Training.

The conventional primary science curriculum in Vietnam has been in use since the recent curriculum reform began in the year 2000. Science is a compulsory subject taught in all levels of primary education from Grade 1 (students aged 6) to Grade 5 (students aged 10). From Grade 1 to Grade 3, science is integrated into the subject called *Nature and Society*. From Grade 4 to Grade 5, science stays separate in the subject named *Science*. Time in each week and academic school year allotted to the subject *Nature and Society* in Grades 1, 2, and 3 and to the subject *Science* in Grades 4 and 5 is presented in Table 1 below.

Table 1. Time for the science subject in primary school education in Vietnam (cited in Hoan, 2002)

Subject	Grade/Unit per week					Number of units in whole academic year (35 weeks)	Percentage in total of subject units
	1	2	3	4	5		
Nature and Society	1	1	2			140	3.53%
Science				2	2	140	3.53%

In general, less time is allotted to science in primary school education in Vietnam than to other subjects. Specifically, the time allowed for science is much less than the time allowed for the subjects of Vietnamese (40.7%) and Mathematics (21.23%). It is also less than the time dedicated to other subjects, such as Arts and Physical Education (7.96% for each of them), and Ethics (4.42%). Only the subjects of Music, and Drawing and Painting are given less time than science (1.76% for each of them).

Science lessons are planned to last around 35 minutes. They are often taught by teachers in charge of the classroom who tend to teach most of the subject areas. In *School Curriculum – For Primary Education Level* (Ministry of Education and Training [Vietnam], 2006), goals of the primary science curriculum are stated. Science should help students gain:

1. Initial and fundamental knowledge on:
   - Human metabolism, nutrient demands, reproduction, and growth;
   - How to prevent some common diseases and infectious diseases;
   - Metabolism and reproduction of animals and plants;
   - Characteristics and applicability of some substances, materials, and energy sources common in real life and in manufacture.
2. Initial skills:
   - React suitably in some situations related to one's own health, as well as one's family and community;
   - Observe and do some simple experiments related to real life and manufacture;
   - Ask questions in science class, seek information for answers, and express ideas in words, texts, drawings, diagrams, and so forth.
3. Attitudes and behaviours:

- Follow hygiene rules consciously and safely for oneself, as well as one's family and community;
- Be interested in science, and consciously apply the lessons learned to real life;
- Actively take part in protecting the environment.

However, there are often gaps between the intended curriculum (the ideal perspectives of education as expressed in policy rhetoric), the implemented curriculum (real life practices in school and classroom), and the attained curriculum (learning outcomes) (Van den Akker, 1998, 2003).

The primary science education integrated into the standard primary education has been strongly criticised for being less than suitable for educating students to become future labourers (Toàn, 2002; Tụy, 2011). Therefore, basically and comprehensively innovating education and training has been considered an objective and urgent task of the enterprise of fostering industrialisation and modernisation in Vietnam (Centre Committee [Vietnam], 2012).

Overview of the Research

Social constructivist features (Beck & Kosnik, 2006) are employed to provide a theoretical framework that underpins a design for a social constructivism-based curriculum for primary science education in Confucian heritage culture. In order to answer the main research question, this research refers to knowledge of curriculum representations (Van den Akker, 2003) and design-based research (Bulte, Westbroek, De Jong, & Pilot, 2006) as its main approaches, as presented in Figure 1.

The main issues addressed in each of the studies in this research are presented in the following paragraphs.

Chapter 2 (*problem analysis*) focuses on characterising the implementation of a social constructivist perspective in primary science education in Confucian heritage culture. Also, it focuses on providing an explanation of the implementation from a cultural perspective. This study addresses two research questions: 1) *To what extent is a social constructivist perspective implemented in primary science education in Confucian heritage culture?* and 2) *How can this implementation be explained from a Confucian cultural perspective and what cultural factors are fostering and hindering the implementation?* To answer the

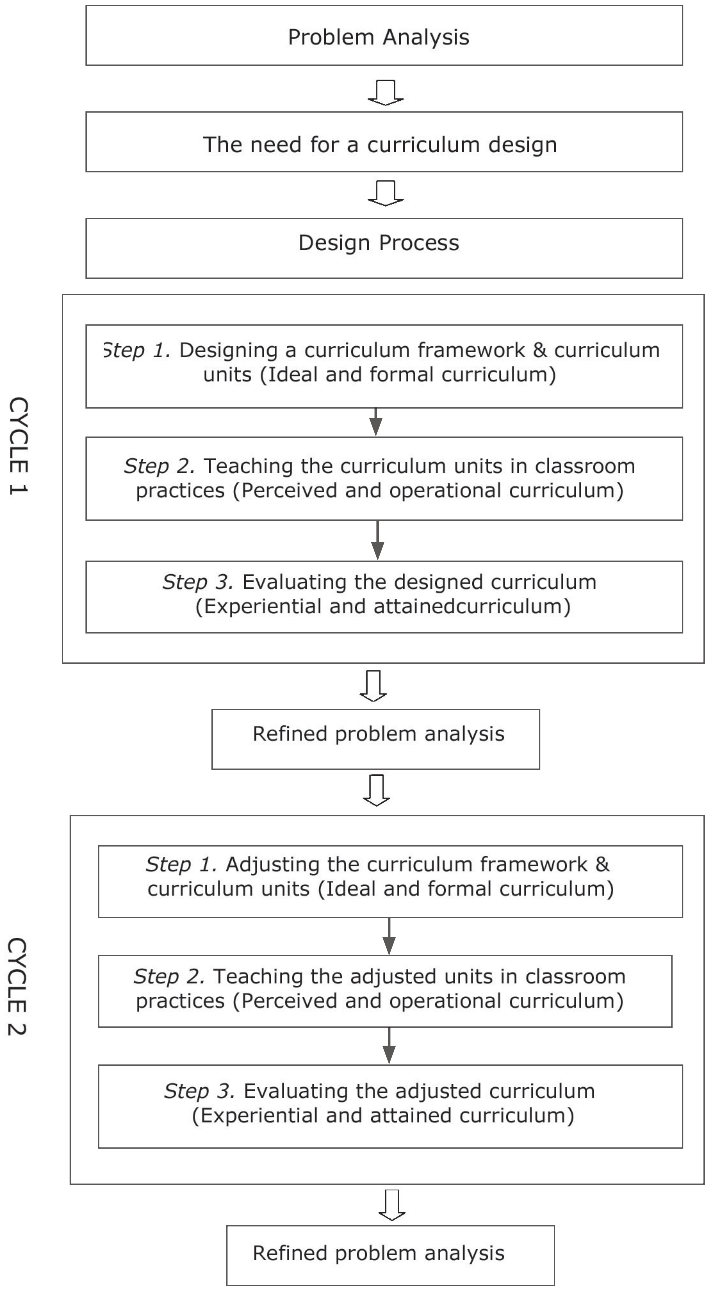


Figure 1. Overview of the design-based research approach of this study

first research question, the study was situated in Vietnam and used social constructivist key features (Beck & Kosnik, 2006) as organising elements to identify the implementation of a social constructivist perspective in primary science education. To answer the second research question, the study referred to knowledge of Confucian heritage culture and relied on characteristics of Confucian heritage culture to provide a cultural explanation of the implementation.

Chapter 3 (*design of formal curriculum*) is a theoretical study which focuses on providing arguments for designing a formal curriculum based on a social constructivist perspective for primary science education in Confucian heritage culture. This study addresses the research question: *What formal curriculum design for primary science education has social constructivist characteristics and is appropriate for Confucian heritage culture?* The design of the formal curriculum is underpinned by a social constructivist perspective and supported by knowledge of the "nature of science" education and Confucian heritage culture. The design of the formal curriculum is considered a possibility in addressing and solving the previously analysed problems in order to improve primary science education in Confucian heritage culture.

Chapter 4 (*perceived and operational curriculum*) reports a study in which Confucian heritage teachers interact with the designed curriculum. It aims to answer the research question: *In a programme of professional development, how do Confucian heritage teachers interact with a primary science curriculum that is based on a social constructivist perspective and made appropriate for Confucian heritage culture?* To answer this research question, the study addresses three sub-questions, including: *a) What changes take place in the attitudes and activities of Confucian heritage teachers in classroom practices through their interaction with a social constructivism-based curriculum? b) How do Confucian heritage teachers perceive the designed curriculum?* and *c) What do Confucian heritage teachers perceive as the major challenges to applying the designed curriculum in practice?* The study referred to the designed curriculum, knowledge of teacher professional development, and the teaching styles of a social constructivist teacher and a traditional Confucian heritage teacher as its theoretical framework.

Chapter 5 (*experiential and attained curriculum*) investigates the practice of a specific curriculum unit designed in accordance with the designed curriculum. It addresses the research question: *To what extent* *does a unit of the curriculum design for primary science education in Confucian heritage culture meet social constructivist expectations in classroom practice?* To answer this research question, the study elaborated educational expectations developed for the design of the formal curriculum. These expectations are used as the theoretical framework of the study to analyse the data.

Chapter 6 (*adjusting the designed curriculum*) describes the adjustments to the designed curriculum in order to support scientific argumentation in science lessons in Confucian heritage culture. Also, it reports the attainment of the adjusted curriculum through the practice of a specific curriculum unit in a science lesson. The study aims to answer two research questions: *1) To what extent does a unit of the adjusted design of the social constructivism-based curriculum for primary science education in Confucian heritage culture support students in practicing scientific argumentation in a science lesson?* and 2) *To what extent does a unit of the adjusted design of the social constructivism-based curriculum for primary science education in Confucian heritage culture support students in attaining consensually agreed knowledge on scientific subject matter?* The study refers to knowledge of the nature of scientific argumentation and takes characteristics of Confucian heritage culture into consideration in adjusting the design of the social constructivism-based curriculum.

Chapter 7 provides a synthesis of these studies in which the problems addressed, the theoretical frameworks, and the research approaches are represented and reflected upon. This chapter also clarifies the contribution of the current research to science education. In addition, limitations of the research and recommendations for further research are presented.

Figure 2 shows the research approach with reference to the separate chapters and the respective research questions.

Chapter 1. Introduction and Research Overview

What is the design of curriculum for primary science education that has social constructivist characteristics and is appropriate with Confucian heritage culture?

PROBLEM ANALYSIS

Chapter 2. The implementation of a social constructivist perspective in primary science education in Confucian heritage culture: the case of Vietnam

RQ1. To what extent is a social constructivist perspective implemented in primary science education in Confucian heritage culture?
RQ2. How can this implementation be explained from a Confucian cultural perspective and what are fostering and hindering cultural factors to the implementation?

DESIGN CYCLE 1

Chapter 3. Designing a formal curriculum based on a social constructivist perspective for primary science education in Confucian heritage culture

RQ. What is the design of formal curriculum for primary science education that has social constructivist characteristics and is appropriate with Confucian heritage culture?

Chapter 4. Teacher professional development: The interaction of Confucian heritage teachers with a social constructivism-based curriculum for primary science education

RQ. In what way do Confucian heritage teachers interact with a primary science curriculum, which is based on a social constructivist perspective and made appropriate with Confucian heritage culture, in a program of professional development?

Chapter 5. Scientific argumentation as bottleneck for implementing a social constructivism-based science curriculum in Confucian heritage culture

RQ. To what extent does the unit of the curriculum design for primary science education in Confucian heritage culture meet the social constructivist expectations in the practice of the classroom?

DESIGN CYCLE 2

Chapter 6. Improving scientific argumentation through a social constructivism-based curriculum for primary science education in Confucian heritage culture

RQ1. To what extent does the unit of the adjusted design of social constructivism-based curriculum for primary science education in Confucian heritage culture support students to practice scientific argumentation in a science lesson?
RQ2. To what extent does the unit of the adjusted design of social constructivism-based curriculum for primary science education in Confucian heritage culture support students to attain consensually agreed knowledge on scientific subject-matter?

Chapter 7. Conclusions, Reflection and Recommendations

RQ. What is the design of curriculum for primary science education that has social constructivist characteristics and is appropriate with Confucian heritage culture?

Figure 2. The research approach with reference to the separate chapters and the research questions

References

Abd-El-Khalick, F., & Lederman, N. G. (2000). Improving science teachers' conceptions of nature of science: A critical review of the literature. *International Journal of Science Education*, *22*(7), 665–701.

Anderson, R. D. (2007). Inquiry as an organizing theme for science curricula. In S.K. Abell & N.G. Lederman (Eds), *Handbook of research on science education* (pp. 807–830). Oxford, UK: Taylor & Francis.

Beck, C., & Kosnik, C. (2006). *Innovations in teacher education – A social constructivist approach*. New York, NY: State University of New York Press.

Berthrong, J. H., & Berthrong, E. N. (2000). *Confucianism: A short introduction*. Oxford, UK: Oneworld.

Bulte, A. M. W., Westbroek, H. B., De Jong, O., & Pilot, A. (2006). A research approach to designing chemistry education using authentic practices as contexts. *International Journal of Science Education, 28*(9), 1063–1086.

Bybee, R., McCrae, B., & Laurie, R. (2009). PISA 2006: An assessment of scientific literacy. *Journal of Research in Science Teaching*, *46*(8), 865–883.

Chan, S. (1999). The Chinese learning – A question of style. *Education and Training*, *41*(6/7), 294–304.

Central Committee [Vietnam] (2012). The sixth Conference of The eleventh Central Committee dated 29/12/2012 about The proposal "Innovating basically and comprehensively education and training for meeting requirements of industrialization and modernization in conditions of market economy oriented in socialism and international integration". The Conclusion numbered 51-KL/TW. [Hội nghị lần thứ 6 BCHTW khóa XI về ngày 29/10/2012 về Đề án "Đổi mới căn bản và toàn diện giáo dục và đào tạo, đáp ứng yêu cầu công nghiệp hóa, hiện đại hóa trong điều kiện kinh tế thị trường định hướng xã hội chủ nghĩa và hội nhập quốc tế". Kết luận số 51-KL/TW]

Coll, R. K., & Taylor, N. (2012). An international perspective on science curriculum development and implementation. In B. J. Fraser, K. G. Tobin, & C. J. McRobbie (Eds), *Second international handbook of science education* (Vol. II, pp. 771–782). Dordrecht, the Netherlands: Springer.

Confrey, J. (1985). Towards a framework for constructivist instruction. In L. Streefland (Ed.), *Proceedings of the Ninth Conference of the International Group for the Psychology of Mathematics Education* (pp. 477–483). Noordwijkerhout: The Netherlands.

Couchman, J. (1997). Making sense: Cross-cultural variation in the organisation of academic texts by Taiwanese and Australian undergraduate students. In Z. Golebiowski & H. Borland (Eds.),

Academic communication across disciplines and cultures (pp. 64–76). Melbourne, Australia: Victoria University of Technology.
Duit, R., & Treagust, D. (1998). Learning in science – From behaviorism towards social constructivism and beyond. In B. L. Fraser & K. G. Tobin (Eds), *International handbook of science education* (pp. 3–25). Dordrecht, Netherlands: Kluwer Academic Publishers.
Đạm, Q. (1994). *Nho giáo xưa và nay [Confucianism: before and now].* Hanoi, Vietnam: Culture Publisher.
Hoan, Đ. Đ. (2002). *Một số vấn đề cơ bản của chương trình tiểu học mới [Some basic issues of the new primary curricula]*. Hanoi, Vietnam: Education Publisher.
Hofstede, G. (1986). Cultural difference in teaching and learning. *International Journal of Intercultural Relations*, *10*, 301–320.
Liu, N. F., & Littlewood, W. (1997). Why do many students appear reluctant to participate in classroom learning discourse? *System*, *25*(3), 371–384.
Ministry of Education and Training [Vietnam]. (2006). *Chương trình dạy học - Dành cho bậc tiểu học [Schooling curriculum – For primary education level].* Hanoi, Vietnam: Education Publisher.
Neuman, Y., & Bekerman, Z. (2000). Cultural resources and the gap between educational theory and practice. *Teachers College Record, 103*(3), 471–484.
Nguyen, M., Elliott, J., Terlouw, C., & Pilot, A. (2009). Neocolonialism in education: Cooperative learning, Western pedagogy in an Asian context. *Comparative Education*, *45*(1), 109–130.
Thêm, T. V. (1997). *Tìm về bản sắc văn hóa Việt Nam [Research on Vietnamese cultural distinctions].* Ho Chi Minh, Vietnam: Ho Chi Minh Publisher.
Toàn, N. C. (2002). *Học và dạy cách học [Learning and teaching of learning].* Hanoi, Vietnam: The Publisher of Hanoi National University of Education
Totten, S., Sills, T., Digby, A., & Russ, P. (1991). *Cooperative learning: A guide to research*. New York, NY: Garland.
Tụy, H. (2011). *Giáo dục: Xin cho tôi nói thẳng [Education: Lets me talk straight].* Hanoi, Vietnam: Knowledge Publisher.
Van den Akker, J. (1998). The science curriculum: Between ideals and outcomes. In B. Fraser & K. Tobin (Eds.), *International handbook of science education* (pp. 421-–447). Dordrecht, the Netherlands: Kluwer Academic Publishers.
Van den Akker, J. J. H. (2003). Curriculum perspectives: An introduction. In J. J. H. Van den Akker, W. Kuiper, & U. Hameyer (Eds.), *Curriculum landscape and trends* (pp. 1–10). Dordrecht, the Netherlands: Kluwer Academic Publisher.

Chapter 1. Introduction and Research Overview

What curriculum for primary science education has social constructivist characteristics and is appropriate for Confucian heritage culture?

PROBLEM ANALYSIS

Chapter 2. The implementation of a social constructivist perspective in primary science education in Confucian heritage culture: the case of Vietnam

RQ1. To what extent is a social constructivist perspective implemented in primary science education in Confucian heritage culture?
RQ2. How can this implementation be explained from a Confucian cultural perspective and what cultural factors are fostering and hindering the implementation?

DESIGN CYCLE 1

Chapter 3. Designing a formal curriculum based on a social constructivist perspective for primary science education in Confucian heritage culture

RQ. What formal curriculum design for primary science education has social constructivist characteristics and is appropriate for Confucian heritage culture?

Chapter 4. Teacher professional development: The interaction of Confucian heritage teachers with a social constructivism-based curriculum for primary science education

RQ. In a program of professional development, how do Confucian heritage teachers interact with a primary science curriculum that is based on a social constructivist perspective and made appropriate for Confucian heritage culture.

Chapter 5. Scientific argumentation as bottleneck for implementing a social constructivism-based science curriculum in Confucian heritage culture

RQ. To what extent does the unit of the curriculum design for primary science education in Confucian heritage culture meet the social constructivist expectations in classroom practice?

DESIGN CYCLE 2

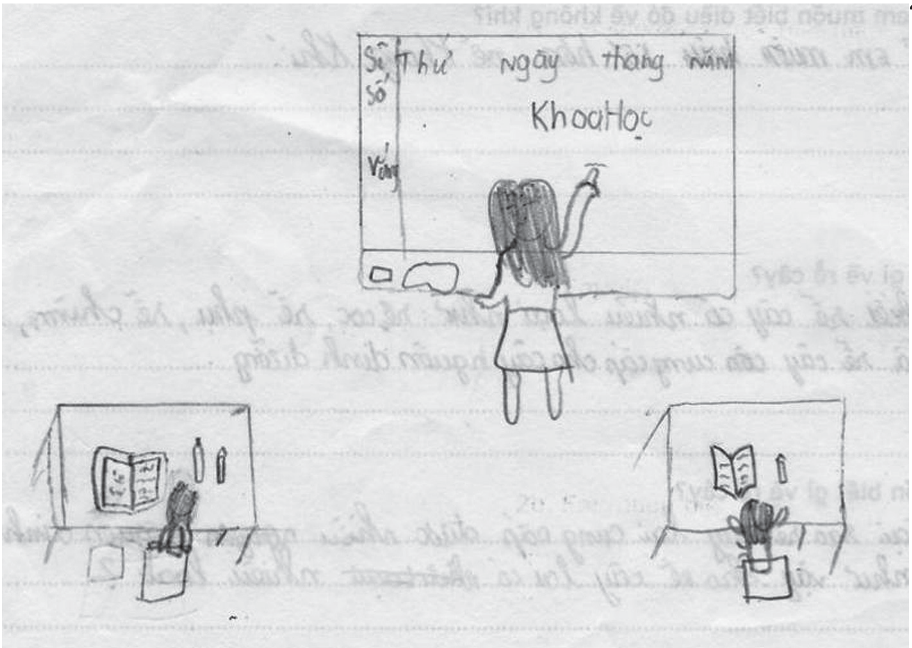
Chapter 6. Improving scientific argumentation through a social constructivism-based curriculum for primary science education in Confucian heritage culture

RQ1. To what extent does a unit of the adjusted design of the social constructivism-based curriculum for primary science education in Confucian heritage culture support students to practice scientific argumentation in a science lesson?
RQ2. To what extent does a unit of the adjusted design of social constructivism-based curriculum for primary science education in Confucian heritage culture support students in attaining consensually agreed knowledge on scientific subject-matter?

Chapter 7. Conclusions, Reflection and Recommendations

RQ. What curriculum design for primary science education has social constructivist characteristics and is appropriate for Confucian heritage culture?

CHAPTER 2 The Implementation of a Social Constructivist Perspective in Primary Science Education in Confucian Heritage Culture: The Case of Vietnam[1]



[2]

Abstract A social constructivist perspective has been increasingly studied and implemented in science education. Nevertheless, there is a lack of holistic studies on the implementation of a social constructivist perspective in primary science education in Confucian heritage culture. This study aims to determine to what extent a social constructivist perspective is implemented in primary science education in Confucian heritage culture and explain it from a Confucian cultural perspective. Findings reveal that in Confucian heritage culture a social constructivist perspective has so far not been implemented well in primary science education. The implementation has been considerably influenced by Confucian heritage culture, which can both foster and hinder it. The study also reveals cultural divergences between Confucian heritage culture and Western educational philosophy in reference to the "nature of science" education and a social constructivist perspective. This analysis indicates a need for design-based research on a social constructivism-based curriculum for primary science education within Confucian heritage culture.

---

1 This chapter is submitted and revised as: Hằng, N. V. T., Meijer, M., Bulte, A., & Pilot, A. *The implementation of a social constructivist perspective in primary science education in Confucian heritage culture: the case of Vietnam*.

2 A student drawing of a conventional science lesson (from the data source of pre-questionnaires, Chapter 5)

Introduction

Social constructivist ideas (Tobin, 1993) have gained increasing attention from various researchers and educators over the past years. It is considered as the outcome of critiques against approaches that tend to overemphasize individual learning and neglect social issues in the knowledge-construction process (Duit & Treagust, 1998). In a social constructivist classroom, cooperative activities can create a learning community giving students strong social and emotional support that enables them to take risks and develop ownership (Beck & Kosnik, 2006). It can thereby help students to develop not only knowledge but also critical thinking (Totten, Sill, Digby & Russ, 1991) and communicating skills (Confrey, 1985).

With widespread acceptance, social constructivist approaches are considered to create a paradigm change in science education (Coll & Taylor, 2012). At the level of primary science education, a social constructivist perspective has been increasingly applied in many countries connected to Western cultural traditions through the predominance of inquiry-based approaches (Anderson, 2007) and the emphasis on the "nature of science" in science education. Abd-El-Khalick and Lederman (2000) were able to connect inquiry and the nature of science by science education organisations' conceptions of the nature of science. According to Anderson (2007), "what is called inquiry learning is very similar to what others call constructivist learning" and "as with inquiry, the constructivist label can be applied to the nature of science, learning and teaching" (p. 809). In a social constructivist approach in science education, students are considered to be active in getting plausible other than correct answers for knowledge of science through their social interactions with the teacher and peers.

Under influences of integration and globalisation, a constructivist perspective has been transferred and implemented in primary school in non-Western cultures. It is found in many studies that a social constructivist perspective has come into focus for primary science education in Confucian heritage cultures through recent school reforms. In Japan, since 1999, science teachers have encouraged to develop curricula in a way that places fieldwork and outdoor learning at the centre of learning (Gato, 2000). The application of inquiry-based and social constructivist approaches also has been encouraged in science classes in China as in the reformed science curriculum (Ministry of Education [China], 2010). In Taiwan, the new science curriculum started in 2001 aims to support students in developing inquiry and research abilities, including applying scientific methods (Ministry of Education [Taiwan], 1999). It is also reported that the emphasis on inquiry orientation was recently brought into the science curriculum in Korea (Ministry of Education and Human Resources [Korea], 2007).

Despite such ideal curricula, there is insufficient in-depth knowledge about the implementation of a social constructivist perspective in primary science education in Confucian heritage culture. Furthermore, there is also a lack of studies about how Confucian heritage culture influences the implementation of a social constructivist perspective in primary science education. Such studies are needed because the culture with its distinct characteristics is a crucial factor that considerably influences teaching and learning (Hofstede, 1986). In response, this study was carried out and had the following two aims: 1) to determine to what extent a social constructivist perspective is implemented in primary science education in Confucian heritage culture; and 2) to explain the implementation from a Confucian cultural perspective. The explanation can explicate cultural influences that are useful for designing and applying a social constructivism-based curriculum in Confucian heritage culture. A culturally appropriate design of science curriculum is considered to improve and enhance primary science education that can be carried out through a design-based research approach (Bulte, Westbroek, De Jong & Pilot, 2006). This study contributes to the knowledge base about the implementation of a social constructivist perspective in primary science education in general and particularly in Confucian heritage culture.

A Social Constructivist Perspective

The multiple roots of social constructivism are based on the research of Jean Piaget and Lev Vygotsky. Piaget's research is understood to be about cognitive constructivism, which regards the development of human intellect to proceed through adaptation and organization; learning therefore was defined as a process of accommodation, assimilation, and equilibration. Rejecting Piaget's assumption that it was possible to separate learning from its social context, Vygotsky argued for the importance of culture and context in forming understanding; hence, learning was defined not to be a purely individual process but a social construct as mediated by language via social discourse (Pitsoe, 2007). Beyond this, a social constructivist view considers the social context in which learning occurs as central to learning itself (Pitsoe, 2007). The common idea of the two perspectives of constructivism is the notion that the individual is "active"; accordingly, human cognitive development is not just responding to stimuli, as in behaviourism, but engaging, grappling, and seeking to make sense of things based on utilizing prior knowledge and experiences (Pitsoe, 2007).

Social constructivist perspectives have provided implications to teaching and learning and re-conceptualised teaching and learning. Traditionally, teaching and learning is understood as a process in which knowledge is transmitted by the teacher and received by students. However, from a social constructivist perspective, teaching and learning is defined to be about negotiation (Hand, 2011) in which learners are actively involved in social activities with the teacher and peers and use their existing knowledge to construct new knowledge. Key features of social constructivist learning were formulated in many studies and proved to be consistent with characteristics of inquiry-based learning (Anderson, 2007) that emphasises process skills (Abd-El-Khalick & Lederman, 2000). In this study, we applied the ones introduced by Beck and Kosnik (2006). These key features were elaborated and examined using literature on social constructivism that provided indicators as summarized in Table 1.

Table 1. Social constructivist (SC) features and indicators

Feature	Indicator
1. Learning is social	i. Students work in whole class, and/or ii. Students work in small groups iii. Students actively share ideas
2. Knowledge is experience-based	i. Students' experiences are provoked ii. Students interpret experiences
3. Knowledge is constructed by learners	i. Students are immersed in realistic learning situations ii. Students elaborate interpretations of their experiences iii. Students test interpretations of their experiences iv. Students construct meanings
4. All aspects of a person are connected	i. Students' attitudes and emotions are revealed in learning ii. Students take part in hands-on activities iii. Students' values are employed and capitalised in learning

Feature	Indicator
5. Learning communities should be inclusive and equitable	i. Types of communities (e.g., families, organizations, institutions, etc.) are involved to support students' learning ii. Interactions of teacher-student and student-student should be equitable rather than hierarchical

The social constructivist features and indicators (Table 1) created an umbrella of a social constructivist perspective based on which a social constructivist teaching and learning strategy could be shaped and analysed.

Confucian Heritage Culture

Confucian heritage culture refers to settings influenced by Confucianism. This is an ethical and philosophical system developed from the teachings of the Chinese philosopher Confucius. The core of Confucianism is humanism with the focus on spiritual concern regarding the world and the family. Countries strongly influenced by Confucianism include Greater China, Taiwan, Korea, Japan, Vietnam, and Singapore. The following features briefly characterize Confucian heritage culture.

a. The collectivist root. Confucian heritage countries share characteristics of a collectivist society (Phuong-Mai, Terlouw & Pilot, 2005) with an agriculture-rooted culture that requires individuals to live a settled life with a fixed residence and value collectivity and solidarity as well (Thêm, 1997).

b. The harmony and stability preference as a cultural and human value. Confucian heritage individuals prefer to remain stable and in harmony with natural and social environments (Berthrong and Berthrong 2000). Social relationships are often handled in ways that are more intimate and family-like (Phuong-Mai et al., 2005).

c. The virtue focus. The cultivation of virtue is emphasised with the aim that the individual be *a good person*. Benevolence, righteousness, civility, knowledge, and loyalty are strongly stressed in Confucian heritage culture (Doãn, 1999). Accordingly, personal interests of *I* should be limited to the interests of *We*.

d. The support of hierarchical order. Confucian heritage culture supports hierarchical relationship between people (Berthrong & Berthrong, 2000) with the emphasis on mutual and complementary obligations:

junior partners owe seniors respect and obedience; seniors owe junior partners protection and consideration (Phuong Mai et al., 2005).

e. The family value. Individuals are required to keep the family at the centre of their life (Doãn, 1999).

f. The emphasis on theoretical knowledge. Knowledge is considered as one of complementary aspects of the ideal person and the *full knower [trên thông thiên văn dưới tường địa lí]*. Knowledge in ancient classics is traditionally appreciated and considered universally correct.

The above features are considered to have influenced traditionally on all aspects of living of individuals in Confucian heritage culture. According to Đạm (1994), the significant and emergent contribution of Confucianism is the virtue focus that encourages individuals to value behaviour and to behave in a ritual manner. However, ritual behaviour-based judgments of Confucianism bind individuals so rigidly that individuals are not able to show and develop their capability and competence (Đạm, 1994).

From a cultural perspective, teaching and learning in Confucian heritage countries is generally characterised to maintain high power distance, rather low individualism and high potential in the collectivist domain and in favour of long-term orientation (Hofstede, 2003). Culture is taken as a point of departure in our research with a reason that it can provide reachable implementation of a social constructivist perspective through a design, as should be dealt with in further studies, of social constructivism-based for primary science education in Confucian heritage culture. The identification of fostering cultural features is necessary in order to have an initial rationale for the application of a social constructivist perspective in Confucian heritage culture. Meanwhile, the identification of hindering cultural features is also needed to develop culturally appropriate design of a social constructivism-based curriculum for primary science education in Confucian heritage culture.

Research Questions

This study examines a social constructivist perspective in primary science education. It aims to provide a holistic view of the implementation of a social constructivist perspective in primary science education in Confucian heritage culture and give explanations for the implementation from a cultural perspective. Therefore, the study answers the following research questions.

1. *To what extent is a social constructivist perspective implemented in primary science education in Confucian heritage culture?*
2. *How can this implementation be explained from a Confucian cultural perspective and what cultural factors are fostering and hindering the implementation?*

To answer these questions, Vietnam was selected as a case study. This country has been deeply influenced by Confucianism for a long time (Đạm, 1994). Also, the Vietnamese primary school curriculum, in which primary school science is integrated, has been recently reformed since the year 2000 with the application of innovative educational theories (Hoan 2002). In addition, Vietnam is currently undergoing an extensive revision of curriculum and textbooks that will be completed by 2015. Basically and comprehensively innovating education and training has been considered an objective and urgent task of the enterprise of fostering industrialisation and modernisation in Vietnam (Centre Committee [Vietnam], 2012). With such conditions, Vietnam is a relevant case for a holistic study to examine the implementation of a social constructivist perspective in primary science education and provide Confucian cultural explanations of the implementation.

Method

For the first research question

Data collection and participants

To answer the first research question (*To what extent is a social constructivist perspective implemented in primary science education in Confucian heritage culture?),* multiple data collection was employed, including: classroom observations, interviews, questionnaires, and analyses of science textbooks and curriculum guidelines. This collection of multiple data was chosen to provide thorough answers from different perspectives and participants. The use of multiple data sources can help researchers characterize the implementation of a social constructivist perspective based on several curriculum representations (Van den Akker, 2003). Below we argue why and how the different data sources were analysed to answer the first research question in the study.

A. Classroom observations

Classroom observations allow the researcher to develop a holistic perspective on the implementation of social constructivism in science classroom practices, i.e. understanding of the context within which a social constructivist perspective is implemented, characterizing teachers' and students' activities, and recognizing which teaching and learning sequence is applied and how it is organised.

Two primary schools in two provinces in Vietnam were selected for classroom observations. The first province is Hanoi, the capital city of Vietnam, and the second province is Bacninh, an urban area. Both of the schools are public schools and labelled as the national standard. These two schools were considered to provide science lesson practices that can be representative of others in Vietnam.

Given that demonstrative science lessons are often different to daily ones, the researcher asked for permission to have classroom observations without informing teachers in advance about specific lessons. With enthusiastic support from the school boards and teachers, the researcher had good opportunities to observe representative science classes. In total, seven science classrooms were observed with note taking and video recording. Information about the observed classes is presented in Table 2.

Table 2. The observed science classrooms

Class	Lesson theme	Time amount	Grade	Class size
1	Using medicine safely	37 minutes	5 (age 10)	35
2	Using medicine safely	45 minutes	5	27
3	Preventing some infectious diseases of the digestion system	38 minutes	4 (age 9)	31
4	Preventing some infectious diseases of the digestion system	47 minutes	4	32
5	Eating vegetables and ripe fruits - Use fresh and safe food	41 minutes	4	43
6	Cleaning out the body excretory system of urine	22 minutes	3 (age 8)	21
7	A balanced diet	25 minutes	2 (age 7)	25

The classroom practices were observed based on the following schemes.

- What are structures of the lessons?
- Which teaching and learning methods are applied and how?
- Which learning forms and learning tasks are applied and how?

- Are students active and curious in their learning of science?
- What kind of interactions takes place? How much time for each kind of interactions?

B. Interviews

The interviews were to help the researchers obtain more information regarding the implementation of a social constructivist perspective in primary science education in Vietnam. The interviews allowed the first researcher to identify opinions and evaluations of primary teachers and students about the current science curriculum, to recognise difficulties, advantages, and expectations that they may have with the implementation of the current science curriculum. Two kinds of semi-structured interviews were applied, as described below.

B1. Interviews with teachers

Eight female primary teachers, seven of them were approached through classroom observations, were interviewed face-to-face individually or in groups by the researcher for approximately one hour. The teachers are different in terms of educational levels and in the age group (age 35 to 50). They have had at least 15 years of experience and won several prizes for efficient teaching. All of them were encouraged to be free in answering open-ended questions, which were focused on the science curriculum, teaching and learning methods, and/or the particular observed science lesson. Main questions for teachers were:

- What do you think about the current primary science curriculum? Why do you think so?
- What do you think about the current science lessons? Why do you think so?
- Do you apply group learning for your science classes? Why and how?
- What do you think about the application of group learning for science classes? Why?

B2. Interview with students

The researcher randomly selected eleven students from the first five observed classrooms (Table 2) for interviewing. They were interviewed face-to-face individually or in groups for about 20-30 minutes. All of them were encouraged to be free in answering open-ended questions, which were focused on the particular observed science lesson and ideal ones. Main questions for students to answer were:

- What do you think about your science lesson(s)? Why do you think so?

- What is your ideal science lesson? Why do you want to have a science lesson like that?

These questions were often elaborated in the interviews.

All of the interviews with the teachers and students were audio-recorded and afterwards transcribed verbatim.

C. Questionnaires

Questionnaires were employed to get information from a large population of teachers and students who could provide information regarding the implementation of the current science curriculum. Two kinds of questionnaires were utilised.

C1. Teacher questionnaires (Appendix A)

One hundred and thirty-two (132) primary teachers from various primary schools in three Northern provinces, including Hanoi, Bacninh, and Namdinh, were involved in the teacher questionnaire survey. The mean age of the teachers is 34 years old and the mean year of teaching experience is 12 years; 91% of them are female. The teachers were asked to answer questions regarding the current primary science curriculum, forms of cooperative learning applied to science classes, and teacher roles in science lessons.

C2. Student questionnaires (Appendix B)

Seventy-four (74) primary students of grade 4 and 5 from two Northern provinces, Hanoi and Bacninh, were involved in the student questionnaire survey. They were asked to answer questions regarding their science lessons and their expectation about science lessons.

D. Analyses of primary science textbooks and curriculum guidelines

D1. Analysis of primary science textbooks

Given the assumption that teachers and students often rely on textbooks as a main source of information for teaching and learning, the official science textbooks were collected and analysed. This study focused on the lesson approaches and knowledge representations in science textbooks.

D2. Analysis of the science curriculum guidelines

The science curriculum guidelines are considered to be important in shaping lessons in the science textbooks and influencing teaching and learning in science classrooms. The analysis of the science curriculum guidelines can help the authors to identify objectives of science lessons and teaching methods which teachers are instructed to apply in science classrooms. To do this, the document *Schooling Curricular – For Primary Education Level* (Ministry of Education and Training [Vietnam], 2006) and primary science syllabi were collected and analysed.

Data analysis

Both quantitative and qualitative data were concurrently analysed and compared. Prior to comparing and analysing the combined data, the quantitative data were analysed by SPSS in order to obtain frequencies and means for each item in the questionnaires.

Classroom observations were utilised as a primary data source of which findings later were clarified and triangulated (Jick, 1979) by data from the other sources. The utilisation of data sources is presented in Table 3.

Table 3. The utilization of the data sources

Social constructivist feature	A	B		C		D	
		B1	*B2*	*C1*	*C2*	*D1*	*D2*
1. Learning is social	X	X	X	X	X		
2. Knowledge is experience-based	X	X		X		X	X
3. Knowledge is constructed by learners	X	X		X			
4. All aspects of a person are connected	X	X	X	X	X		
5. Learning communities should be inclusive and equitable	X	X		X		X	

Note: X means the data source was utilized.

The analysis of data sources was implemented in three main cycles. In the first cycle, the researcher analysed the data sources using the social constructivist features and corresponding indicators (Table 1) as the organising elements in order to go to the findings. To present the findings, each of the social constructivist features was used as the leading theme for the description of the corresponding finding related to the implementation of that social constructivist feature. The description of the findings started with summaries as sub-themes for the implementation and followed by evidences from the data sources.

The second cycle analysis had the involvement of a second and a third researcher (both supervisors). In this cycle, the analysis made by the researcher was thoroughly discussed with the second and the third researcher for several times. The second and the third researcher validated the findings formulated by the first researcher.

The third cycle analysis had the involvement of a third and a fourth researcher. After that, the analysis and findings from the former discussions were discussed and validated in the entire research team for a consensus of the research team on the findings. The discussions of many cycles of analysis along with the involvement of four researchers in total provided opportunities to do cross-check and validate data (Creswell & Clark, 2007). Thereby, a thorough description about the implementation of a social constructivist perspective in primary science education was completed.

For the second research question

Data collection

To answer the second research question (*How can this implementation be explained from a Confucian cultural perspective and what cultural factors are fostering and hindering the implementation?*), diverse cultural literature, including cultural traditions, folklore and custom practices experienced by the general population, were needed for references and searched for. This is because culture is a collective phenomenon that "consists of the unwritten rules of the social game" (Hofstede, Hofstede & Minkov, 2010, p. 6). The analysis of literature on Confucian heritage culture can provide an in-depth cultural explanation for the implementation of a social constructivist perspective in primary school science in Confucian heritage culture.

Data analysis

To formulate the cultural explanations for the implementation of a social constructivist perspective in primary science education in Confucian heritage culture, the eight Confucian cultural features (a thru f) were relied on and used as the leading themes for the presentation of the explanations. These themes were often clarified by evidences from the literature of Confucian heritage culture.

The analysis of the cultural literature took place in several steps. Firstly, knowledge of Confucian heritage culture correspondingly to each of the features of Confucian heritage culture (a thru f) was generalised. Secondly, it was explored in relation to science education and compared to a social constructivist perspective embedded into Western philosophy of science education. Subsequently, cross-cultural comparative knowledge was connected to the findings of the implementation of a social constructivist features. In this way, cultural explanations for the implementation were formulated and led to characterisations of Confucian heritage cultural influences on the implementation of a social constructivist perspective. Hindering and fostering themes emerged and were categorised as characterisations of cultural influences.

The analysis process was carried out in several cycles. The researcher accomplished the first analysis of Confucian cultural features and formulated the cultural explanations for the implementation of a social constructivist perspective in primary science education. After that, the analysis and the formulated explanations were thoroughly discussed with two other researchers (supervisors three and four). The analysis and the cultural explanations were then discussed again by all researchers for a consensus. Thereby, the careful explanations showing the influences of Confucian heritage culture on the implementation of a social constructivist perspective in primary science education were created.

Findings

The implementation of a social constructivist perspective in primary science education in Vietnam

To present the findings, the indicators of social constructivist features (Table 1) are used as organising elements that provide themes for the implementation of a social constructivist perspective in primary science education. The description starts with summaries as sub-themes for the implementation and followed by evidence from the data sources. The findings are subsequently summarized in Table 4.

1. SC Feature 1: Learning is social

1.1. Whole class grouping was dominant for social learning

The amount of time spent for whole class activities was significantly higher than for group learning in the observed science classrooms. On average, 32 minutes were spent for the whole class activities and 3 minutes were spent for group learning (Source A). Group tasks were applied in separate periods and on average two group tasks were utilised for cooperative learning in a science lesson (Source A).

The dominance of whole class grouping could be inferred from results of teacher questionnaires. The teachers reported that they applied whole class grouping more than pair grouping and other learning forms, e.g. learning in a group of four, learning in a group of six, and individual learning (Source C1). Only 20% of the primary teachers applied group learning for all of their science classroom practices, 33% of them applied it for the majority of science classroom practices, 29% of them applied it for half of science classroom practices, 16% of them applied it for some science classroom practices, and 2% of them almost never applied group learning for their science classroom practices (Source C1).

1.2. Short-term pair grouping was dominant for group learning

Eighty-five per cent (85%) of cooperative tasks in the observed classroom practices were applied for pair grouping, which took place on average for 2 minutes (Source A). The teachers confirmed the dominance of pair grouping for group learning for science lessons (Source B1). They explained its use based on convenience and suitability with discussion content and classroom material conditions of pair group in comparison to other group forms (Source B1). The short time for group learning was confirmed by both teachers and students (Source B1 & B2). It was explained by time constraint for science lessons and the overlooking to the subject of science in the primary school curricula (Source B1 & C1).

1.3. Learning in small groups was appreciated

It was observed that group learning with the participation of more than two students was rare but took place more actively and excitedly than learning in other forms (Source A). Both the teachers and students reported that they appreciated group learning with the participation of more than two students for science lessons (Source B1, B2, C1 & C2). According to them, students felt freer and learned more actively in group learning with the participation of more than two students than in other learning forms (Source B1 & B2).

2. SC Feature 2: Knowledge is experience-based

2.1. Teaching and learning was textbook-based

Science textbooks were used as a main source for teachers and students to follow (Source A). Teaching and learning was implemented by teachers asking questions and students reading textbooks (Source A). The teachers confirmed the high dependence on science textbooks and explained this dependence by work overload, their limited pedagogical content knowledge, and institutional constraints (Source B1 & C1).

- If you do not follow it, "your body will be beaten to pulp"... (Teacher Y., Class 6, explained for the rigid dependence of the primary teachers on science textbooks, Source B1)

2.2. Teaching and learning was teacher-centred

For whole class activities, time spent for teacher activities was significantly higher than for student activities (Source A). On average, teacher activities consumed 21 minutes and student activities consumed 11 minutes (Source A). In the majority of teaching time, the teachers stood in front of students to ask questions and transmit knowledge (Source A). For few cases of group learning, the teachers communicated with individual students rather than with groups as a whole (Source A). During students' group discussions, the teachers not only provided students with judgments on their discourses but also adjusted students' discussions and gave them information to answer questions (Source A). The majority of group discussions stopped or were stopped earlier than time announced (Source A). These findings were confirmed by the teachers reporting that they applied oral methods more often than practical methods for science lessons (Source C1).

2.3. Lessons were focused on factual knowledge

Teaching was mainly focused on factual knowledge in the observed science classrooms (Source A). This is consistent with the lesson design in the science textbooks (Source D1). The lessons were structured with different learning phases, which are labelled as i) *Observing and Answering*, ii) *Relating and Answering*, iii) *Game playing*, iv) *Drawing*, v) *Practicing*, and vi) *Key note* (Source D1). However, these so-called different learning phases could provide similar activities and were structured in varied orders (Source D1). Moreover, they were different in times of application in lessons and among lessons (Source D1). The phase *Observing and Answering* was applied more than the other phases (Source D1). Yet, representative questions about *What*, *When*, *Where*, or *How*, related to subject-matter frequently appeared along with illustrative figures, which could reveal the information for answering questions (Source D1). These designs were consistent with the science curriculum's priority of learning goals with a strong emphasis on factual knowledge (Source D2). Typical scientific skills and attitudes, i.e. hypothesising, experimenting, and arguing vs. curiosity and response to science, were almost absent in the learning goals (Source D2). The priority of learning goals on factual knowledge of the science curriculum was confirmed by the teacher reports (Source B1 & C1).

3. SC Feature 3: Knowledge is constructed by learners

3.1. Knowledge was transmitted and reproduced

For the whole class activities, transmission and reproduction were implemented as main activities for teaching and learning (Source A); it followed a communication pattern as presented in Figure 1.

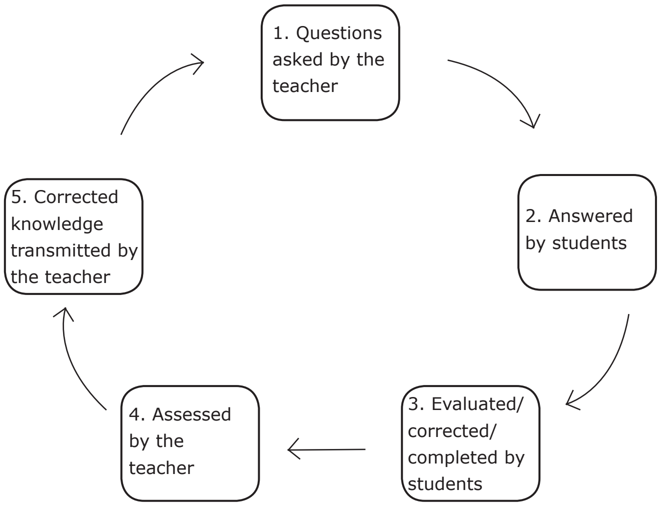


Figure 1. A communication pattern in the science classroom practices (Source A)

Sometimes, actions 3 and 4 (Figure 1) were skipped and action 5 (Figure 1) appeared longer than the others (Source A).

For students' group activities, the majority of group tasks were mutual asking and answering in pairs; for instance students were required to ask each other which medicine they ever used and for what (Class 1, Table 2), whether they ever got any infectious diseases of the digestion system (Class 3, Table 2), and what they often consume for their daily meals (Class 5, Table 2). Eighty-six per cent (86%) of group tasks had a low complexity without an emphasis on conceptual and procedural knowledge (Source A). The teachers confirmed the utilisation of the transmission method for science lessons and asserted that it could not be replaced under the influence of lesson design in the science textbooks (Source B1).

3.2. Hands-on complex tasks were absent

Hands-on complex tasks with an emphasis on conceptual and procedural knowledge were hardly utilised in the observed science classroom practices (Source A). This was confirmed by teachers and explained by various factors, such as institutional constraints of time, teachers' work overload, teachers' limited pedagogical content knowledge, the insufficient and low quality of facilities of primary schools (Source B1 & C1).

4. SC Feature 4: All aspects of a person are connected

4.1. Personal student aspects were discounted

The students stayed passive in listening to the teacher and answering representative questions for whole class activities (Source A). In cooperative activities, passive learning was often demonstrated in the activity of reproducing knowledge for simple cooperative tasks (Source A), for instance students were required to tell each other about the medicines they ever used (Class 1 & 2, Table 2), infectious diseases of the digestion system (Class 3 & 4, Table 2), food consumed for daily meals (Class 5 & 7, Table 2), and health problems if the excretory system of urine is not cleaned (Class 6, Table 2). The classroom practices were strictly controlled by the teachers to maintain well-ordered classrooms (Source A). According to teachers, the overload of the primary science curriculum had made science lessons become less effective in helping students develop scientific skills and attitudes (Source B1). In addition, the institutional focus of assessment on students' achievements of factual knowledge did not make the teachers give up the teaching style of "packing and filling" of knowledge for their science lessons (Source B1).

4.2. Students would prefer cooperative learning and experimental tasks

Students were more excited and enthusiastic in the few cases of group activities, especially in ones which required more than two student participants and were provided with a longer time for cooperation and discussion (Source A). This was confirmed by both teachers and students who expected science lessons to be more practical (Sources B1 & C1). In contrast to the actual situation, students would prefer science lessons in which they could do cooperative learning and experimental activities in realistic contexts (Sources B2 & C2).

5. SC Feature 5: Learning communities should be inclusive and equitable

5.1. Families and fieldwork were included to support school science

Learning tasks, which required students to cooperate with families and adults, were recognised in the observed science classroom practices (Source A), e.g. students of classes 1 and 2 (Table 2) were asked to study the names of some medicines, the ingredients and the usage in advance. Fieldwork was applied for students to learn science (Source D1); for instance students visited the zoo to collect materials related to science lessons, etc. According to the teachers, the involvement of families and fieldwork was necessary and meaningful since it could help students to apply and to transfer scientific knowledge in a better way (Source B1).

5.2. Hierarchical interactions remained in science classroom practices

Students generally deferred to the teacher and considered her as a superior authority (Source A). Students hardly showed reactions to improper or inadequate interventions from the teacher (Source A). The following (Class 3, Table 2) illustrates this.

> The students were asked to discuss in pair groups by asking each other about infectious diseases of the digestion system they had got in the past. For one group, when asked by his partner whether he had ever got any infectious disease of the digestion system, the student answered "No". After hearing his response, the teacher immediately criticised him and stressed that if the answer was just "no", the group discussion would end because there was nothing more to discuss. Then she asked him to change his answer to "yes" to continue the discussion (Class 3, Table 2).

The teachers confirmed that hierarchical interactions remained in science classroom practices (Source B1). Hierarchical interactions between teacher and student were also confirmed by the results from the teacher questionnaires. According to the teachers, the three most important teacher roles for science teaching were a) delivering the learning task, b) asking questions, and c) directing students to learn. These teacher roles are considered to reflect the superior authority of teachers. Meanwhile, other teacher roles, which are regarded to be more neutral and reflect the equitability in interactions between teacher and students, such as supervising students' learning and facilitating students to learn when necessary, were less valued (Source C1).

Explaining the implementation from a Confucian cultural perspective

The findings on the implementation of a social constructivist perspective in primary science education in Vietnam, as summarised in Table 4, were related to Confucian cultural features 'a thru f' for explanations. Through the relation and comparison to a social constructivist perspective for science education, influences of a Confucian heritage culture were explored and characterised. Accordingly, fostering and hindering cultural factors for the application of a social constructivist perspective into primary science education were determined.

Table 4. The implementation of a social constructivist perspective in primary science education

Social constructivist feature	Implementation
1. Learning is social	1.1. Whole class grouping was dominant for social learning 1.2. Short-term pair grouping was dominant for group learning 1.3. Learning in small groups was appreciated
2. Knowledge is experience-based	2.1. Teaching and learning was textbook-based 2.2. Teaching and learning was teacher-centred 2.3. Lessons were focused on factual knowledge
3. Knowledge is constructed by learners	3.1. Knowledge was transmitted and reproduced 3.2. Hands-on complex tasks were absent
4. All aspects of a person are connected	4.1. Personal student aspects were discounted 4.2. Students would prefer cooperative learning and experimental tasks
5. Learning communities should be inclusive and equitable	5.1. Families and fieldwork were included to support school science 5.2. Hierarchical interactions remained in science classroom practices

a. The collectivist root

In highly collectivist societies such as China, Korea, Japan, and Vietnam, the significance of collectivity and the power of solidarity are stressed (Thêm, 1997). In Vietnam, there are various folk sayings indicating and educating the significance of collectivity and the power of solidarity, e.g., *One tree cannot build up a forest but many trees can [Một cây làm chẳng nên non. Ba cây chụm lại nên hòn núi cao]*. Learning in a whole class grouping can be a way to educate students about collectivity and solidarity. This can be reasoned for the extensive application of the form of whole class grouping in classical Confucian classroom practices that was acknowledged to have influenced current learning forms applied in Vietnamese schools at the present time (Đạm, 1994). Therefore, the cultural factor of collectivist root could have influenced primary science education by the dominance of the whole class grouping learning form (Finding 1.1).

The cultural values of collectivity and the solidarity, as influenced by the collectivist root, can derive to and support the tradition of learning together and peer learning. The tradition of learning together is assumed to have existed in classical Confucian learning communities, wherein students were taught to consider each other as brothers and sisters and provide mutual academic assistance and affective support to each other. The tradition of peer learning is highlighted in various Vietnamese cultural idioms, for instance: *Learning from the teacher is not better than learning from the peer [Học thầy không tày học bạn]* and *Learning from the teacher, learning from the peer, numberless prosperity [Học thầy, học bạn, vô vạn phong lưu]*. The cultural value of learning together and peer learning can support the application of *group learning [học nhóm]*, which was acknowledged to have been popular during the 1970s and 1980s and still maintained in Vietnam to date (Mai, 2008). Therefore, it could have influenced primary science education by the appreciation of learning in small groups (Finding 1.3) and the student preference towards cooperative tasks (Finding 4.2).

Besides, the cultural value of learning together is inferred to have supported and been supported by folklore, for instance, the Vietnamese idiom *Travel for a day, gain a lot of wisdom [Đi một ngày đàng học một sàng khôn]*. The acknowledgement and value of the availability of learning contexts can be recognised in Confucian thoughts, i.e. the Confucius statement *Among any three persons, there must be one who can be my teacher [Tam nhân hành, tất hữu ngã sư yên]* (Lê, 1992). As expressed in these statements, learning is considered a social activity that can take place and should take place in any situation and context, with anyone, not only with the teacher and inside schools. Confucius himself is an authentic specific model for demonstrating the position on the availability of learning contexts since he spent many years as a globetrotter to learn about human life and world affairs (Lê, 1992). Therefore, this cultural factor could have influenced primary science education in Vietnam by the inclusion of families and fieldwork (Finding 5.1).

With the influence on primary science education, related to Finding 1.1, Finding 1.3, Finding 4.2, and Finding 5.1, the collectivist root of a Confucian heritage culture is considered to *foster* the implementation of a social constructivist perspective in primary science education.

Nevertheless, the tradition of peer learning, as influenced by the collectivist root, is considered to have supported pair grouping for learning. The traditional appreciation for pair grouping for learning has stimulated movements of pair learning in Vietnamese schools, wherein the learning movements such as *Going-forward pair of peers [Đôi bạn cùng tiến]* and *Well-learning pair of peers [Đôi bạn học tốt]* have been largely applied in the past and remained to date (Mai, 2008). The learning approach that involves two students has also been applied in China (Watkins, 2000). Therefore, the traditional appreciation of pair grouping for learning could have influenced the implementation of a social constructivist perspective by the dominance of pair grouping for cooperative learning in science classroom practices (Finding 1.2). Since a social constructivist approach often requires more than two students for group work, the traditional appreciation for pair grouping is considered to *hinder* the implementation of a social constructivist perspective in a Confucian heritage culture.

In short, collectivism can provide both *fostering* and *hindering* factors for the implementation of a social constructivist perspective in primary science education in Confucian heritage culture.

b. The harmony and stability preference as a cultural and human value
Individuals in collectivism-rooted cultures prefer harmony and stability as showed in humanity-valued lifestyle (Thêm, 1997). This can be influenced by the agriculture-rooted culture, which originally promoted settled cultivations and fixed residences and made individuals tend to depend on nature (Thêm, 1997). The well-known Vietnamese proverb *Settle down then a fruitful job [An* cư l*ạc nghiệp]* indicates the importance of settling down and also highlights stability for the living. The traditional humanity-valued lifestyle is expressed in various Vietnamese idioms, i.e. *A bit of humanity outweighs a lot of rationality [Một bồ cái lý không bằng một tí cái tình]*. This idiom indicates that Vietnamese individuals traditionally take importance in humanity in relationships. The humanity value prevails in Confucian thoughts. It could have been emphasised so much that rationality has been almost overlooked. Consequently, moral-related lessons of ritual behaviours rather than critical and rational thinking with the emphasis on argumentation have been largely used as subjects to educate individuals in Confucian heritage culture.

In the cultural humanity value, individuals in Confucian heritage culture strive to remain peaceful and stay in harmony with surrounding environments (Thêm, 1997). Harmony is supported and recommended by Confucianism, as expressed in the statement *Harmony maintained is appreciated [Dĩ hòa vi quý]* and *Stay harmony like unconflicting [Hòa như bất đồng].* In a Confucian heritage classroom, confrontation and conflicts should be avoided (Hofstede, Hofstede, & Minkov, 2010).

The harmony and stability preference within the humanity value of Confucian heritage culture could have influenced the implementation of a social constructivist perspective by the application of inert/static teaching and learning activities, including the transmission and reproduction of knowledge (Finding 3.1), and the lack of inquiry activities because of the absence of hands-on tasks (Finding 3.2). Therefore, to a certain extent, the stability preference and the humanity value of Confucian cultural traditions could be a cultural factor that (indirectly) *hinders* the implementation of a social constructivist perspective in primary science education.

c. The virtue focus

Confucianism, as a social philosophy with a focus on spiritual concern in which moral virtue matters, highlights five virtues, namely benevolence, righteousness, civility, knowledge, and loyalty (Doãn, 1999). Confucianism encourages individuals to *learn civility first and foremost and then learn literacy [Tiên học lễ, hậu học văn]*. This has become an active slogan for teaching and learning in primary schools in Vietnam. According to Đạm (1994), Confucian virtue overemphasises civility or ritualistic behaviours, hinders individuals in proving themselves and binds the personal ego. This cultural feature could have influenced the implementation of a social constructivist perspective by discounting personal student aspects (Finding 4.1) in teaching and learning practice. Therefore, the focus on virtue in Confucian heritage culture could be a factor that *hinders* the implementation of a social constructivist perspective in primary science education.

d. The support of hierarchical order

Confucianism stresses a hierarchical order with its core objective of building a stable and well-ordered society (Berthrong & Berthrong, 2000). In Confucian heritage culture, hierarchical relationships are manifested by respect for age, position and family background. Accordingly, two kinds of subjects, superior and inferior are determined for human interactions and social communications. Due to the teacher's age and academic level, the teacher was regarded as superior in communications between the teacher and students. Confucianism regards the teacher as the parent, as expressed in the statement *A teacher for a day, a father for life [Thày dạy một ngày là cha cả đời]*, and affirms that *in the world no parent is wrong [Thiên hạ* vô b*ất thị để phụ mẫu]*, meaning that whatever the parent says or does is always right. Many Vietnamese folk sayings also highlight the significance of the teacher, for instance, *No teacher, no success [Không thầy đố* mày làm nên] and *To cross a river, build up a bridge/ To become knowledgeable, tie to the teacher [Muốn sang thì bắc cầu kiều/ Muốn con hay chữ thì yêu lấy thầy].* As an inferior, students are traditionally encouraged to be trustful, grateful and respectful to the teacher. They remain modest and humble in communicating with their teacher. This can lead to dependence on and deferring of students to the teacher. The support of Confucian heritage culture for hierarchical order could have influenced the implementation of a social constructivist perspective in primary science education by the teacher-centred approach (Finding 2.2), by which the transmission and reproduction of knowledge is supported (Finding 3.1), discounting personal student aspects (Finding 4.1), and hierarchical interactions in science classroom practice (Finding 5.2). Therefore, the support of hierarchical order in Confucian heritage culture could be a cultural factor that *hinders* the implementation of a social constructivist approach, which encourages an equitable interaction between the teacher and students.

e. The family value

Family value is a norm of Confucian thought (Doãn, 1999). Family is considered a miniature version of the country and cannot be separated from society as a whole. In Confucian heritage culture, it is regarded as an educational environment for individuals to cultivate virtue and to have significant influence on the stability of society (Doãn, 1999). According to Confucianism, parents need to teach and educate their children from early ages with various subjects and support their learning. This aligns with the Confucian norms in which the teacher is regarded as the parent and vice versa. In addition, in old Chinese, the word *sư phụ [master]* was combined with the word *sư [teacher]* and the word *phụ [parent]*. This word combination manifests the closeness between the parent and the teacher in Confucian heritage culture. The value of family in Confucian heritage culture could have influenced the implementation of a social constructivist perspective by the inclusion of families for primary science education (Finding 5.1). Therefore, this cultural factor can *foster* the implementation of a social constructivist approach for primary science education.

f. The emphasis on theoretical knowledge
Confucianism considered that theoretical knowledge in classic works was universally correct. Traditionally, the Confucius's proverb *Revise the old to make sense of the new [Ôn cố nhi tri tân]* has been popularly used and interpreted to value the universal correctness of classical theoretical knowledge (Đạm, 1994). The appreciation of theoretical knowledge and classic works can be found in many Confucian statements, for instance: *Without studying the Shih Ching, one does not know what to speak? [Không học Kinh Thi biết gì mà nói]* (The Shih Ching, whose author is attributed to Confucius, is a compilation of documentary records related to ancient historic events in China). Notably, the method of *educating by ancient classic works [giáo dục lục nghệ]* was traditionally applied by Confucius during his life as a teacher and considered to have created a teaching and learning tradition that values the old (Doãn, 1999). In Confucian heritage culture, the method of quoting and citing the classics and examples *[tầm chương trích cú]* has been largely applied in social communications and also in teaching and learning (Chan, 1999). Such an activity has stimulated rote learning. The Confucian cultural emphasis on theoretical knowledge therefore could have influenced the implementation of a social constructivist perspective by the application of textbook-based teaching and learning (Finding 2.1), the teacher-centred approach (Finding 2.2), the focus on factual knowledge (Finding 2.3), the transmission and reproduction of knowledge (Finding 3.1), and the absence of hands-on complex tasks (Finding 3.2). Therefore, it can be a cultural factor that *hinders* the implementation of a social constructivist approach in primary science education.

Conclusions and Discussion

A social constructivist perspective so far has not been well implemented in primary science education in Vietnam. This is because of the following:

- Teaching and learning was textbook-based (Finding 2.1) and teacher-centred (Finding 2.2);
- Lessons were focused on factual knowledge (Finding 2.3);

- Knowledge was transmitted by the teacher and reproduced by students (Finding 3.1);
- Hands-on complex tasks were absent (Finding 3.2);
- Students' personal aspects were discounted (Finding 4.1); and
- Hierarchical interactions remained in science classes (Finding 5.2).

In addition, the dominance of whole class grouping (Finding 1.1) and short-term pair grouping for group learning (Finding 1.2) could also be the aspects that demonstrate the low implementation of a social constructivist perspective in primary science education.

Nevertheless, the findings also reveal some optimistic signals for the application of a social constructivist perspective in primary science education in Confucian heritage culture. They are the appreciation to learn in small groups (Finding 1.3), the expectation of cooperative experimental tasks (Finding 4.2), and the inclusion of families and fieldwork (Finding 5.2) for primary science education.

The implementation of a social constructivist perspective in primary science education in Vietnam has been considerably influenced by Confucian heritage culture. Accordingly, Confucian heritage culture was speculated to have provided both hindering and fostering factors for the implementation of a social constructivist perspective.

The fostering factors account for the cultural root of collectivism that bolsters the tradition of learning together, peer learning, and the value of family, which supports the inclusion of families for primary science education. In this way, it is consistent with the notion that there exists cooperative and group work in learning environments of Confucian heritage culture, and Confucian heritage culture students prefer a collaborative learning environment (Biggs, 1996). Also, it reinforces the assertion that Asian students want to explore knowledge themselves and do this together with their peers in an atmosphere which is friendly and supportive (Littlewood, 2000).

The hindering factors of Confucian heritage culture account for the root of collectivism, which supports the appreciation and the application of pair grouping for learning. In addition, the hindering factors could come from the stability preference, the virtue focus, the hierarchical order, and the emphasis on theoretical knowledge. All of them are considered to nurture and stimulate static teaching and rote learning of science that focuses on theoretical knowledge and overlooks inquiry activities and personal aspects of learners.

This study used Vietnam as a case study due to its relevance to Confucian heritage culture and the recent reform of primary school curricula. Though Vietnam is considered as a country that has been deeply influenced by Confucianism, it might contain differences in its Confucian heritage culture in comparison to other Confucian heritage countries, i.e. Japan, Korea, and China. However, in this study, differences in Confucian heritage culture among these countries were not taken into account. In addition, the study surveys were carried out in three provinces of Vietnam; however, all of them were located in the Northern Vietnam (note that the country is officially divided into three main parts: the North, the Middle, and the South). It is assumed that there are certain differences and influences in Confucian heritage culture among these three regions.

In attempting to provide cultural explanations for the implementation of a social constructivist perspective in primary science education in Vietnam, the study often referred to folklore. Applying the model of uniqueness levels in mental programming (Hofstede et al., 2010), including a) universal level – human nature, b) cultural level – specific to group/culture, and c) personal level – specific to individual, it is assumed that the folklore utilised in the study takes the cultural level. It means that the values expressed in the utilised folk saying may exist elsewhere in other cultures due to human nature, however, they are more important and emphasised in Confucian heritage culture and have been inherited and learned by Confucian heritage individuals.

The findings of this study showed that implementation of social constructivist ideas in science education in Confucian heritage culture remains problematic. The findings are consistent with the proposition in the conclusion of Central Committee [Vietnam] (2012), in which many weak points of school education are clarified, i.e. the curricula are overloaded with academic knowledge, learning goals are separated from each other, learners' capabilities are not focussed, and so forth. These findings are also consistent with cross-cultural studies which revealed that lessons in Asian countries were traditionally dominated by a teacher-centred, book-centred method and an emphasis on rote memory (Liu & Littlewood, 1997) with little emphasis on critical thinking (Couchman, 1997); teaching influenced by Confucian heritage culture is primarily one-sided in an one-way process: what the teacher says is right and the students are not entitled to ask about sense and purpose, to require reasons or to question the content (Chan, 1999).

In a culture-approach on teaching and learning of science, Tao et al. (2013) acknowledged the profound influences of Confucian philosophy on science teaching and learning in China wherein Chinese primary teachers were described to avoid utilising the recommended group work and memorising science facts was a frequent activity for Chinese primary students, who participated more frequently in passive and closed activities. However, Tao et al. (2013) overlooked the existence of cultural divergence between Confucian philosophy and Western philosophy about nature of science and social constructivism. Cultural divergence between Confucian philosophy and Western philosophy on science education are revealed in this study.

Cultural divergences

There are three striking cultural divergences between Confucian heritage culture and Western educational philosophy that emerged from this study, as presented below.

(1) Confucian heritage culture emphasises stability and harmony among its human values, whereas Western educational philosophy emphasises the rationality (Totten, Sills, Digby, & Russ, 1991) that supports argumentation and conflict in discussion and helps students be prepared for citizenship (Kolstø, 2001). In the "nature of science" education (Abd-El-Khalick & Lederman, 2000; Dekkers, 2006), conflicts and argumentation are preferred over harmony.

By recognizing this cultural divergence, this study can reinforce the claim asserted in other studies that cooperative learning has been applied both in Western culture and Confucian heritage culture (Mai, 2008) but the way of applying is different: Cooperative learning in Confucian heritage culture is in harmony (Xiao, 2009) rather than in argumentation or in conflicts. Harmonious cooperative learning in Confucian heritage culture does not contradict with the assertion that learners in China in particular and in Confucian heritage culture in general are more individualistic (Reid, 1987). Rather, it refers to the acknowledgement that though in Confucian heritage culture cooperative learning exists by the visible form of student learning together, but in essence, student learning is more individualistic. This can be supported by the notion that the Chinese approach to group work is knowledge-centred in contrast with the Western approach that tends to be more skill-centred (Watkins, 2000).

(2) Confucian heritage culture emphasises theoretical knowledge, considering “classical” knowledge and theory as universally correct, whereas Western educational philosophy emphasises empirical knowledge and well-substantiated scientific claims, believing that there is no complete truth and that every aspect of theoretical knowledge is changeable (Abd-El-Khalick & Lederman, 2000; Dekkers, 2006).

(3) Confucian heritage culture emphasises hierarchical order in which the teacher is considered superior and the transmitter of the body of knowledge to students, whereas Western educational philosophy emphasises equitability: the teacher is considered a more advanced learner (Vygotsky, 1978) who facilitates students to learn in order to achieve not only knowledge but also the skills and attitudes used to study science (Bybee, McCrae, & Laurie, 2009; Hofstede, 1986).

With the cultural divergences between Confucian heritage culture and Western educational philosophy emerged from this study, the study advocates the claim that curriculum development needs to be built upon careful evaluation of past local experience (Coll & Taylor, 2012) and to take cultural resources (Neuman & Bekerman, 2000) into consideration to avoid a “false universalism” (Nguyen, Elliott, Terlouw, & Pilot, 2009) and to reduce practical difficulties (Serpell, 2007).

The finding of low implementation of a social constructivist perspective that reveals problems of primary science education in Confucian heritage culture requires a need for a culturally appropriate design of curriculum aimed to improve primary science education in Confucian heritage culture. For such science curriculum development, a design-based approach (Bulte et al., 2006) is recommended to provide theoretical and empirical curriculum guidelines that can address problems found in primary science education in Confucian heritage culture. A culturally appropriate designed curriculum based on a social constructivist perspective can be promising for primary science education in Confucian heritage culture because despite being culture-bound, teaching and learning is highly contextual and learners are highly adaptive (Biggs, 1996). For an example, it is reported that the longer the students study in Australia the more likely they adapt to and adopt the style of Australian teaching and learning (Wong, 2004).

By providing a holistic research on the implementation of a social constructivist perspective in primary science education in Confucian heritage culture through a case study of Vietnam, this study fills in the lack of educational research regarding the implementation of a social constructivist perspective in primary science education in Confucian heritage culture. In this way, the study provides grounds for further research to improve primary science education in Confucian heritage culture and contributes to the knowledge base about the implementation of a social constructivist perspective in primary science education in general and in Confucian heritage culture in particular. Moreover, by providing the explanations for the implementation from a Confucian cultural perspective and showing the emergent cultural divergences between Confucian heritage culture and Western educational philosophy on science education, this study also contributes to the knowledge base about cross-national research of science education.

Acknowledgements

The researchers wish to thank to the two primary schools, Đông Ngàn and Quan Hoa in Vietnam, for providing the first researcher with good opportunities to do classroom observations.

References

Abd-El-Khalick, F., & Lederman, N. G. (2000). Improving science teachers' conceptions of nature of science: A critical review of the literature. *International Journal of Science Education*, *22*(7), 665–701.

Anderson, R. D. (2007). Inquiry as an organizing theme for science curricula. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 807–830). Oxford, England: Taylor & Francis.

Beck, C., & Kosnik, C. (2006). *Innovations in teacher education – A social constructivist approach*. New York: State University of New York Press.

Berthrong, J. H., & Berthrong, E. N. (2000). *Confucianism: A short introduction*. Oxford: Oneworld.

Biggs, J. (1996). Western misperceptions of the Confucian-heritage learning culture. In D. Watkins & J. Biggs (Eds.), *The Chinese learner: Cultural, psychological and contextual influences* (pp. 45–67). Hong Kong: The University of Hong Kong Comparative Education Research Centre.

Bulte, A. M. W., Westbroek, H. B., De Jong, O., & Pilot, A. (2006). A research approach to designing chemistry education using authentic practices as contexts. *International Journal of Science Education, 28*(9), 1063–1086.

Chan, S. (1999). The Chinese learning – A question of style. *Education and Training*, *41*(6/7), 294–304.

Central Committee [Vietnam] (2012). The sixth Conference of The eleventh Central Committee dated 29/12/2012 about The proposal "Innovating basically and comprehensively education and training for meeting requirements of industrialization and modernization in conditions of market economy oriented in socialism and international integration". The Conclusion numbered 51-KL/TW. [Hội nghị lần thứ 6 BCHTW khóa XI về ngày 29/10/2012 về Đề án "Đổi mới căn bản và toàn diện giáo dục và đào tạo, đáp ứng yêu cầu công nghiệp hóa, hiện đại hóa trong điều kiện kinh tế thị trường định hướng xã hội chủ nghĩa và hội nhập quốc tế". Kết luận số 51-KL/TW]

Coll, R. K., & Taylor, N. (2012). An international perspective on science curriculum development and implementation. In B. J. Fraser, K. G. Tobin, & C. J. McRobbie (Eds.), *Second international handbook of science education* (Vol. II, pp. 771–782). Dordrecht, the Netherlands: Springer.

Confrey, J. (1985). Towards a framework for constructivist instruction. In L. Streefland (Ed.), *Proceedings of the Ninth Conference for the Psychology of Mathematics Education* (pp. 477–483). Noordwijkerhout, the Netherlands.

Couchman, J. (1997) Making sense: Cross-cultural variation in the organisation of academic texts by Taiwanese and Australian undergraduate students. In Z. Golebiowski & H. Borland (Eds.), *Academic communication across disciplines and cultures* (pp. 64–76). Melbourne: Victoria University of Technology.

Creswell, J. W., & Clark, V. L. P. (2007). *Designing and conducting mixed methods research*. Thousand Oaks, CA: SAGE Publications.

Dekkers, P. (2006). Reconstructing the Creature – Exploring design criteria for teaching NOS. In E.V. Den Berg, T. Ellermeijer, & O. Stooten (Eds.). Proceedings of Conference *Modelling in Physics and Physics Education* (pp.459-464). University of Amsterdam, the Netherlands.

Doãn, P. Đ. (1999). *Một số vấn đề về Nho giáo Việt Nam [Some issues on Vietnamese Confucianism]*. Hanoi, Vietnam: Publishing House of National Politics.

Duit, R., & Treagust, D. (1998). Learning in science – From behaviorism towards social constructivism and beyond. In B. L. Fraser & K. G. Tobin (Eds.), *International Handbook of Science Education* (pp. 3–25). Dordrecht, the Netherlands: Kluwer Academic.

Đạm, Q. (1994). *Nho giáo xưa và nay [Confucianism: past and present].* Hanoi, Vietnam: Culture Publisher.

Gato, M. (2000). Japan. In M. Poisson (Ed.), *Science education for contemporary society: problems, issues, and dilemmas* (pp.31-37). International Bureau of Education & The Chinese National Commission for UNESCO. Retrieved from http://www.ibe.unesco.org/fileadmin/user_upload/archive/curriculum/China/Pdf/beijingrep.pdf

Hand, B. (2011). An immersion approach to argument-based inquiry – Does it look the same in different countries? In Y. Kim, J. Park, H. E. Seo, J. A. Lee, & J. Kim (Eds.), *Proceeding of the 2011 EASE International Conference – Lighting the World with Science* (pp. 45–54). Gwangju, Korea.

Hoan, Đ. Đ. (2002). *Một số vấn đề cơ bản của chương trình tiểu học mới [Some basic issues of the new primary curricula]*. Hanoi, Vietnam: Education Publisher.

Hofstede, G. (1986). Cultural difference in teaching and learning. *International Journal of Intercultural relations*, *10*, 301–320.

Hofstede, G. (2003). *Cultures and organization - Software of the minds*. London: Profile Books Ltd.

Hofstede, G., Hofstede, G. J., & Minkov, M. (2010). *Cultures and organizations: Software of the mind: Intercultural cooperation and its importance for survival* (3rd ed.). New York: McGraw-Hill.

Jick, T. D. (1979). Mixing qualitative and quantitative methods: Triangulation in action. *Administrative Science Quarterly*, *24*, 602–611.

Kolstø, S. D. (2001). Scientific literacy for citizenship: tools for dealing with the science dimension of controversial socioscientific issues. *Science Education*, *85*, 291-310.

Lê, N. L. (1992). *Khổng Tử [Confucius]*. Hanoi: Culture Publisher.

Liu, N. F., & Littlewood, W. (1997). Why do many students appear reluctant to participate in classroom learning discourse? *System*, *25*(3), 371–384.

Littlewood, W. (2000). Do Asian students really want to listen and obey? *ELT Journal*, *54*(1), 31–36.

Mai, N. P. (2008). Culture and Cooperation: Cooperative learning in Asian heritage cultures – The case of Vietnam. Doctoral dissertation. Utrecht University.

Ministry of Education [China] (2010). *National Outline for Medium and Long-term Education Reform and Development 2010-2020*. Retrieved from http://www. cov.cn/jrzg/2010-07/29/content-1667143.htm

Ministry of Education [Taiwan] (1999). *Curriculum outline for "Nature science and living technology"*. Taipei: Ministry of Education.

Ministry of Education and Human Resources [Korea] (2007). *Science Education Curriculum*. Seoul, Korea.

Ministry of Education and Training [Vietnam] (2006). *Chương trình dạy học - Dành cho bậc tiểu học [Schooling curricular – For Primary Education Level].* Hanoi, Vietnam: Education Publisher.

Nguyen, M., Elliott, J., Terlouw, C., & Pilot, A. (2009). Neocolonialism in education: cooperative learning, Western pedagogy in an Asian context. *Comparative education*, *45*(1), 109–130.

Phuong-Mai, N., Terlouw, C., & Pilot, A. (2005). Cooperative learning vs. Confucian heritage culture' collectivism: Confrontation to reveal some cultural conflicts and mismatch. *Asia Europe Journal 3*(3), 403–419.

Pitsoe, V. J. (2007). *A conceptual analysis of constructivist classroom management.* University of Pretoria.

Reid, J. (1987). The learning style preferences of ESL students. *TESOL Quarterly, 21*(1), 87–111.

Serpell, R. (2007). Bridging between orthodox western higher educational practices and an African sociocultural context. *Comparative Education*, *43*(1), 23–51.

Tao, Y., Oliver, M., & Venville, G. (2013) A comparison of approaches to the teaching and learning of science in Chinese and Australian elementary classrooms: Cultural and socioeconomic complexities. *Journal of Research in Science Teaching*, *50*(1), 33–61.

Thêm, T. T. (1997). *Tìm về bản sắc văn hóa Việt Nam [Research on Vietnamese cultural distinctions].* Ho Chi Minh, Vietnam: Ho Chi Minh Publisher.

Tobin, K. G. (1993). *The practice of constructivism in science education*. Washington, DC: AAAS.

Totten, S., Sills, T., Digby, A., & Russ, P. (1991). *Cooperative learning: A guide to research*. New York: Garland.

Van den Akker, J. J. H. (2003). Curriculum perspectives: An introduction. In J. J. H. Van den Akker, W. Kuiper, & U. Hameyer (Eds.), *Curriculum landscape and trends* (pp. 1-10). Kluwer Academic Publisher.

Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Watkins, D. (2000). Learning and teaching: A cross-cultural perspective. *School Leadership & Management*, *20*(2), 161–174.

Wong, J. K. K. (2004). Are the learning styles of Asian international students culturally or contextually based? *International Education Journal*, *4*(4), 154–166.

Xiao, L. (2009). What can we learn from a learning needs analysis of Chinese English majors in a university context? *Asian EFL Journal, 8*(4), 74–79.

Appendix A - Teacher questionnaires

A. Personal information

A1. Name (optional): ………………………………………………………..

A2. School: ……………………………………………………...............

A3. Province: 1. Hanoi 2. Bacninh 3. Namdinh 4. Other

A4. Gender: 1. Male 2. Female

A5. Age: ……………………………………………………......................

A6. Teaching grade:

1. Grade 1 2. Grade 2 3. Grade 3

4. Grade 4 5. Grade 5 6. None

A7. Years of teaching experience: ………………………………………………

A8. Educational academic level:

1. Intermediate 2. College graduation

3. University graduation 4. Master

B. Answer the following questions about the primary science curriculum

1. To what extent do you think the following learning goals emphasize student development in primary science curriculum? Please circle one number for each question.

i. Scientific knowledge	Not at all				Very much
	1	2	3	4	5
ii. Skills	Not at all				Very much
	1	2	3	4	5
iii. Attitudes	Not at all				Very much
	1	2	3	4	5

2. How often do you apply the learning and teaching method below in your science classes? Please circle one number for each question.

i. Question asking	Never				Very often
	1	2	3	4	5
ii. Lecturing	Never				Very often
	1	2	3	4	5
iii. Student exercises	Never				Very often
	1	2	3	4	5
iv. Visual modelling	Never				Very often
	1	2	3	4	5
v. Game playing	Never				Very often
	1	2	3	4	5
vi. Problem solving	Never				Very often
	1	2	3	4	5
vii. Inquiring	Never				Very often
	1	2	3	4	5
viii. Dictating	Never				Very often
	1	2	3	4	5
ix. Brain storming	Never				Very often
	1	2	3	4	5
x. Play-acting	Never				Very often
	1	2	3	4	5
xi. Experimenting	Never				Very often
	1	2	3	4	5
xii. Other: ……………………	Never				Very often
	1	2	3	4	5

3. Circle three numbers corresponding to science teacher roles that you think are most important

i. Introduce lesson
ii. Give lectures
iii. Set up student groups
iv. Ask questions
v. Direct student learning
vi. Answer students' questions
vii. Deliver learning tasks
viii. Supervise student learning
ix. Maintain active learning atmosphere
x. Set up tight control of the classroom

xi. Solve student-learning conflicts
xii. Facilitate students when necessary
xiii. Assess student learning
xiv. Other: ………………………………

4. How often do you apply learning-in-groups for your science classroom practices? Please circle only one.
i. For all of the science lessons
ii. For majority of the science lessons
iii. For half of the science lessons
iv. For some of the science lessons
v. For one or very few of the science lesson(s)
vi. Never
vii. No idea/I don't know

5. Which learning form is most applied in your science classroom practices? Please circle only one.
i. Individually
ii. Pair grouping
iii. Grouping with more than two participant students
iv. Whole class grouping
v. Other (please specify: ……………………………………………………………….)
vi. No idea/I don't know

6. Which learning form do you appreciate for students to learn science? Please circle only one.
i. Individually
ii. Pair grouping
iii. Grouping with more than two participant students
iv. Whole class grouping
v. Other (please specify: ……………………………………………………………….)
vi. No idea/I don't know

7. What do you think about the current primary science curriculum?

8. Which factors influence, foster or hinder your application of group learning for science lessons?

Appendix B - Student questionnaires

A. Personal information

1. Name (optional): ………………………………………………………………

2. School: ……………………………………………………………..............

3. Province: i. Hanoi ii. Bacninh iii. Namdinh iv. Other

4. Gender: i. Male ii. Female

5. Grade:…………………………………………………………………………….

B. Answer the following questions about the primary science curriculum

1. Which learning form do you like most to learn science?

i. Individually
ii. Pair grouping
iii. Grouping with more than two participant students
iv. Whole class grouping
v. Other (please specify: ……………………………………………………………….)
vi. No idea/I don't know

2. Please describe an ideal science lesson for you.

Chapter 1. Introduction and Research Overview

What is the design of curriculum for primary science education that has social constructivist characteristics and is appropriate with Confucian heritage culture?

PROBLEM ANALYSIS

Chapter 2. The implementation of a social constructivist perspective in primary science education in Confucian heritage culture: the case of Vietnam

RQ1. To what extent is a social constructivist perspective implemented in primary science education in Confucian heritage culture?

RQ2. How can this implementation be explained from a Confucian cultural perspective and what are fostering and hindering cultural factors to the implementation?

DESIGN CYCLE 1

Chapter 3. Designing a formal curriculum based on a social constructivist perspective for primary science education in Confucian heritage culture

RQ. What is the design of formal curriculum for primary science education that has social constructivist characteristics and is appropriate with Confucian heritage culture?

Chapter 4. Teacher professional development: The interaction of Confucian heritage teachers with a social constructivism-based curriculum for primary science education

RQ. In what way do Confucian heritage teachers interact with a primary science curriculum, which is based on a social constructivist perspective and made appropriate with Confucian heritage culture, in a program of professional development?

Chapter 5. Scientific argumentation as bottleneck for implementing a social constructivism-based science curriculum in Confucian heritage culture

RQ. To what extent does the unit of the curriculum design for primary science education in Confucian heritage culture meet the social constructivist expectations in the practice of the classroom?

DESIGN CYCLE 2

Chapter 6. Improving scientific argumentation through a social constructivism-based curriculum for primary science education in Confucian heritage culture

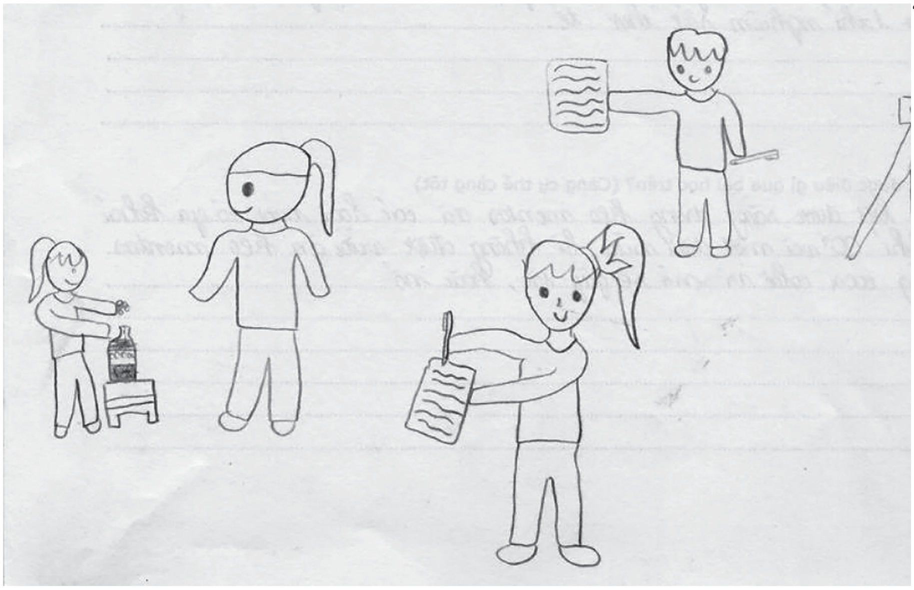
RQ1. To what extent does the unit of the adjusted design of social constructivism-based curriculum for primary science education in Confucian heritage culture support students to practice scientific argumentation in a science lesson?

RQ2. To what extent does the unit of the adjusted design of social constructivism-based curriculum for primary science education in Confucian heritage culture support students to attain consensually agreed knowledge on scientific subject-matter?

Chapter 7. Conclusions, Reflection and Recommendations

RQ. What is the design of curriculum for primary science education that has social constructivist characteristics and is appropriate with Confucian heritage culture?

CHAPTER 3 Designing a Formal Curriculum based on a Social Constructivist Perspective for Primary Science Education in Confucian Heritage Culture[1]



[2]

Abstract The implementation of a social constructivist perspective in primary science education in Confucian heritage countries remains challenging and problematic. Applying a design-based research approach, this theoretical paper describes the design of a formal curriculum based on a social constructivist perspective for primary science education in Confucian heritage culture. The design of a formal curriculum comprises three main strategic components: learning aims, a framework which is the synthesis of learning functions, learning settings and educational expectations for learning phases, and exemplary curriculum units. Learning aims are determined to comprehensively develop scientific knowledge, skills, and attitudes toward science for primary students. Derived from the determined learning aims, four learning phases are established and respectively labelled as Engagement, Experience, Exchange, and Follow-up. The design of the four learning phases is underpinned by a social constructivist perspective and referred to knowledge of the "nature of science" education and Confucian heritage culture. The curriculum design is considered as a possibility in addressing and solving the previously analysed problems that can improve primary science education in Confucian heritage culture.

1 This chapter is submitted as: Hằng, N. V. T., Meijer, M., Bulte, A., & Pilot, A. *Designing a formal curriculum based on a social constructivist perspective for primary science education in Confucian heritage culture*.

2 A drawing of an experimental lesson made by a student who participated in the research (Chapter 4)

Introduction

The implementation of a social constructivist perspective in primary science education in Confucian heritage culture has remained problematic and challenging (Chapter 2; Tao, Oliver, & Venville, 2013). In Confucian heritage culture, teaching and learning is textbook-based and teacher-centred, hands-on complex tasks are absent, students' personal perspectives aspects, i.e. emotion, attitudes and values, discounted, and hierarchical interactions remain in science classrooms (Chapter 2).

Confucian heritage culture has considerably influenced the implementation of a social constructivist perspective in primary science education (Chapter 2; Tao et al. 2013). It provides both hindering and fostering factors for implementation (Chapter 2). The cultural hindering factors show cultural divergences between Confucian heritage culture and Western educational philosophy of the "nature of science" education (Abd-El-Khalick & Lederman, 2000) and a social constructivist perspective (Chapter 2). The identification of the cultural divergences and a low implementation of a social constructivist perspective in primary science education in Confucian heritage culture provided grounds for a curriculum development aimed at enhancing primary science education in Confucian heritage culture. In addition, the development of a curriculum based on a social constructivist perspective for primary science education in Confucian heritage culture can be supported by the assertion that teaching and learning is highly contextual and learners are highly adaptive (Biggs, 1996). Moreover, the application of a social constructivist perspective to primary science education in Confucian heritage culture can be facilitated and promoted by fostering characteristics of Confucian heritage culture that converge with a social constructivist perspective (Chapter 2).

In thinking of developing a curriculum based on a social constructivist perspective for primary science education in Confucian heritage culture, a design-based approach (Bulte, Westbroek, De Jong, & Pilot, 2006; Kortland & Klaassen, 2010) was chosen and applied. This research approach was considered to be feasible to incorporate educational issues and cultural issues regarding the problems of primary science education in Confucian heritage culture. The design-based research could take the divergences between Western educational philosophy and Confucian heritage culture into consideration to provide an educational guideline that is promising for educational progress.

This study is a part of a broader research project regarding supporting and promoting the application of a social constructivist perspective in primary science education in Confucian heritage culture. This study presents the first step of the design cycle: describing the development of a formal curriculum (Van den Akker, 2003) within the application of a social constructivist perspective in primary science education in Confucian heritage culture. It focuses on the research question: *What formal curriculum design for primary science education has social constructivist characteristics and is appropriate for Confucian heritage culture?.* In answering this research question, knowledge of the "nature of science" education and Confucian heritage culture was embedded in the design in which a social constructivist perspective was used as the scaffolding idea. By designing a well-argued formal curriculum for primary science education in Confucian heritage culture, this study contributes to the development of a knowledge base for designing a social constructivism-based curriculum for primary science education in Confucian heritage culture.

A Social Constructivist Perspective and the Development of Science Curricula

A social constructivist perspective

A social constructivist perspective is an outcome of a growing line of critique against approaches in science education that tend to overemphasize the individual's learning and neglect social issues in knowledge-construction processes (Duit & Treagust, 1998). In a social constructivist approach of science education, students are considered to be active in constructing knowledge of science through their social interactions with the teacher and peers to provide plausible answers and problem solutions. Key features of a social constructivist perspective (Beck & Kosnik, 2006) and its indicators are summarised and presented in Table 1.

With a widespread acceptance, a social constructivist approach is considered to create a paradigm change in science education (Cobern, 1998; Coll & Taylor, 2012; Tobin, 1993). At the level of primary science education, a social constructivist perspective has been increasingly applied in many countries connected to Western cultural traditions through the predominance of inquiry-based approaches with the emphasis on the "nature of science" education that values process skills (Abd-El-Khalick & Lederman, 2000). This is because "what is called inquiry learning is very similar to what others call constructivist learning" and "as with inquiry, the constructivist label can be applied to the nature of science, learning and teaching" (R.D. Anderson, 2007, p. 809). Recently, the historical, tentative, empirical, logical, and well-substantiated nature of scientific claims and the value of open communication and the interaction between personal, societal, and cultural beliefs in the generation of scientific knowledge are considered as the "nature of science" education (Abd-El-Khalick & Lederman, 2000).

Table 1. Social constructivist (SC) features and indicators

SC Feature	Indicator
1. Learning is social	i. Students work in whole class, and/or ii. Students work in small groups iii. Students actively share ideas
2. Knowledge is experience-based	i. Students' experiences are provoked ii. Students interpret experiences
3. Knowledge is constructed by learners	i. Students are immersed in realistic learning situations ii. Students elaborate interpretations of their experiences iii. Students test interpretations of their experiences iv. Students construct meanings
4. All aspects of a person are connected	i. Students' attitudes and emotions are revealed in learning ii. Students take part in hands-on activities iii. Students' values are employed and capitalised in learning
5. Learning communities should be inclusive and equitable	i. Types of communities, e.g., families, organisations, institutions, etc., are involved to support students' learning ii. Interactions of teacher-student and student-student should be equitable rather than hierarchical

The development of science curricula

Reform efforts in science education have called for new designs of a curriculum that can improve science teaching and learning, thereby enhancing learning outcomes. Many science curricula have been developed so far. According to McGee (cited from Coll &Taylor, 2012), curriculum development and implementation in most countries have involved the centre-periphery model. Traditional science curricula were applied up until about the 1980s (Coll & Taylor, 2012). The 1980s and 1990s witnessed "explosive" curriculum reforms world-wide, including non-Western countries, and arguably the single most commonly shared attribute of these curricula was their constructivist origins and learner-centred education, with its origins in constructivism and variants of constructivism became something of "a mantra" (Coll & Taylor, 2012, p. 773).

Through exploring the development of science curricula, several terms are used by educational researchers, i.e. *didactical structure* (Kortland, 2001; Lijnse, 1995; Lijnse & Klaassen, 2010), *instructional model* (Bybee et al., 2006), *curriculum materials* (Krajcik et al., 2008*)*, *framework* (Nentwig et al., 2007; Prins, 2010). All of these terms share a commonplace theory about "intentions as specified in curriculum documents and/or materials" as defined by Van den Akker (2003) for *formal curriculum*. Accordingly, strategic components for structuring a formal curriculum of science can be identified; these include: instructional aims, instructional phases which are constructed by functions, activities of teaching and/or learning, and educational expectations. In this study, these strategic components are elaborated to formulate a framework of a formal curriculum based on a social constructivist perspective for primary school science in Confucian heritage culture.

To a certain extent, the design in this study is influenced by *Dewey's Instructional Model* and the *BSCS 5E Model* (Bybee et al., 2006). Despite certain differences between these two models, both of them emphasize and employ students' experiences, inquiry activities, and curiosity to help students to learn science. Though Dewey is considered as one of the pioneers of social constructivism, *Dewey's Instructional Model* (Bybee et al., 2006) is less possible to provide an instructional framework that is well-argued and specific enough to set up corresponding social constructivist units. Meanwhile, the *BSCS 5E Model* presents the conceptual change tradition (Guzzetti et al., 1993) as one of the three main research traditions in science education: conceptual change, socio-cultural, and critical (C. W. Anderson, 2007). All of these models were designed for application to Western science education.

Applying a social constructivist perspective, this study follows the socio-cultural tradition in the research of science education (C. W. Anderson, 2007). Although the social constructivist view has been criticised as resulting in relative content knowledge (Benson, 2001), social constructivism is accepted to be a learning approach that can help students to become lifelong learners, providing students with learning in which they "are fully engaged, find the process meaningful, and relate ideas to the real world to a considerable extent" (Beck & Kosnik, 2006, p. 2). Social constructivist approaches therefore can promise to develop not only scientific knowledge but, rather and can be more important, skills and attitudes towards science for Confucian heritage students. In this way, social constructivist approaches is considered as a possibility to improve and enhance primary science education in Confucian heritage culture.

Confucian Heritage Culture

Confucian heritage culture refers to settings influenced by Confucianism. The countries strongly influenced by Confucianism are Greater China, Taiwan, Korea, Japan, Vietnam, and Singapore. The features briefly characterising Confucian heritage culture are: (a) the collectivist root; (b) the harmony and stability preference as a cultural and human value; (c) the virtue focus; (d) the support of hierarchical order; (e) the family value; and (f) the emphasis on theoretical knowledge (Chapter 2).

Confucian heritage culture has been influential in teaching and learning, which was instigated to maintain a hierarchical distance, a rather low individualism and a high potential in the collectivist domain and in favour of long-term orientation (Hofstede et al., 2010). Lessons are traditionally dominated by a teacher-centred, book-centred method and an emphasis on rote memory (Liu & Littlewood, 1997) with little emphasis on critical thinking (Couchman, 1997); teaching is primarily one-sided in a one-way process: what the teacher says is right and the students are not entitled to ask about sense and purpose, to require reasons or to question the content (Chan, 1999); teachers avoid the use of the recommended group work and memorising of science facts is a frequent activity for students, who participate more frequently in passive and closed activities (Tao et al., 2013; Xiao, 2009).

The implementation of a social constructivist perspective in Confucian heritage culture has been considerably influenced by the culture, which can provide fostering but also hindering factors (Chapter 2).

The influences of Confucian heritage culture on the implementation of a social constructivist perspective in primary science education are summarised and presented in Table 2.

Table 2. Confucian heritage culture features (CHC features) and its influences on the SC implementation

CHC feature	Characterisation	Influence	
a. The collectivist root	1. The tradition of learning together	Fostering	
	2. The tradition of peer learning	Fostering	
	3. The tradition of pair grouping		Hindering
	4. The availability of learning contexts	Fostering	
b. The harmony and stability preference as a cultural and human value	1. The discount to rationality		Hindering
	2. The avoidance of argumentation and conflicts in discussions		Hindering
c. The virtue focus	1. Ritualistic behaviours (over) stressed		Hindering
	2. Personal interests of *I* is limited		Hindering
d. The support of hierarchical order	1. A superior teacher		Hindering
	2. The teacher considered as a parent who is never wrong		Hindering
e. The family value	1. Family considered as an initial learning cradle	Fostering	
	2. The parent considered as the teacher	Fostering	
f. The emphasis on theoretical knowledge	1. Knowledge in ancient classics considered as universally correct		Hindering
	2. The popular application of classics quoting and citing, and rote learning		Hindering

The hindering factors of Confucian heritage culture to the implementation of a social constructivist perspective in primary science education in Confucian heritage culture showed the three main divergences between Confucian heritage culture and Western educational philosophy (Chapter 2) as presented in the following.

(1) Confucian heritage culture emphasises stability and harmony among its human values, whereas Western educational philosophy

emphasises the rationality (Totten, Sills, Digby, & Russ, 1991) that supports argumentation and conflict in discussion and helps students be prepared for citizenship (Kolstø, 2001). In the "nature of science" education (Abd-El-Khalick & Lederman, 2000; Dekkers, 2006), conflicts and argumentation are preferred over harmony.

(2) Confucian heritage culture emphasises theoretical knowledge, considering "classical" knowledge and theory as universally correct, whereas Western educational philosophy emphasises empirical knowledge and well-substantiated scientific claims, believing that there is no complete truth and that every aspect of theoretical knowledge is changeable (Abd-El-Khalick & Lederman, 2000; Dekkers, 2006).

(3) Confucian heritage culture emphasises hierarchical order in which the teacher is considered superior and the transmitter of the body of knowledge to students, whereas Western educational philosophy emphasises equitability: the teacher is considered a more advanced learner (Vygotsky, 1978) who facilitates students to learn in order to achieve not only knowledge but also the skills and attitudes used to study science (Bybee, McCrae, & Laurie, 2009; Hofstede, 1986).

The above divergences were taken into consideration in designing a formal curriculum based on a social constructivist perspective for primary science education in Confucian heritage culture.

A Design-based Approach

To design a curriculum based on a social constructivist perspective for primary school science in Confucian heritage culture, a design-based approach (Bulte, Westbroek, De Jong, & Pilot, 2006; De Vos, Bulte, & Pilot, 2002) was applied, since it can provide a holistic development of the curriculum. In this design of a formal curriculum, a social constructivist perspective was utilised as the scaffolding idea or curriculum foundation, defined as an instructional theory from learning research (Gagne & Dick, 1983). It represents the *ideal curriculum* based on which the *formal curriculum* was designed that can lead to the corresponding *operational curriculum* in practice (Van den Akker, 2003). These three curriculum representations were defined by Van den Akker (2003) as follows:

(i) the ideal curriculum describes the original philosophy (rationale, vision and mission) of the designers of a curriculum;

(ii) the formal curriculum describes an elaboration of the ideal curriculum, presented in a written document and materials such as a curriculum guide;

(iii) the operational curriculum can be observed in the actual teaching and learning in the practice of the classroom.

In this study, the framework of curriculum design introduced by Meijer et al. (2008) was used. Accordingly, the design of a formal curriculum based on a social constructivist perspective was sub-divided into three parts interconnected with each other in a way that the former is the pre-requisite for the next one, including: learning aims, an instructional framework, and exemplary curriculum units.

Learning aims are necessary to provide a direction for designing an instructional framework with the alignment of four main components: learning phases, functions, learning settings, and educational expectations. They are strategic components which emerged from existing formal curricula of science education (Bulte et al., 2006; Bybee et al., 2006, Kortland, 2001; Lijnse, 1995; Lijnse & Klaassen, 2010). Functions, defined as instructional theories prescriptive in nature (Gagne & Dick, 1983) were set up for a transition between the learning phases and learning settings (Mettes, Pilot, & Roossink, 1981). In other words, they were aimed at providing a rationale for the determination of appropriate learning settings. In this study, learning setting is defined to comprise learning activities and learning forms that students take up to accomplish the task. Learning activities are a chain of actions which can be realised through operations (Prins, 2010). Learning form is defined as visible shape or organisation of learning that takes place in classroom practice, i.e. individually, in small groups, or in the class as a whole. The determination of learning activities and learning forms provide a strategic structure to shape corresponding science units for teaching in classroom practice. The determination of the learning settings leads to the establishment of educational expectations, which were defined as important predictors of educational attainment (Duncan et al., 1972). In this study, educational expectations are the link between the formal curriculum and the operational curriculum (Van den Akker, 2003), which is needed for a curriculum design since a design process often takes place in several cycles (Bulte et al., 2006). The operational curriculum can be observed in the actual teaching and learning through the enactment of science units in classroom practice and is needed for the evaluation of the formal curriculum. For that reason, educational expectations play an important role and are considered as hypotheses of what the curriculum is expected to bring about. The overview of the design-based approach of the study is presented in Figure 1.

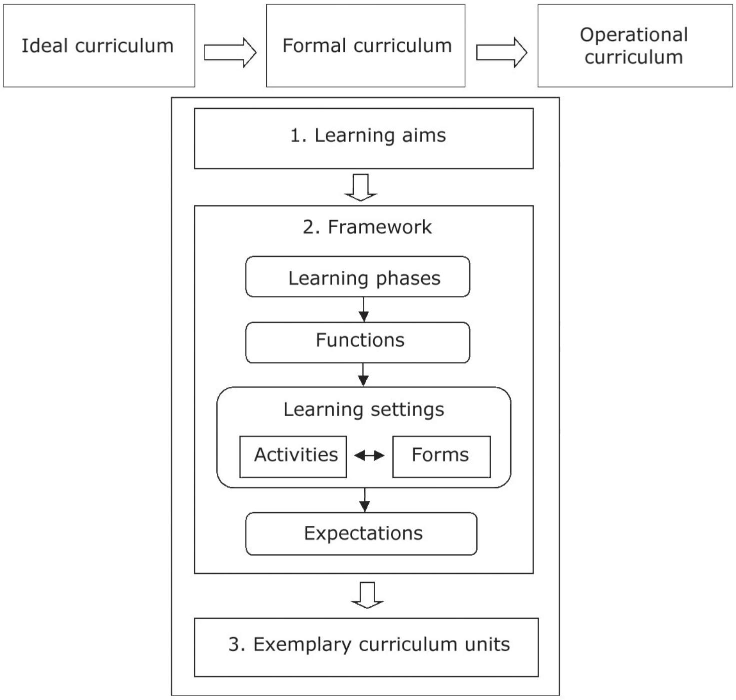


Figure 1. Overview of the design-based approach of the study

Designing the formal curriculum

This section describes the design of a formal curriculum based on a social constructivist perspective for primary science education in Confucian heritage that follows the design-based approach (Figure 1). The design was constructed with three parts: 1) learning aims, 2) the framework, and 3) exemplary curriculum units. Accordingly, learning aims regarding scientific knowledge, skills and attitudes were determined and this led to the establishment of a specific instructional framework. Based on the designed instructional framework of the formal curriculum, exemplary curriculum science units were correspondingly designed that were intended to be enacted in classroom practice in Confucian heritage culture in the next cycle of the design process.

1. Learning aims

The design of a social constructivism-based curriculum for primary science education in Confucian heritage culture aims to develop scientific skills, attitudes, and knowledge for students, as follows:

1. *Scientific skills*: observing, hypothesising, experimenting, reasoning, arguing, questioning, and applying
2. *Appropriate attitudes*: curiosity, interests in, and response to science
3. *Scientific knowledge* relevant to students' daily lives

The above learning aims are consistent with the goals of the social sciences that go with the constructivist principles as introduced by Sunal and Haas (2002) and with the ultimate goal of science education (Duschl et al., 2007). These learning aims also align with the goals of primary school education in Vietnam: to help students to know how to develop self-directed learning and to be cooperative in learning, to remain positive, active, and creative in finding and solving problems in order to master new knowledge (Hoan, 2002).

2. The framework

In the design of the formal curriculum, four learning phases were determined and labelled as Engagement, Experience, Exchange, and Follow-up, all of which were considered to explicitly reflect a social constructivist approach in teaching and learning. These learning phases are composed of the alignments of learning functions, learning settings and educational expectations. The designed instructional framework of the formal curriculum is summarised and presented in Table 3.

2.1. Phase 1 – Engagement

The word *Engagement* was chosen for this phase from various terms, such as: *orientation, attention, ice-breaking,* and *engagement*, which can be used to indicate the starting activity of learning. It was chosen because of its higher manifestation for a direct and active involvement of students. The phase *Engagement* has one main function: to provide students with a motivation to learn (*Function A*).

Motivation is defined as the force that arouses enthusiasm for and persistence in pursuing a certain course of action (Daft & Marcic, 2000). It is considered to affect students' participation in science classrooms and have consequences for the quality of their learning (Duschl et al., 2007; Ryan & Deci, 2000). Motivation is necessary for students to achieve the learning goals (Gagne & Medsher, 1996). Thank to learning motivation, communication between the teacher and students can flow smoothly, anxiety associated with learning decreases, and learning engagement is more evident (Wlodkowski, 1999).

Students can be motivated by using real-world problems and by letting them reconsider their own understanding in light of new experiences (Harkness et al., 2007). Therefore, in this phase, two activities are set up for students to do, including:

- Doing a small hands-on task with a relevant example related to scientific subject-matter (*Activity 1*)
- Answering *What*, *How*, and *Why* questions about a relevant example related to scientific subject-matter (*Activity 2*)

Hands-on tasks and relevant examples along with questions are considered to provoke in students emotional or personal information through which motivation can be aroused (Dick et al., 2001; Morrone et al., 2004). The activities in this phase are recommended to take place in learning forms which can stay rather flexible: in small groups and/or in the class as a whole (*Form 1*).

The function of learning motivation led to the educational expectation determined for this phase, that is: Students are interested in scientific subject-matter (*Expectation a*). This expectation means that students realise that they do not yet know enough to be able to explain the problem. Thus, students develop a content-related motive for further learning which is carried out in the next phases.

2.2. Phase 2 - Experience

The word *Experience* was chosen for this phase from various terms such as *exploration*, *experimentation*, *practice*, and *experience*, which all can refer to experimental and hands-on activities that are emphasized for students to carry out in this phase. It was selected because it better indicates experience-based activities as stressed by a social constructivist perspective. The phase *Experience* is determined to have four functions, including:

- To evoke attitudes toward science (*Function B*)
- To acquire procedural knowledge (*Function C*)
- To acquire conceptual knowledge (*Function D*)
- To acquire argumentative skills (*Function E*)

Science is not simply a body of knowledge. Skills and attitudes towards science play an important role in scientific literacy (Bybee et al., 2009). Science teaching needs to accomplish much more than simply detailing "what we know" but needs to educate students in "how we know" and "why we believe" (Drive et al., 1996; Driver et al., 1994; Millar & Osborne, 1998). Therefore, students should learn science with three aspects: knowledge, skills, and attitudes, by doing scientific activities like observing, describing, discussing, hypothesising, questioning, arguing, experimenting, following procedures, judging, evaluating, concluding, writing and reporting (Lemke, 1990). Such activities reflect methodical activities in the "nature of science" education (Abd-El-Khalick & Lederman, 2000) in which scientific argumentation is centred. In this phase, students are organised to work with representative examples of scientific subject-matter and do the following interrelated activities:

- Predicting: Observe and discuss in order to answer questions: *What do you observe? What will happen if…? Why do you think so?* (*Activity 3*)
- Hands-on: Do an experiment and discuss in order to answer questions: *What did you observe? How can you explain it? Why do you think so?* (*Activity 4*)
- Questioning: Formulate questions related to scientific subject-matter (*Activity 5*)

These activities are considered to support argumentation in science classes (Driver et al., 2000). The setting up of these activities in discussing tasks for this phase is consistent with constructivist teaching and learning strategies which place importance on student negotiations within small groups (Hand et al., 1997). Much of what a student learns is considered to come from their social interactions in the academic setting (Graves et al., 1999). In the process of attempting to answer the questions posed, students are recommended to work in groups so that they can use their own language to discuss the concepts being examined (Von Glaserfeld, 1989). Therefore, it is recommended that the activities in this phase take place in small groups (*Form 2*).

Based on the above learning functions and activities, four educational expectations were determined for this phase, including: students are curious about representative examples of scientific subject matter (*Expectation b*), students are active in learning about representative examples of scientific subject-matter (*Expectation c*), students use their intuitive knowledge to learn about scientific subject-matter (*Expectation* *d*), and students argue with each other to attain consensually agreed knowledge on representative examples of scientific subject-matter (*Expectation e*).

Curiosity is a basic spirit in science learning. When students are curious, they remain attentive and interested in learning. Curiosity generates actions to answer questions which lead to new questions (Minstrell & Van Zee, 2000). Science learning that which makes students curious become active participants and is exciting to students.

Intuitive knowledge plays an important role in science learning (Driver et al., 1998). It can provide beliefs, which are the source of biases because of having not been justified scientifically, but are attained by personal experiences. It enables students to respond quickly and often appropriately. These responses are raw, metaphorical, but primary sources need to be utilised to help students to construct their new knowledge (Watson, 2001).

Scientific argumentation contains personal aspects, referred to as the content of argument, and social aspects, and referred to as the argumentative interactions among participants (Driver et al., 2000; Duschl & Osborne, 2002). Through scientific argumentation, students can develop critical thinking and other skills, which are considered to be crucial for an individual, as implied in a metaphoric saying, which is attributed to Lao Tzu, *Give a man a fish and you feed him for a day, teach him how to catch a fish and you feed him for a lifetime*.

2.3. Phase 3 - Exchange

The word *Exchange* was chosen for this phase from various terms such as *presentation*, *discussion*, *explicitness*, *interpretation* and *exchange*. Compared to the other words, *exchange* better reflects social interactions that require oral activities, such as presenting, sharing, discussing, explaining, arguing, and negotiating, as the ones stressed by a social constructivist perspective. The functions in this phase are determined so as to build on the ones in the previous phase, *Experience*. Therefore, this phase is determined to have four functions, as follows:

- To build on attitudes toward science *(Function F)*
- To build on procedural knowledge *(Function G)*
- To build on conceptual knowledge *(Function H)*
- To build on argumentative skills *(Function I)*

Based on these functions, three learning activities, which are interconnected with the ones in phase *Experience*, are set up for students to do in this phase:

- Presenting results to other groups (*Activity 6*)
- Discussing results with other groups (*Activity 7*)
- Answering formulated questions related to scientific subject-matter (*Activity 8*)

According to Hand et al. (1997), social interactions among students should not be limited to small group discussion but extend to whole class settings (p.562). In addition, scientific argumentation on science requires students to negotiate meaning both publicly and privately (Hand, 2011). By presenting and discussing the results with other groups, which are the outcome of the inquiry activities in phase *Experience*, students can develop scientific argumentation, thereby acquiring a deeper and broader knowledge, skills, and attitudes towards science. These activities are recommended to take place in the class as a whole and/or in combined groups (*Form 3*).

Since science is about finding and justifying the best possible answers (Dekkers, 2006), this phase is determined to have two educational expectations, including: students are interactive in learning scientific subject-matter (*Expectation f*) and students argue with each other to attain consensually agreed knowledge on scientific subject-matter (*Expectation g*).

2.4. Phase 4 – Follow-Up

The word *Follow-up* was chosen for this phase from various terms such as *correction, reinforcement, application*, *transferring, reflection*, *connection,* and *follow-up* due to its higher manifestation for an open ending for science lessons to indicate that the science lessons should be continued and involved with other learning communities outside schools. This is supported by the social constructivist feature *Learning communities should be equitable and inclusive* (Table 1). This phase is determined to have two functions:

- To acquire cognitive flexibility (*Function J*)
- To further learning motivation (*Function K*)

Students must acquire flexibility in order to use their new knowledge effectively. Nurturing student motivation is important because it is a critical factor for the development and sustainability of self-regulated learning that helps students to become lifelong learners (Wolters, 2011).

It is acknowledged that cognitive flexibility and motivation can be gained through answering formulated questions or solving problems that involve the use of relevant knowledge. Motivation is also enhanced when students experience themselves as capable (Hammond et al., 2001). Therefore, in this phase, students are organised to do the activity: providing answers and/or solutions for new questions and/or problems related to scientific subject-matter (*Activity 9*). This activity is recommended for students to do in the class as a whole (*Form 4*).

With the function and the activities determined, this phase has two educational expectations: students can provide appropriate answers and/or solutions (*Expectation h*) and students show their desire to learn more about scientific subject-matter (*Expectation i*).

Summarising This section presents arguments for the design of a framework of a formal curriculum based on a social constructivist perspective with the alignment of the components: functions, learning settings, and educational expectations for the learning phases. The designed framework is summarised and presented in Table 3.

The above instructional framework shows features of a social constructivist perspective applied in the formal curriculum. The SC feature *Learning is social* (SC Feature 1, Table 1) underpins the organisation of learning forms of the class as a whole (Forms 1, 3 and 4, Table 3) and cooperative groups (Forms 1, 2 and 3, Table 3). The SC features *Knowledge is experience-based* and *Knowledge is constructed by learners* (SC Features 2 and 3, Table 1) underpin the application of cooperative and inquiry activities (Activity 1 thru' 9, Table 3) which are organised to take place in a spiral process. The SC feature *All aspects of a learner are connected* (SC Feature 4, Table 1) underpins the application of practical tasks (Activities 1 and 4, Table 3) which is considered to reveal students' attitudes, emotions, and actions in their learning. The SC feature *Learning communities should be inclusive and equitable* (SC Feature 5, Table 1) underpins the application of group learning with similar tasks for groups (Phase Experience, Table 3, Table 5) and the organisation of phase Follow-up which indicates an open-ended learning that supports students to continue their learning with other communities outside school (i.e. families).

3. Exemplary curriculum units

Criteria for the choosing of scientific themes

Due to particular characteristics of social constructivist teaching and learning and primary school students, some criteria are needed for the choosing of themes for science units that make them fit the designed framework of formal curriculum (Table 3). The three main criteria for the choosing of scientific themes are determined and expressed as follows:

a. Assessable. The position of the Zone of Proximal Development (Vygotsky, 1978) requires students to develop their knowledge based on their potential through social interactions. The scientific theme therefore should be neither too difficult, i.e. too complex or too abstract, that students are unable to understand it, nor too easy, i.e. too simple or nothing new, that they learn nothing new from it.

b. Relevant. The relevance of science (Meijer, 2011; Stuckey et al., 2013) can help students to find scientific knowledge interesting and meaningful that can potentially impact students' interests in science and have positive consequences for the students' life. By relating and connecting scientific knowledge to everyday life through science lesson, students can be motivated to learn actively.

c. Experimental. Experiments play an important role in science education (Kreitler & Kreitler, 1974). Science experiments can help students develop a way of thinking, of approaching problems, of investigating and evaluating evidence; students thereby learn not only scientific knowledge but also skills, and attitudes towards science. Primary students are acknowledged to concentrate more and be more curious in science learning, which provides them with interesting and feasible experiments. Such experiments can help them to learn science scientifically but also enjoyably, and therefore, students can be inspired to learn science.

Design of exemplary curriculum units

With the above criteria, many curriculum units can be designed with appropriately chosen themes. This study was carried out in Vietnam; therefore, lessons of curriculum units should be adaptable to the practice of science classrooms in Vietnam. To make Vietnamese primary teacher and students who are used to traditional teaching and learning methods as influenced by Confucian heritage culture (Chapter 2), accommodate to the innovative formal curriculum, more than one curriculum unit is needed. When more than one Confucian heritage teacher teaches more than one curriculum unit, teachers can learn

Table 3. The designed framework of the social constructivism-based curriculum for primary science education in Confucian heritage culture

PHASE	FUNCTION	LEARNING SETTING		EDUCATIONAL EXPECTATIONS
		Activity	Form	
Engagement	A. To provide students with a motivation to learn	1. Doing a small hands-on task with a relevant example related to scientific subject-matter 2. Answering *What*, *How*, and *Why* questions about a relevant example related to scientific subject-matter	1. In small groups and/or in the class as a whole	a. Students are interested in scientific subject-matter
Experience	B. To evoke attitudes towards science C. To acquire procedural knowledge D. To acquire conceptual knowledge E. To acquire argumentative skills	3. Predicting: Observe and discuss in order to answer questions: *What do you observe? What will happen if…? Why do you think so?* 4. Hands-on: Do experiment and discuss in order to answer questions: *What did you observe? How can you explain it? Why do you think so?* 5. Questioning: Formulate questions related to scientific subject-matter	2. In small groups	b. Students are curious about representative examples of scientific subject-matter c. Students are active in learning about representative examples of scientific subject-matter d. Students use their intuitive knowledge to learn about scientific subject-matter e. Students argue with each other to attain consensually agreed knowledge on representative examples of scientific subject-matter

PHASE	FUNCTION	LEARNING SETTING		EDUCATIONAL EXPECTATIONS
		Activity	Form	
Exchange	F. To build on attitudes towards science G. To build on procedural knowledge H. To build on conceptual knowledge I. To build on argumentative skills	6. Presenting results to other groups 7. Discussing results with other groups 8. Answering formulated questions related to scientific subject-matter	3. In the class as a whole and/or in combined groups	f. Students are interactive in learning scientific subject-matter g. Students argue with each other to attain consensually agreed knowledge on scientific subject-matter
Follow-up	J. To acquire cognitive flexibility K. To further learning motivation	9. Providing answers and/or solutions for new questions and/or problems related to scientific subject-matter	4. In the class as a whole	h. Students can provide appropriate answers and/or solutions i. Students show their desire to learn more about scientific subject-matter

from each other, as in accordance with a social constructivist perspective. Therefore, the designed formal curriculum can be evaluated for its feasibility to primary science education in Confucian heritage culture.

Vietnamese teachers are restricted by institutional constraint of time and workload and cannot be involved in a long-term action research. Thereby, three curriculum units were designed, which aim to illustrate the designed framework (Table 3) and which could be taught in the practice of science classrooms in Vietnam in the next step of the study. Three scientific themes, air pressure, plant roots, and CO_2 reaction, were selected to design exemplary curriculum units. These scientific themes came from science websites and scientists. These themes were planned to be taught for primary students at age 10. The extent to which these themes meet the criteria for the choosing of themes is presented in Table 4.

Table 4. The selected themes meeting the determined criteria

Theme	Assessable	Relevant (in example)	Experimental
Air pressure	Air has its movements and can be compressed.	Wind is air in motion	Pressing two connected cylinders
Plant root	- Plant root systems have different types, i.e. fibrous system and taproot systems with many variations. These types of root systems have different characteristics. - Plant root systems have different functions, i.e. anchorage in soil, storage of energy resources, absorption of water and minerals from the soil, and conduction of water and minerals to and from the shoot, and vegetative reproduction.	Most of the plants need to be watered to stay alive	Interacting with real plants to learn about root systems
CO_2 reaction	- Soft drinks contain Carbon dioxide, which is compressed, i.e. Coca Cola and Pepsi, and in Mentos. - Carbon dioxide compressed in coke and Mentos will be released when Mentos is put into coke and reacts with the carbon dioxide creating a bubble fountain.	Eating Mentos and drinking coke at the same time can make the human mouth hurt	Putting Mentos into Coca Cola bottle

With these chosen scientific themes, three corresponding curriculum units were designed using the curriculum framework (Table 3). These exemplary curriculum units were designed with specific learning activities for each of the phases and are presented in Table 5.

The Appropriateness of the Curriculum Design to Confucian Heritage Culture

The designed formal curriculum presented in this study is expected to be applicable in Confucian heritage culture. It refers to cultural traditions and Confucian thoughts in Confucian heritage countries. On the one hand, Confucianism may have negative influences on contemporary society and education (Doãn, 1999; Đạm, 1994). In this sense, Confucian thoughts are ideal rather than practical. On the other hand, Confucianism may have positive aspects within society and education but has often been misinterpreted in practice. In this study, positive aspects and a re-interpretation of Confucianism are employed to argue for the applicability of the designed formal curriculum based on a social constructivist perspective.

The designed formal curriculum is expected to develop learning motivations in students (Function A, Table 3). This is consistent with Confucian heritage culture wherein learning motivation is important. Confucius' statement *I do learning for myself, for my own dignity, not to show off for others* (Lê, 1992) is inferred to stress intrinsic learning motivation. As a teacher, Confucius expected his students to have a desire to learn, to think for themselves, and not to act without knowing why. Traditionally, individuals in Confucian heritage culture were encouraged to become as knowledgeable as possible, as in a style of *a full knower [trên thông thiên văn dưới tường địa lí].* This traditional learning motivation was rather about *learning to know*. Today learning motivation has been changed and shifted to those influenced by globalisation. As in the current primary school curriculum in Vietnam, the motivations of *learning to know, learning to do, learning to live together, learning to be*, as integrated into the educational goals determined by UNESCO, are stressed in raising and nurturing students (Hoan, 2002).

The designed curriculum places importance on the application of small groups and/or the class as a whole and this is considered to be supported by the collectivist root of a Confucian heritage culture with the traditions of learning together and peer learning (CHC Feature a1 and a2, Table 2).

Experience-based learning applied in the designed curriculum is considered to be consistent with Confucius' thoughts about the method called *individual-oriented instruction [nhân tài thi giáo]* (Lê, 1992).

Table 5. The design of exemplary curriculum units

Phase	Unit Air Pressure	Unit Plant Roots	Unit CO_2 Reaction
Engagement	1. Answering: *What will happen if we blow air into the inflated balloon? Why do you think so? What will happen if the inflated balloon is released at once? Why do you think so?* 2. Blowing air into the inflated balloon and releasing it, and answering: *What happened? How can you explain what was observed?*	1. Drawing a complete plant 2. Answering: *What did you draw? Why did you draw the plant roots like that? How did you know it?*	1. Answering: *What will happen if we blow air through a straw into a water bottle? Why do you think so?* 2. Blowing air through a straw into a water bottle and answering: *What happened? How can you explain what was observed?*
Experience	3. Predicting (Exercise 1): Connect two cylinders by a plastic tube. Discuss with peers and answer the following questions: a. *What will happen if one cylinder is pressed down?* b. *Why do you think so?* 4. Hands-on (Exercise 2): Press one of the connected cylinders down. Discuss in the group an answer to the following questions: a. *What did you observe?*	3. Predicting (Exercise 1): Choose a wild plant in the school garden to observe. Discuss in the group the answers to the following questions: a. *What do you think the plant root looks like? Draw it.* b. *Why do you think so?* 4. Hands-on (Exercise 2): Pull out the wild plant in the school garden. Discuss in the group the answers to the following questions: a. *What does the plant root system look like? Draw it.*	3. Predicting (Exercise 1): Given a Coca Cola bottle and Mentos. Discuss in your group the answer to the following questions: a. *What will happen if all Mentos are dropped into the coke bottle?* b. *Why do you think so?* 4. Hands-on (Exercise 2): Drop all the Mentos into the coke bottle. Discuss in the group the answers to the following questions:

Experience	b. *How can you explain what was observed?* 5. Questioning (Exercise 3): Write down questions or ideas related to the subject-matter that you want to discuss.	b. *Why does this plant have a root system like that?* c. *What are the functions of the plant root system? Why do you think so?* 5. Questioning (Exercise 3): Write down questions or ideas related to the subject matter that you want to discuss.	a. *What did you observe*? b. *Why did it happen*? 5. Questioning (Exercise 3): Write down questions or ideas related to the subject-matter that you want to discuss.
Exchange	6. Presenting results to other groups 7. Discussing results with other groups 8. Answering formulated questions related to subject matter.	6. Presenting results to other groups 7. Discussing results with other groups 8. Answering formulated questions related to subject matter.	6. Presenting results to other groups 7. Discussing results with other groups 8. Answering formulated questions related to subject matter.
Follow-up	9. Answering the questions: *What did you learn from the lesson today? Can you provide some examples related to air pressure and explain why you think what you do about them? How can you relate this knowledge to a natural phenomenon, for example, the wind?*	9.a. Answering questions: *What did you learn from the lesson today? Can you provide some examples of root types and explain why you think those plants have such root types?* *9.b. Determining types of root for some plants.*	9. Answering questions: *What did you learn from the lesson today? Can you provide some examples of carbon dioxide reaction and explain why you think what you do about them?*

This teaching method is about teaching and learning that derived from learners in their distinctions to go to lessons, to nurture and develop the learners' strength, and to limit the learners' weakness. According to Confucius, the teacher role was not providing the knowledge mechanically to students but guiding them to obtain the path of finding knowledge (Lê, 1992). The emphasis on experience for learning is also encouraged by Confucius, as in his statement: *"I hear and I forget, I see and I remember, I do and I understand."* The well-known dogma of Confucius, *Revise the old to make sense of the new [Ôn cố nhi tri tân]*, is traditionally interpreted to value ancient classical works and support rote-learning. It is re-interpreted here with a meaning that fits with a social constructivist perspective: using prior knowledge and experiences (*the old*) to construct new knowledge (*the new*). The value to experience-based learning is lively illustrated by Confucius, who spent years as a globe-trotter to learn about human life and world affairs. In Vietnam, experience-based learning is appreciated and indicated in various idioms, i.e. *Travel for a day, gain a lot of wisdom [Đi một ngày đàng học một sàng khôn]; Get knowledge by learning, get learning by experiencing [Có học mới hay, có cày mới biết]*.

The designed curriculum utilises question-asking (Activity 5) as a way to support social interactions among students. Question-asking was largely used by Confucius in his life as a teacher, who often encouraged the students to engage in discussion and use questioning for their learning (Lê, 1992). In Vietnam, question-asking is traditionally stressed for learning, as expressed in the idiom: *To know, you have to ask questions/To be good, you have to learn [muốn biết phải hỏi, muốn giỏi phải học].* The Vietnamese compound verb *học hỏi* is a combination of the verb *học [learn]* and the verb *hỏi [question]*. This compound verb can be interpreted with different meanings, i.e. to indicate an action of learning beyond curiosity, learning of questioning and learning by questioning. With all the meanings, it shows the role of questioning is stressed in learning.

The possibility of the involvement of families in student learning, as manifested through the open-ending of the designed curriculum, is supported by the family value of Confucian heritage culture (CHC Feature e, Table 2). In addition, emphasizing the importance of cognitive flexibility in the designed curriculum suits Confucian heritage culture where learning is emphasized to develop cognitive flexibility. This is illustrated by the Confucian metaphoric statement: *Reading the*

Shih Ching book three hundred times but neither being able to do government jobs when entrusted with them nor being able to deal with troubles when ordered to act as an envoy, what is your learning worth? (The Shih Ching, whose writing is attributed to Confucius, is a compilation of documentary records related to ancient historic events in China) *[Tụng thi tam bách, thụ chi dĩ chính bất đạt, sứ ư tứ phương, bất năng chuyên đối, tuy đa diệc hề dĩ vi]* (Lê, 1992). Confucius himself appreciated students who could go further within the subject-matter beyond what was taught (Lê, 1992). In Vietnam, cognitive flexibility from learning is stressed in folklore. The idioms: *Learn one, know ten [Học một biết mười]*; *Learning alongside practicing [học đi đôi với hành]* are popularly used in current daily life to indicate the significance of cognitive flexibility from learning. The mission of the contemporary schooling education in Vietnam is training students to become citizens who have the skills and flexibility to cope with and adapt to the rapid changes of modern life (Hoan, 2002).

Addressing Problems in Primary Science Education in Confucian Heritage Culture

The employment of small groups and the class as a whole for student learning in this curriculum design is used to avoid the employment of pair grouping (CHC Feature a3, Table 2) as in traditional lessons in which this student asked a written question and the other one reproduced answers with a low interaction between them (Chapter 2). The utilisation of cooperative inquiry activities, as manifested by the organisation of predicting and experimental tasks and discussing activities (Phase Experience, Table 3), is aimed at promoting empirical knowledge, social interactions and scientific argumentation. This is considered to reduce the negative influence of the harmony and stability preference and the virtue focus of Confucian heritage culture (CHC Feature b and Feature c, Table 2) that made students to avoid argumentation and conflicts in discussions (Chapter 2). The employment of cooperative inquiry tasks is also considered to limit rote learning, as influenced by the traditional emphasis on theoretical knowledge (CHC Feature f, Table 2) that supports transmission and reproduction in teaching and learning (Chapter 2). In addition, the employment of group works and discussion for students is aimed at promoting equitable interactions in classroom practice, thus the support for the hierarchical order of Confucian heritage culture (CHC Feature d, Table 2), is expected to be limited.

Discussion

This study originated from the problems found in the analysis of the implementation of a social constructivist perspective in primary science education in Confucian heritage culture (Chapter 2). It has provided a description of a detailed design of a formal curriculum based on a social constructivist perspective for primary science education in Confucian heritage culture. In this study, an instructional framework of the formal curriculum (Table 3) and outlines for curriculum units (Table 5) have been developed using knowledge of the "nature of science" education and Confucian heritage culture. In this way, the designed formal curriculum can help Confucian heritage students be "more adequately prepared for their lives as citizens when they are afforded a fuller understanding of the nature of this thing called science" (McComas et al., 1998, p. 528). It is a needs-based curriculum (Coll & Taylor, 2012) for Vietnam where students are expected to become future labours well-equipped with knowledge, skills, and attitudes to cope with the challenges and changes of modern life (Hoan, 2002). Taking into consideration the cultural divergences between Confucian heritage culture and Western educational philosophy and applying Western educational ideas, the design is also a response to a call for interactive teaching strategies for "culture broking" in science education (Jegede & Aikenhead, 1999) to teach Western science in non-Western contexts.

In addition, with the detailed design with a specific framework, this study can reduce gaps between the formal curriculum, the operational and the attained curriculum that can exist with abstract designs of curricula. Moreover, this study provides curriculum units that can be applied in the practice of science classrooms in Confucian heritage culture, i.e. in Vietnam. These science units are different from those of the conventional primary school science in Vietnam (Chapter 2) and considered to provide possibilities to have learning outcomes that are more promising.

Nevertheless, the study still has certain limitations. Due to the scope of the study of the design of the formal curriculum, the study focuses on formative assessments, as presented in the educational expectations (Table 3). Issues of summative assessment are not dealt with in this designed formal curriculum. Since the interrelation between the formal curriculum and the attained curriculum (Van den Akker, 2003), the summative assessment of learning corresponding with the designed curriculum is necessary and needs to be studied in further research.

To apply this design to the practice of primary science education in Confucian heritage culture, the role of the teachers is crucial, since they are considered as the most influential factors in educational change (Duffee & Aikenhead, 1992; Fullan, 1991). Many studies show that teachers' actions in classrooms are largely determined by their knowledge and beliefs about teaching and learning (Barnett & Hodson, 2001; Loughran et al., 2004; Van Driel et al., 1998). Teachers frequently do not implement curriculum materials that contradict their ideas about content and how this content should be taught (Cotton, 2006). Therefore, the application of this design in Confucian heritage culture requires a teacher professional development programme.

A programme of teacher professional development should help Confucian heritage teachers to improve content knowledge of science (i.e. knowledge of air pressure, plant roots, and CO_2 reaction) and pedagogical knowledge of a social constructivist perspective. The design will only address current curriculum problems when Confucian heritage teachers accept a social constructivist perspective for science education. This can make them change from traditional teaching to a social constructivist approach. Without the teachers' acceptance of a social constructivist perspective and without the necessary changes in the practice of science teaching, the application of the design leads to the state of "*a new vase, and old wine" [bình mới rượu cũ]*. There is a need for the evaluation of the design in a next step of research. Providing a concrete design (formal curriculum), this study is first stage in contributing to the development of a knowledge base for designing a social constructivism-based curriculum for primary school science in Confucian heritage culture.

Acknowledgements

The researchers wish to thank Koos Kortland and Hanno van Keulen (both in Utrecht University) for their supportive contributions to the designing of learning phases and science units of the formal curriculum.

References

Abd-El-Khalick, F., & Lederman, N. G. (2000). Improving science teachers' conceptions of nature of science: A critical review of the literature. *International Journal of Science Education*, *22*(7), 665–701.

Anderson, C.W. (2007). Perspectives on science learning. In S.K. Abell & N.G. Lederman (Eds), *Handbook of research on science education* (pp. 3-30). Oxford, England: Taylor & Francis.

Anderson, R.D. (2007). Inquiry as an organizing theme for science curricula. In S.K. Abell & N.G. Lederman (Eds), *Handbook of research on science education* (pp. 807–830). Oxford, England: Taylor & Francis.

Barnett, J. & Hodson, D. (2001). Pedagogical context knowledge: Toward a fuller understanding of what a good science teacher knows. *Science Education, 85*(4), 426–453.

Beck, C. & Kosnik, C. (2006). *Innovations in teacher education – A social constructivist approach*. New York: State University of New York Press.

Benson, G. D. (2001). Science Education from a social constructivist position: A worldview. *Studies in Philosophy and Education*, 20, 443–452.

Biggs, J. (1996). Western misperceptions of the Confucian-heritage learning culture. In D. Watkins & J. Biggs (Eds), *The Chinese learner: Cultural, psychological and contextual influences* (pp. 45–67). Hong Kong: The University of Hong Kong Comparative Education Research Centre.

Bulte, A.M.W., Westbroek, H.B., De Jong, O., & Pilot, A. (2006). A research approach to designing chemistry education using authentic practices as contexts. *International Journal of Science Education, 28*(9), 1063–1086.

Bybee, R., McCrae, B., & Laurie, R. (2009). PISA 2006: An assessment of scientific literacy. *Journal of Research in Science Teaching*, *46*(8), 865–883.

Bybee, R., Taylor, J., Gardner, A., Van Scotter, P., Powell, J.C., Westbrook, A., & Landes, N. (2006). *The BSCS 5E instructional model: Origins, effectiveness, and applications*. Colorado Springs, CO: BSCS.

Chan, S. (1999). The Chinese learning – A question of style. *Education and Training*, *41*(6/7), 294–304.

Cobern, W.W. (Ed.) (1998). *Socio-cultural perspectives on science education: An international dialogue*. Dordrecht: Kluwer.

Coll, R.K., & Taylor, N. (2012). An international perspective on science curriculum development and implementation. In B. J. Fraser, K. G. Tobin, & C. J. McRobbie (Eds), *Second international handbook of science education* (Vol. II, pp. 771–782). Dordrecht: Springer.

Cotton, D.R.E. (2006). Implementing curriculum guidance on environmental education: The importance of teachers' beliefs. *Journal of Curriculum Studies*, *36*, 67–83.

Couchman, J. (1997) Making sense: Cross-cultural variation in the organisation of academic texts by Taiwanese and Australian undergraduate students. In Z. Golebiowski & H. Borland (Eds.), *Academic communication across disciplines and cultures* (pp. 64–76). Melbourne: Victoria University of Technology.

Daft, R.L., & Marcic, D. (2000). *Understanding management* (3rd Ed.). Orlando: Harcourt College Publishers.

De Vos, W., Bulte, A.M.W., & Pilot, A. (2002). Chemistry curricular for general education: Analysis and elements of a design. In J.K. Gilberts, O. De Jong, R. Justu, D.F. Treagust, & J.H. Van Driel (Eds), *Chemical Education: Towards research based practice* (pp. 101–124). Dordrecht,: Kluwer.

Dekkers, P. (2006). Reconstructing the creature – Exploring design criteria for teaching NOS. In E.V. Den Berg, T. Ellermeijer, & O. Stooten (Eds.). *Modelling in Physics and Physics Education* (pp.459–464), Proceedings of Conference. Amsterdam: University of Amsterdam.

Dick, W., Carey, L., & Carey, J.O. (2001). *The systematic design of instruction* (5th ed.). New York, NY: Longman.

Doãn, P.Đ. (1999). *Một số vấn đề về Nho giáo Việt Nam* [*Some issues on Vietnamese Confucianism*]. Hanoi, Vietnam: Publishing House of National Politics.

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher*, *23*(7), 5–12.

Driver, R., Guesne, E., & Tiberghien, A. (1998). *Children's ideas in science*. Milton Keynes: Open University Press.

Driver, R., Leach, J., Millar, R., & Scott, P. (1996). *Young people's images of science*. Milton Keynes: Open University Press.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms, *Science Education, 84*, 287–312.

Duffee, L., & Aikenhead, G. (1992). Curriculum change, student evaluation, and teacher practical knowledge. *Science Education, 76*, 493–506.

Duit, R., & Treagust, D. (1998). Learning in science – From behaviorism towards social constructivism and beyond. In B. L. Fraser & K. G. Tobin (Eds), *International Handbook of Science Education* (pp. 3–25). Dordrecht, the Netherlands: Kluwer Academic.

Duncan, O. D., Featherman, D.L., & Duncan, B. (1972). *Socioeconomic background and achievement.* New York, NY: Seminar Press

Duschl, R. A., & Osborne, J. (2002). Supporting and promoting argumentation discourse in science education. *Studies in Science Education*, *38*, 39–72.

Duschl, R.A., Schweingruber, H.A., & Shouse, A.W. (Eds.) (2007). *Taking science to school – Learning and teaching science in grades K-8.* Washington, D.C.: National Research Council of the National Academies; The National Academies Press.

Đạm, Q. (1994). *Nho giáo xưa và nay* [*Confucianism: past and present*]. Hanoi: Culture Publisher.

Fullan, M.G. (1991). *The new meaning of educational change*, 2nd ed., New York, NY: Teachers College Press.

Gagne, R.M., & Dick, W. (1983). Instructional psychology. *Annual Review of Psychology*, *34*, 261–295.

Gagne, R.M., & Medsher, K.L. (1996). *The condition of learning: Training application.* Fort Worth, TX: Harcourt Brace College Publishers.

Graves, M.F., Watts-Taffe, S.M., & Graves, B.B. (1999). *Essentials of elementary reading.* Boston, MA: Allyn and Bacon.

Guzzetti, B.J., Snyder, T.E., Glass, G.V., & Gamas, W.S. (1993). Promoting conceptual change in science: A comparative meta-analysis of instructional interventions from reading education and science education. *Reading Research Quarterly*, *28*(2), 117–155.

Hammond, L-D., Austin, K., Orcutt, S., & Rosso, J. (2001). *How people learn: Introduction to learning theories.* Stanford University. Retrieved from http://www.stanford.edu/class/ed269/hplintrochapter.pdf

Hand, B. (2011). An immersion approach to argument-based inquiry – Does it look the same in different countries? In Y. Kim, J. Park, H.E. Seo, J.A. Lee, & J. Kim (Eds), *Proceedings of the 2011 EASE International Conference – Lighting the world with science* (pp.45-54). Gwangju: The University of Chosun.

Hand, B., Treagust, D.F., & Vance, K. (1997). Student perceptions of the social constructivist classroom. *Science Education*, *81*(5), 561–474.

Harkness, S.S., Morrone, A.S., & D'Ambrosio, B. (2007). Pre-service elementary teachers' voices describe how their teacher motivated them to do mathematics. *Educational Studies in Mathematics, 65*(2), 235–254.

Hoan, Đ.Đ. (2002). *Một số vấn đề* cơ b*ản của chương trình tiểu học mới* [*Some basic issues of the new primary curricula*]. Hanoi: Education Publisher.

Hofstede, G. (1986). Cultural difference in teaching and learning. *International Journal of Intercultural relations*, *10*, 301–320.

Hofstede, G., Hofstede, G.J., & Minkov, M. (2010). *Cultures and organizations: Software of the mind: Intercultural cooperation and its importance for survival* (3rd ed.). New York, NY: McGraw-Hill.

Jedege, O. J. & Aikenhead, G. S. (1999). Transcending cultural borders: Implications for science teaching. *Journal for Science & Technology Education, 17*(1), 45–66.

Kolstø, S. D. (2001). Scientific literacy for citizenship: tools for dealing with the science dimension of controversial socioscientific issues. *Science Education*, *85*, 291–310.

Kortland, J. (2001). *A problem-posing approach to teaching decision making about the waste issue*. Utrecht: CDBeta Press.

Kortland, K. & Klaassen, K. (Eds) (2010). *Designing theory-based teaching-learning sequences for science education*. Proceedings of the symposium in honour of Piet Lijnse at the time of his retirement as Professor of Physics Didactics at Utrecht University. Utrecht University: FISME.

Krajcik, J., McNeill, K.L., & Reiser, B. (2008). Learning-goals-driven design model: Developing curriculum materials that align with national standards and incorporate project-based pedagogy. *Science Education, 92*(1), 1–32.

Kreitler, H., & Kreitler, S. (1974). The role of the experiment in science education. *Instructional Science*, *3*, 75–88.

Ku, H.Y., & Lohr, L.L. (2003). A case study of Chinese students' attitudes toward their first online learning experience. *Educational Technology Research and Development, 51*(3), 94–102.

Lemke, J. (1990). *Talking Science: Language, Learning, and Values.* Norwood, NJ: Ablex.

Lê, N. H. (1992). *Khổng Tử [Confucius].* Hanoi: Culture Publisher.

Lijnse, P.L. (1995). "Developmental research" as a way to an empirically based "didactical structure" of science. *Science Education, 79*, 189–199.

Lijnse, P. & Klaassen, K. (2010). Didactical structures as an outcome of research on teaching-learning sequences? In Koos Kortland & Kees Klaassen (Eds), *Designing theory-based teaching-learning sequences for science education*. Utrecht: Faculty of Science. Utrecht University.

Liu, N.F., & Littlewood, W. (1997). Why do many students appear reluctant to participate in classroom learning discourse? *System*, *25*(3), 371–384.

Loughran, J., Mulhall, P., & Berry, A. (2004). In search of pedagogical content knowledge in science: Developing ways of articulating and documenting professional practice. *Journal of Research in Science Teaching*, *41*(4), 370–391.

McComas, W.F., Almazroa, H., & Clough, M. (1998). The nature of science in science education: An introduction. *Science and Education*, *7*, 511–532.

Meijer, M. (2011). Macro-meso-micro thinking with structure-property relations for chemistry education: An explorative design-based study (Unpublished doctoral dissertation). Utrecht University.

Meijer, M. R.; Prins, G. T.; Bulte, A. M. W. ; & Pilot, A. (2008). *Method of Educational Design-Based Research in science education: Why and How?*. Paper presented at the 19th Dortmund Symposium on Chemical Education, Dortmund, 22-24 May 2008.

Mettes, C.T.C.W., Pilot, A., & Roossink, J.H. (1981). Linking factual knowledge and procedural knowledge in solving science problems:

A case study in a thermodynamics course. *Instructional Science*, *10*, 333–361.
Millar, R., & Osborne, J.F. (Eds). (1998). *Beyond 2000: Science education for the future*. London: King's College London.
Minstrell, J. & Van Zee, E.H. (Eds) (2000). *Inquiring into inquiry learning and teaching in science.* Washington, D.C.: American Association for the Advancement of Science.
Morrone, A.S., Harkness, S.S., D'Ambrosio, B., & Caulfield, R. (2004). Patterns of instructional discourse that promote the perception of mastery goals in a social constructivist mathematics course. *Educational Studies in Mathematics, 56,* 19–38.
Nentwig, P.M., Demuth, R., Parchmann, I., Grasel, C., & Ralle, B. (2007). Chemie im kontext: Situating learning in relevant contexts while systemactically developing basic chemical concepts. *Journal of Chemical Education, 84*(9), 1439–1444.
Neuman, Y., & Bekerman, Z. (2000). Cultural resources and the gap between educational theory and practice. *Teachers College Record, 103*(3), 471–484.
Prins, G. (2010). Teaching and learning of modelling in chemistry education: Authentic practices as contexts for learning (Unpublished doctoral dissertation). Utrecht University.
Ryan, R.M. & Deci, L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, *55*(1), 68–78.
Stuckey, M, Mamlok-Naaman, R., Hofstein, A., & Eilks, I. (2013). The meaning of 'relevance' in science education and its implications for the science curriculum. *Studies in Science Education*, *34,* 1–34.
Sunal, S.C. & Haas, M.E. (2002). *Social studies for the elementary and middle grades. A constructivist approach.* Boston, MA: Allyn and Bacon.
Tao, Y., Oliver, M., & Venville, G. (2013). A comparison of approaches to the teaching and learning of science in Chinese and Australian elementary classrooms: Cultural and socioeconomic complexities. *Journal of Research in Science Teaching*, *50*(1), 33–61.
Tobin, K.G. (1993). *The practice of constructivism in science education*. Washington, D.C.: AAAS.
Totten, S., Sills, T., Digby, A., & Russ, P. (1991). *Cooperative learning: A guide to research*. New York, NY: Garland.
Van den Akker, J.J.H. (2003). Curriculum perspectives: An introduction. In J.J.H. Van den Akker, W. Kuiper, & U. Hameyer (Eds), *Curriculum landscape and trends* (pp.1–10). Dordrecht, the Netherlands:Kluwer Academic.

Van Driel, J.H., Verloop, N., & De Vos, W. (1998). Developing science teachers' pedagogical content knowledge. *Journal of Research in Science Teaching*, *35*(6), 673–695.

Von Glasersfeld, E. (1989). Cognition, construction of knowledge and teaching. *Synthese, 80*, 121–140.

Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Watson, J. (2001). Social constructivism in the classroom. *Support for Learning*, *16*(3), 140–147.

Wlodkowski, R. J. (1999). *Enhancing adult motivation to learn* (Rev. ed.). San Francisco, CA: Jossey-Bass.

Wolters, C. (2011). Regulation of motivation: Contextual and social aspects. *Teacher's College Record, 113*, 265–283.

Xiao, L. (2009). What can we learn from a learning needs analysis of Chinese English majors in a university context? *Asian EFL Journal, 8*(4), 74–79.

Chapter 1. Introduction and Research Overview

What is the design of curriculum for primary science education that has social constructivist characteristics and is appropriate with Confucian heritage culture?

PROBLEM ANALYSIS

Chapter 2. The implementation of a social constructivist perspective in primary science education in Confucian heritage culture: the case of Vietnam

RQ1. To what extent is a social constructivist perspective implemented in primary science education in Confucian heritage culture?
RQ2. How can this implementation be explained from a Confucian cultural perspective and what are fostering and hindering cultural factors to the implementation?

DESIGN CYCLE 1

Chapter 3. Designing a formal curriculum based on a social constructivist perspective for primary science education in Confucian heritage culture

RQ. What is the design of formal curriculum for primary science education that has social constructivist characteristics and is appropriate with Confucian heritage culture?

Chapter 4. Teacher professional development: The interaction of Confucian heritage teachers with a social constructivism-based curriculum for primary science education

RQ. In what way do Confucian heritage teachers interact with a primary science curriculum, which is based on a social constructivist perspective and made appropriate with Confucian heritage culture, in a program of professional development?

Chapter 5. Scientific argumentation as bottleneck for implementing a social constructivism-based science curriculum in Confucian heritage culture

RQ. To what extent does the unit of the curriculum design for primary science education in Confucian heritage culture meet the social constructivist expectations in the practice of the classroom?

DESIGN CYCLE 2

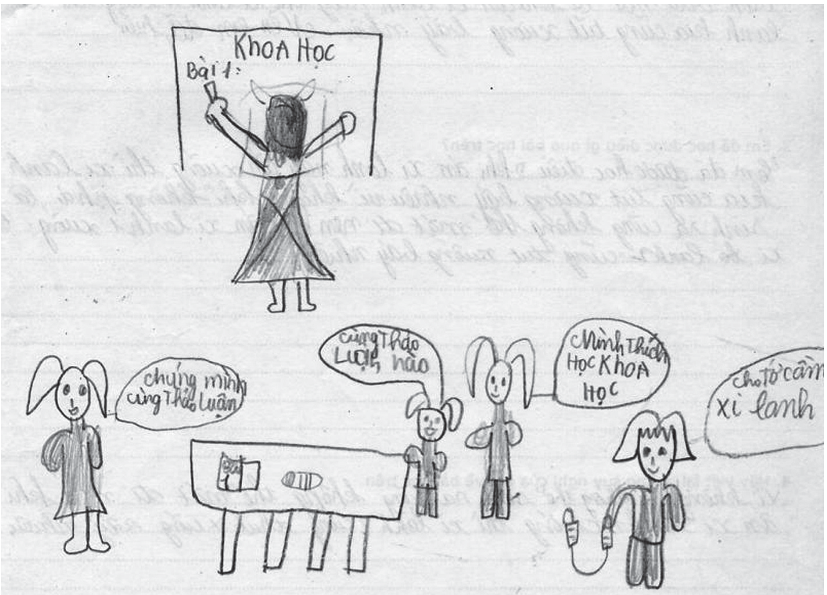
Chapter 6. Improving scientific argumentation through a social constructivism-based curriculum for primary science education in Confucian heritage culture

RQ1. To what extent does the unit of the adjusted design of social constructivism-based curriculum for primary science education in Confucian heritage culture support students to practice scientific argumentation in a science lesson?
RQ2. To what extent does the unit of the adjusted design of social constructivism-based curriculum for primary science education in Confucian heritage culture support students to attain consensually agreed knowledge on scientific subject-matter?

Chapter 7. Conclusions, Reflection and Recommendations

RQ. What is the design of curriculum for primary science education that has social constructivist characteristics and is appropriate with Confucian heritage culture?

CHAPTER 4 Teacher Professional Development: The Interaction of Confucian Heritage Teachers with a Social Constructivism-Based Curriculum for Primary Science Education[1]



[2]

Abstract This study aims to determine and describe the perception of a social constructivist approach to teaching among Confucian heritage teachers and the changes these teachers undergo through interaction with a new science curriculum designed according to such an approach. A framework of teacher professional development combining state-of-the-art knowledge on professional development and knowledge on curriculum design was adapted and applied to the establishment of learning communities with a facilitator and the teachers as critical co-designers. Through the spiral approach of the development programme, the Confucian heritage teachers changed from a traditional way of teaching to a more social constructivist way of teaching. The teachers proposed concrete teaching activities that can be applied to the design of the curriculum to make it a better teaching guideline. The teachers perceived challenges in the application of the newly designed science curriculum based on a social constructivist perspective to primary science education within Confucian heritage culture. This study aims at the possibility of improving the curriculum design and emphasises the need to facilitate teacher application of the designed curriculum, in which the roles of teacher input and professional development are stressed.

1 This chapter is submitted as: Hằng, N. V. T., Bulte, A. M. W., & Pilot, A. *Teacher Professional Development: The Interaction of Confucian Heritage Teachers with a Social Constructivism-Based Curriculum for Primary Science Education.*

2 A drawing of an experimental science lesson made by a participating student in this study

Introduction

Despite having been increasingly applied in Western science education since the 1980s, social constructivism (Beck & Kosnik, 2006), with its characteristics consistent with an inquiry-based approach emphasised by the "nature of science" education (Abd-El-Khalick & Lederman, 2000; Anderson, 2007), is challenging to implement in Confucian heritage culture (see Kang et al., 2007; Kim & Tan, 2011; Lee et al., 2000; Tao et al., 2013). Our previous study carried out in Vietnam revealed that teaching and learning of science in Confucian heritage culture maintains a traditional approach in which the teacher is the central authority and students are passive in constructing and grasping knowledge (Chapter 2). It is considered difficult to apply a constructivist approach to a community in which students have taken a passive role in receiving data (Neuman & Bekerman, 2000).

Confucian heritage culture has considerably influenced the implementation of a social constructivist perspective in primary science education in Confucian heritage countries (Chapter 2). It provides both hindering and fostering factors, with the hindering factors related to cultural divergences between Confucian heritage culture (CHC) and Western educational philosophy which includes both the "nature of science" education and a social constructivist perspective (Chapter 2). CHC emphasises theoretical knowledge, hierarchy, stability, and harmony among its cultural and human values and almost overlooks the significance of rationality and empirical knowledge. A social constructivist perspective and the "nature of science," however, place importance on the equitability, empirical knowledge, and rationality that support and encourage critical thinking and scientific argumentation (Abd-El-Khalick & Lederman, 2000; Beck & Kosnik, 2006; Osborne, 1996). Without an acknowledgement of the cultural divergences and cultural contexts, the application of Western constructivist theories to Confucian heritage culture can create practical difficulties (Serpell, 1997) and a false universalism (Nguyen et al., 2009).

In order to address the problems of primary science education and the cultural divergences as revealed in Chapter 2, a curriculum based on a social constructivist perspective was designed, taking characteristics of CHC into consideration (Chapter 3). The social constructivism-based curriculum design follows a learning structure and refers to the "nature of science" education. Using the curriculum framework, science curriculum units were designed for the practice of teaching and learning (Chapter 3).

It is stressed in this study that teachers are the most influential factors in educational change (Duffee & Aikenhead, 1992; Fullan, 1991) and curriculum implementation needs to be accompanied by teacher professional development (Coll & Taylor, 2012). Therefore, to apply the designed curriculum to the practice of science classes, a programme of professional development for Confucian heritage teachers was carried out. The programme was intended to help teachers accommodate and adapt to the ideas of the designed curriculum. In this way, they could teach the science lessons (operational curriculum; Van den Akker, 2003), which is a necessary process for evaluating the designed formal curriculum (Bulte et al., 2006).

This study, as a part of a broader design-based research project on designing a social constructivism-based curriculum for primary science education in CHC, focuses on the interaction of Confucian heritage teachers with a newly designed science curriculum. Thereby, this study is considered to fill the lack of scientific research on teacher professional development within the application of a social constructivist perspective in Confucian heritage culture.

Teacher Professional Development and a Social Constructivism-Based Science Curriculum

Teacher development can be defined as the professional growth a teacher achieves as a result of gaining increased experience (Glatthorn, 1995). When a new curriculum is drawn up by specialists, it is left to the teachers to accommodate their knowledge, skills, and attitudes (Guskey, 2002) in accordance with the new curriculum demands (Coenders, 2010). Teacher professional development is often considered to produce a change in the teacher, which is seen as a complex process (Clarke & Hollingsworth, 2002). Changes in teachers can occur in practice, as shown by changes in their attitudes and teaching activities. Changes also can occur in teachers' perceptions and beliefs about teaching and learning (Coenders, 2010). Many studies show that the actions of teachers in the classroom are largely determined by their knowledge about teaching and learning (Loughran et al., 2004; Van Driel et al., 1998). They frequently do not implement curriculum materials that contradict their own ideas about content and how this content should be taught (Cotton, 2006; Gees-Newsome, 1999). To induce changes in teachers, a professional development programme needs to help teachers feel sufficiently confident to apply their new knowledge and skills in practice (Stolk et al., 2011).

A social constructivist perspective has led to a new paradigm of teacher professional development (Le Cornu & Peters, 2005), and has influenced teacher professional development through changes in the concepts of both teacher and teaching. In a social constructivist perspective, teaching is about asking questions and negotiating (Hand et al. 1997). According to Beck and Kosnik (2006), key features of a social constructivist perspective on learning are: 1) Learning is social; 2) Knowledge is experience-based; 3) Knowledge is constructed by learners; 4) All aspects of a person are connected; and 5) Learning communities should be inclusive and equitable. These features were the foundational ideas in designing a formal curriculum of primary school science that took into consideration the cultural divergences between Confucian heritage culture and Western educational philosophy (Chapter 3). A curriculum framework with four learning phases was selected; these were labelled *Engagement*, *Experience*, *Exchange*, and *Follow-up* (APPENDIX A). Based on the framework, three curriculum units were designed (APPENDIX B).

In a social constructivist perspective, the teacher fosters a culture in the classroom that supports critical and productive inquiry, and teaching is made a more attractive and respected profession (Beck & Kosnik, 2006). Social constructivist teaching and learning is considered a passionate approach, involving the whole person: thought, emotion, and action (Beck & Kosnik, 2006, p.8). The situation is different with the traditional teaching and learning style in CHC, which is acknowledged to be primarily one-sided in a one-way process: what the teacher says is right and the students are not entitled to ask about sense and purpose, to require reasons, or to question the content (Chan, 1999); teachers avoid the use of recommended group work and memorising science facts is a frequent activity for students, who participate more frequently in passive and closed activities (Tao et al., 2013); rote memory is emphasised (Liu & Littlewood, 1997) with little attention to critical thinking (Couchman, 1997); teaching and learning are textbook-based and teacher-centred with science lessons focussed on factual knowledge, personal aspects of students discounted, and hierarchical interactions is the norm (Chapter 2). The basic characteristics of a social constructivist teacher (Brooks & Brooks, 1993; Le Cornu & Peters, 2005; Watson, 2001) and a Confucian heritage teacher are synthesised and presented in Table 1.

Table 1. Basic characteristics of a social constructivist teacher and of a traditional CHC teacher

Category	Item	Social constructivist teacher	Traditional CHC teacher
1. Attitude	a	Being open-minded	Tending to be closed-minded by teaching for "correct" answers
	b	Being friendly	Maintaining a superior role
2. Activity	a	Encouraging students to engage in inquiry	Not encouraging students to engage in inquiry
	b	Providing time and space for students to carry out self-regulated learning	Imposing knowledge on students
	c	Promoting social interactions among students	Adhering to one-way teacher-student interaction
	d	Seeking elaboration of students' initial responses	Asking for single answers

In the characteristics of a social constructivist teacher, open-mindedness is an attitude prerequisite for teaching (Dewey, 1933). It is defined as an active desire to listen to more than one side or perspective on an issue. In this study, open-mindedness is perceived as teachers' not judging students' answers based on a standard of "correct or incorrect," but in a neutral way, accepting students' initiatives and metaphors, allowing students' responses to determine the direction of lessons and shift instructional strategies, and encouraging students to ask questions (Brooks & Brooks, 1993; Watson, 2001). In addition, it is used to indicate flexibility in teaching with regard to teacher roles and material use (Anderson, 1996).

Friendliness is a necessary attitude for a social constructivist teacher, who is considered an *advanced learner* (Vygotsky, 1978) who facilitates students' learning by negotiating (Hand et al. 1997), rather than a person who transmits factual knowledge to students as *empty vases*. In this sense, the friendliness in teaching attitudes is also supported by the feature of equitable learning communities in a social constructivist perspective (Beck & Kosnik, 2006). In this study, the teacher attitude of friendliness is perceived as a loosely-controlled learning environment that teachers create to support students' involvement in learning freely and enthusiastically.

The teaching activities of a) encouraging students to engage in inquiry, b) providing time and space for students to carry out self-regulated learning, c) promoting social interaction among students, and d) seeking elaboration of students' initial responses (Category 2, Table 1) reflect the neutral roles of a social constructivist teacher as an encourager, a facilitator, and a coach for student learning (Anderson, 1996). Along with the characteristics of attitudes, the characteristics of the activities of the social constructivist teacher are considered as necessary for the implementation of the designed formal curriculum in science classrooms in Confucian heritage culture.

Research Question

Based on the above arguments, this study aims to answer the following research question:

In a programme of professional development, how do Confucian heritage teachers interact with a primary science curriculum that is based on a social constructivist perspective and made appropriate for Confucian heritage culture?

To answer this research question, three sub-questions were formulated:

1. What changes are there in the attitudes and activities of Confucian heritage teachers in classroom practices through their interaction with the designed curriculum?
2. In what ways do Confucian heritage teachers perceive the designed curriculum?
3. What do Confucian heritage teachers perceive as major challenges to the implementation of the designed curriculum?

Research Strategy

Setting up a programme of teacher professional development

The programme of teacher professional development was adapted from a framework for empowering teachers to teach innovative units (Dolfing, 2013; Stolk et al., 2012). Accordingly, three main phases were chosen as follows.

Phase 1 - Preparation for teaching the designed curriculum units. This phase has four functions:

(a) Connect to the views of individual teachers on a social constructivist approach to science education.

(b) Let teachers discover differences and similarities between their views on the social constructivism-based curriculum and curriculum units and their views on their conventional curriculum.

(c) Let teachers explore strategies for teaching the social constructivism-based curriculum units.

(d) Provide an opportunity for teachers to elaborate their specific teaching activities for the new curriculum units and co-design science lessons.

Phase 2 - Teaching and observing the science lessons. This phase has a single function:

(e) Provide teachers with an opportunity to apply knowledge of the designed formal curriculum to classroom practice and to acquire practical knowledge of the designed curriculum.

Phase 3 - Reflection on teaching activities and effects on students. This phase has two functions:

(f) Give teachers an opportunity to reflect on their teaching experiences.

(g) Evaluate the designed curriculum in terms of supporting the learning of science.

These phases were carried out in a spiral process in which iterative sub-phases were accomplished, creating a weave of professional development (Figure 1). This programme combined state-of-the-art knowledge on professional development and design knowledge on curriculum frameworks and units. The framework presented in Figure 1 can be considered a synthesis between professional development and curriculum design (Bulte et al., 2006; Meijer, 2011; Prins, 2010). In this programme of teacher professional development, knowledge of the establishment of learning communities with a facilitator (the researcher) and the teachers as critical co-designers (Agung, 2013) was also adapted and applied. The spiral approach in which the three teachers changed sequence so that each teacher was able to teach a first lesson in a unit (Figure 1) balanced the pattern of hierarchy between participants. This is also consistent with a social constructivist approach which emphasises equitability (Beck & Kosnik, 2006).

Three Vietnamese primary teachers were selected for the professional development programme by the researcher through a survey study (Chapter 2) and were considered competent in teaching. These teachers (Table 2) were willing to experience new methods of teaching with the designed curriculum and were stimulated by the supportive attitude of the administrative school board.

Table 2. Participating teachers

Teacher	Age	Experience (in years)	Class (in charge)	Class size	Student age
T1	38	18	A	31	10
T2	36	16	B	24	10
T3	30	8	C	27	10

The study is situated in Vietnam, a country which has been deeply influenced by Confucian heritage culture (Đạm, 1994). All of the participating teachers come from a public primary school in Bacninh, a small urban area located in the North of Vietnam. The school has been applying a centralised science curriculum and has remained traditional in the teaching and learning of science. Although Vietnam is officially divided into three main parts, including the North, the Middle, and the South, this school is considered representative of other primary schools in Vietnam.

The three units (APPENDIX B) were taught by the participating teachers. In total, nine lessons were prepared and co-designed, taught and observed, and, finally, discussed. The programme of professional teacher development took place within a period of six months with twelve face-to-face meetings (Figure 1), and ten communications by emails via internet.

Data Collection

A qualitative methodology was applied in this study. Three main data sources were employed: classroom observations, students' feedback through questionnaires and interviews, and post-lesson discussions with the teachers. Each of the data sources is described in detail below.

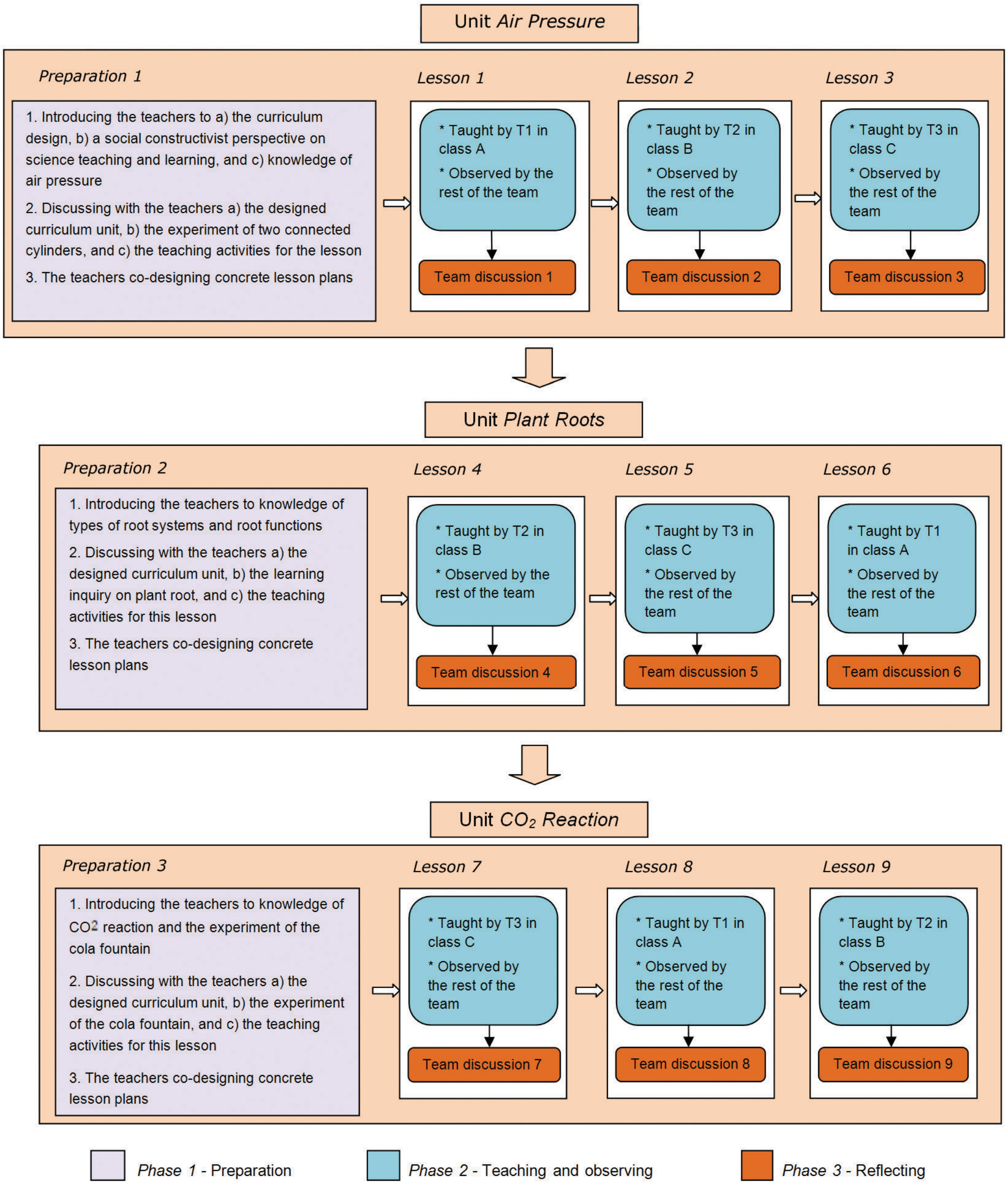


Figure 1. The framework of the programme of professional development (in relation to Table 2)

A. Classroom observations

Classroom observations were considered to provide visible findings on the changes in teachers and their approaches that occurred in classroom practice. Classroom observations were carried out by the researcher and the teachers who did not teach the lesson. All of the observers were required to take field notes during the observations. The themes for classroom observations were established and provided for the teachers through the following questions:

1. What do you think about the lesson? Why?
2. What do you think about the teacher's practice in this lesson? Why?
3. What do you think about the students' learning in this lesson? Why?

Video and voice recordings were utilised for all of the observed lessons. A camera was located at a convenient place in each classroom to gain the best overview of the lesson. All of the video tapes were watched carefully and transcribed verbatim.

B. Student questionnaires

Questionnaires were employed to help the researcher reach a large population of the students who could provide their reflections on the experimental lessons. The questionnaires comprised the following questions:

1. To what extent do you like the lesson? Why?
2. Is the lesson different from or similar to your conventional science lessons? Please specify differences or similarities.
3. What do you think about the three lessons you were involved in? Compare them to your conventional science lessons.
4. What is the lesson you like most among the three lessons you were involved in? Why?

The first and second questions were administrated after every lesson, while the third and fourth questions were administrated only after the teaching of all of the lessons. The first and fourth questions used Likert scales, whereas the second and third questions were open-ended.

C. Student interviews

The interviews took place to help the researcher and the teachers obtain elaborative feedback from the students. Thereby, changes in teachers could be recognised more explicitly. To do that, semi-structured interviews were organised with students who were selected randomly by the researcher after each of the lessons. In these interviews, the questions used in the questionnaire surveys were used and elaborated based on the initial answers of the students. The students were often encouraged to provide specific examples for ideas regarding the changes they noticed in their teachers. The interviews with students took place face to face individually or in groups of three to five students. All of the interviews were voice recorded and transcribed verbatim.

D. Post-lesson discussions with the teachers

The post-lesson discussions with the teachers aimed to provide the teachers with opportunities to discover differences and similarities between the social constructivism-based science lessons and the science lessons they usually taught. The discussions helped the researcher discover changes in the teachers' perceptions about science teaching and learning.

All of the teachers were involved in face-to-face discussions after every lesson when the themes of classroom observations were elaborated under the guidance of the researcher. The teachers were encouraged to feel free to share personal opinions and evaluate the designed curriculum and the experimental lessons. Based on their answers for the overall questions (the themes of the classroom observations), the teachers were gradually encouraged to zoom in on, analyse, and evaluate teaching and learning discourses in detail. Two key issues in the analysis and evaluation of the lessons and teaching discussed with the teachers are expressed in the following questions:

1. Are the students socially interactive in learning in the lesson? To what extent are they interactive during each of the phases? If to a small extent, what should be changed in the lesson design? And what should the teacher do in the next lessons to improve students' social interactions?
2. Do the students construct knowledge by themselves? To what extent do they construct knowledge? If to a small extent, what should be changed in the design of the lesson? And what should the teacher do in the next lessons to improve students' construction of knowledge?

All of the discussions with the teachers were audiotaped and transcribed verbatim.

Table 3. Reports on the experimental lessons (in relation to Figure 1)

Report	Achievements	Shortcomings/Problems
Lesson 1	Students were active and excited in doing hands-on activities	Students were passive in oral communications with the teacher, who transmitted knowledge rather than helping the students construct knowledge
Lesson 2	Students were active in cooperative tasks	Knowledge was sometimes imposed on students by the teacher
Lesson 3	The teacher was effective in developing elaborative questions	The one-way interaction from teacher to students was rather dominant
Lesson 4	The lesson was developed naturally and the students enjoyed the lesson	The students were still passive and static in learning in the Exchange phase
Lesson 5	The students were enthusiastic in learning, especially in the Experience phase	The teaching and learning in the Exchange phase did not lead to the active participation of the students
Lesson 6	The interaction between students became dominant in the lesson and the students were highly enthusiastic in learning	The teacher was rather confused in dealing with some of the students' answers
Lesson 7	The teacher was notably effective in creating elaborative questions to help the students construct knowledge	Scientific argumentation in students' discussions was still limited
Lesson 8	The students were engaged in the experiment and excited about learning	Scientific argumentation in students' discussions was still limited
Lesson 9	Teaching activities were arranged to correspond smoothly to each of the phases	The students were not provided with enough guidance to be effective in answering some of the teacher's questions when the students had to apply their knowledge to a new problem

Both students' feedback (from the questionnaires and interviews) and the knowledge the teachers agreed upon in the post-lesson discussions were summarised in single reports by the researcher and regularly sent to the teachers before the next lesson. In total, nine reports were made (Table 3) and structured based on the following elements:

a. *General evaluations* about the recent lesson, which were categorised in two groups: achievements and shortcomings or problems. Students' reflections on the lesson were embedded in a summary or in quotations.

b. *Consensually agreed suggestions* for the design and teaching activities to apply in the next lessons.

c. *Additional literature* on social constructivist teaching and learning (e.g., Beck & Kosnik, 2006) and/or the "nature of science" education (e.g., Abd-El-Khalick & Lederman, 2000).

The brief summaries (elements a and b) of the nine reports are presented in Table 3.

In addition, the teachers were encouraged to explore more of the content knowledge regarding air pressure, plant roots, and CO_2 reaction by contacting other science teachers and using the internet.

Data Analysis

To answer the first research sub-question – *What changes are there in the attitudes and activities of Confucian heritage teachers in classroom practices through their interaction with the designed curriculum?* – the characteristics of a social constructivist teacher and a traditional CHC teacher presented in Table 1 were used as organising elements to characterise the teachers' changes in practices. The characteristics of the teachers in teaching the experimental lessons were compared to those of a social constructivist teacher and to those of a traditional Confucian heritage teacher (Table 1). This characterisation was primarily determined by classroom observations (Source A) and was triangulated with data from the student questionnaires (Source B) and the student interviews (Source C). The characterisation of changes in teachers' attitudes and activities in the experimental lessons was first created by the researcher. Then it was sent to the participating teachers to verify and come to an agreement among the members of the team. After that, the characterisation was discussed thoroughly with a second researcher (supervisor) several times. Later, it was discussed and validated again in the entire research group before reaching final consensus. These discussions provided opportunities to cross-check and validate data (Creswell, 2009).

To answer the second research sub-question – *In what ways do Confucian heritage teachers perceive the designed curriculum?* – critical ideas with high consensus that emerged from the post-lesson discussions with the teachers (Source D) and show their perception of the designed curriculum were used as main themes for clustering the arguments. Three themes emerged:

1. The designed curriculum brings more benefits for students than the conventional science curriculum does.
2. The designed curriculum helps reconceptualise the teaching and learning of science.
3. The designed curriculum needs to have a formulation of teacher activities corresponding with each of the phases.

To analyse data, several steps were carried out. The first data analysis was accomplished by the researcher. The results of the initial analysis were then discussed with a second researcher to come to the first consensus on the findings. Afterward, these findings were discussed in the entire research group to come to the final consensus on findings.

To answer the third research sub-question – *What do Confucian heritage teachers perceive as major challenges to the implementation of the designed curriculum?* – the data source of discussions with the teachers (Source D) was employed again. Teachers' ideas regarding the challenges of applying the designed curriculum in practice that achieved a high consensus were remarked and described. The challenges perceived by the teachers are presented in two categories: teacher challenges and institutional challenges. Themes for challenges emerged from the discussions with the teachers. With respect to the challenges for the teachers, the teachers identified three major challenges for the application of the designed curriculum: a) the influences of habits and traditional teaching and learning methods, b) the need for deep understanding of scientific content knowledge, and c) the difficulty of teaching and learning social argumentations. With respect to the challenges for the institution, they again identified three major challenges: a) the issue of time, b) the measurement of learning results, and c) the difficulty involved in making systemic changes.

To analyse data for answering the third sub-question, several steps, as in answering the second research sub-question, were applied again. In this way, a thick description of the perception of Confucian heritage primary teachers regarding the designed curriculum and its challenges was provided.

Findings

The findings are presented below according to the three aforementioned sub-questions.

1. Changes in teachers' attitudes and activities (sub-research question 1)

Changes in teachers' attitudes and activities regarding social constructivist teaching were gradually implemented in the experimental lessons. These changes did not always consistently move toward social constructivist teaching over the course of the experimental lessons. Sometimes, the changes did not occur in the later experimental lessons although they had already occurred in the previous lessons. Overall, however, changes in teachers' attitudes and activities toward social constructivist teaching did take place. The changes in attitudes and activities of Confucian heritage teachers during their interaction with the designed curriculum are summarised and presented in Table 4.

As seen in Table 4, a few aspects of social constructivism came to the fore in the first three lessons. The changes were moderate in Lessons 4 and 5, which could be considered as the middle lessons in the transition from traditional Confucian heritage teaching to social constructivist teaching. The teachers' changes became significant in the last four lessons. The changes in teachers' attitudes and activities are described below in more detail.

1.1. Changes in teachers' attitudes

1.1.a. Being open-minded

In the first three experimental lessons, the teachers judged students' answers based on a "correct or incorrect" standard (Source A). Specifically, many times they used words such as *right*, *correct*, *incorrect*, or *false* to assess students' answers (Source A). These direct assessing words were used less in Lessons 4 and 5 (Source A), and they were not used at all by the teachers in the last four lessons (Source A). Rather, in these lessons, more neutral assessing words and expressions were used by the teachers to assess the answers of the students, such as *properly*, *interesting*, and *it sounds plausible* (Source A).

The students reported about the open-mindedness of the teachers in the last four experimental lessons. For instance, the interviewed students of Lesson 6 acknowledged that their teacher had been more tender, humorous and easy-going in her teaching (Source C). According

Table 4. Changes in attitudes and activities of the Confucian heritage teachers

Category	Item (see Table 1)	Unit Air Pressure			Unit Plant Roots			Unit CO_2 Reaction		
		Lesson 1 (T1)	Lesson 2 (T2)	Lesson 3 (T3)	Lesson 4 (T2)	Lesson 5 (T3)	Lesson 6 (T1)	Lesson 7 (T3)	Lesson 8 (T1)	Lesson 9 (T2)
1. Attitude	a	Closed-minded	Closed-minded	Closed-minded	Closed-/ Open-minded	Closed-/ Open-minded	Open-minded	Open-minded	Open-minded	Open-minded
	b	Superior role	Superior role	Superior role	Superior role	Friendly/ Superior role	Friendly	Friendly	Friendly/ Superior role	Friendly
2. Activity	a	Encouraging inquiry	Encouraging inquiry	Encouraging inquiry	Encouraging inquiry	Encouraging inquiry	Encouraging inquiry	Encouraging inquiry	Encouraging inquiry	Encouraging inquiry
	b	Imposing knowledge	Imposing knowledge	Imposing knowledge	Self-regulated learning/ Imposing knowledge	Self-regulated learning/ Imposing knowledge	Self-Regulated learning	Self-Regulated learning	Self-Regulated learning/ Imposing knowledge	Self-Regulated learning
	c	Mixed	Mixed	Adhering to one-way interactions	Mixed	Mixed	Promoting social interactions	Promoting social interactions	Promoting social interactions	Promoting social interactions
	d	Asking for single answers	Asking for single answers	Seeking elaborative answers	Mixed	Mixed	Seeking elaborative answers	Seeking elaborative answers	Seeking elaborative answers	Seeking elaborative answers

to them, they had been encouraged by the teacher to speak their thoughts freely in order to answer questions asked by the teacher and their peers. Hence, many "funny-sounding" words and expressions had been pronounced by them in the experimental lesson, such as the root system of grass having been compared to *thinly shredded meat* (Source C). They acknowledged that such a "funny-sounding" expression would not have been accepted by the teacher in their conventional science lessons; therefore, they would have avoided this in their conventional lessons (Source C).

The teachers' open-mindedness could also be confirmed in the students' answers to the questionnaires of the last four experimental lessons (Source B), as illustrated by the quotation below:

> I like the lesson today because I was more self-confident and volunteered to pose ideas.… I see that my peers posed ideas and discussed more than in our usual science lessons. (Student Quynh about Lesson 7; Source B)

The above quotation shows that the students were more engaged and more active in the experimental lesson than in their conventional lessons. This learning characteristic could have been supported by the teachers' open-mindedness that could well have provided students with more confidence and opportunities to assume ownership in their learning.

1.1.b. Being friendly

In the first four experimental lessons, the teachers maintained a superior role in their communication with the students (Source A). Though the students were highly active and enthusiastic in the Engagement and Experience phases, they were passive and static in the Exchange phase (Source A). The superior role adopted by the teachers remained moderate in Lessons 4, 5, and 8 (Source A). The teachers showed an explicitly friendly attitude in Lessons 6, 7, and 9 (Source A). This was recognised in the students' answers in the questionnaires and in the interviews while reflecting on the lessons (Sources B and C), as in the following quotations:

> The teacher was gentler than in the usual lessons. She did not reprimand us at all when we provided wrong answers. (Student Cuong about lesson 6; Source C)

> Today the teacher spoke and questioned softly and in a friendly manner. (Student Linh about Lesson 7; Source B).

The students' characterisations of their teachers' discourses as *gentle*, *not reprimanding students for wrong answers*, and *speaking and questioning softly* in their communications with the students represented the friendly attitude that the teachers demonstrated in the later experimental lessons.

1.2. Changes in teachers' activities

1.2.a. Encouraging students to engage in inquiry

In all nine of the lessons, inquiry activities were encouraged by the teachers (Source A). The students were provided with hands-on cooperative tasks and the teachers often asked the students to reason and explain their ideas (Source A). In their reflection on the experimental lessons, the students acknowledged that they were more active and enthusiastic in learning and explained that they were provided opportunities to engage in and carry out experiments and group discussions (Sources B and C). They stressed that these activities were absent in their conventional science lessons; this made the experimental lessons completely different compared to the conventional science lessons (Sources B and C). The teachers' encouragement of inquiry on the part of students can be found in the following quotations:

> The lesson was wonderful because it made me feel like a scientist. (Student Chien about Lesson 6; Source B)

> Great! We did experiments. We discussed with each other; spoke out what we thought. (Student Thong after three lessons; Source B)

The students' quoted expressions, such as *feel like a scientist*, *we did experiments*, and *discussed with each other* show that inquiry activities were organised and encouraging for students.

1.2.b. Providing time and space for self-regulated learning

In the first three experimental lessons, the teachers did not provide time and space for self-regulated learning in the inquiry tasks of the Experience phase (Source A). The teachers reached student groups and provided them with guidance and questions right after they delivered the cooperative inquiry tasks (Source A). The teachers in Lessons 4, 5, and 8 provided a bit more time and space for self-regulated learning in the Experience phase (Source A). This had changed considerably in Lessons 6, 7, and 9 (Source A). In these lessons, the teachers' roles as a learning observer and a supervisor were adopted after the teachers delivered the cooperative inquiry tasks to the students but before the teachers provided student groups with instructional interventions. In this way, the students had time and space to discuss and explore scientific subject matter using their prior knowledge and experiences (Source A). This can be recognised in the students' reflections on the lesson (Source C), as in the quotation below:

> I find this lesson freer than the usual science lessons. (Student Ha about Lesson 6; Source C)

The *freer* nature of the lesson mentioned by this student to characterise her feelings about the lesson may indicate the autonomy and ownership that the students assumed in the lesson.

1.2.c. Promoting social interactions among students

Generally, social interactions among the students were not very frequent in the first five experimental lessons, especially in Lesson 3, in which one-way interaction from teacher to students was dominant (Source A). Social interactions among students were promoted in the last four experimental lessons, especially in Lesson 6, in which the students were more active in discussions than were the students in the other lessons (Source A). The students in these lessons acknowledged and highlighted the cooperative learning organised in the lessons (Sources B and C).

> The lesson was very interesting. My peers were very noisy and enthusiastic. They provided many ideas. (Student Lan about Lesson 6; Source B)

> I see Duc Anh changed a lot in the lesson today. He rarely posed his ideas in the usual lessons. Normally, he sat quietly and listened to the teacher and his peers. However, today he was very enthusiastic in posing his ideas and had many initiatives for our group. (Student Chi about Lesson 9; Source C).

The learning characteristics mentioned in the above quotations, along with the specific example of a student (Duc Anh) who had changed toward a more interactive way of learning, show that social interactions were promoted by the teachers in those experimental lessons.

1.2.d. Seeking elaboration of students' initial responses

In the first two lessons, the teachers provided the students with single questions rather than elaborative questions developed from students' initial responses (Source A). Elaborative questions developed from students' initial responses were used much more in Lessons 4 and 5 (Source A). The teachers' search for elaborative answers was shown explicitly in Lesson 3 and in the last four experimental lessons (Source A). For instance:

1	Teacher T3	What did you observe?
2	Student Ly	When the first cylinder was pressed down, the air pushed the connected second cylinder up.
3	Teacher T3	Why did that happen?
4	Student Ly	Because the first cylinder pushed the air down and made the second one jut out.
5	Teacher T3	What do you mean by "the air"?
6	Student Manh	The air in the cylinders.
7	Teacher T3	How did the air do that?
8	Student Manh	It was pushed down and made the cylinder go out.
9	Teacher T3	Who can explain it more explicitly?
10	Students	(No answer)
11	Teacher T3	Let's observe! (Doing the experiment). When I pushed the first cylinder down, do you think the amount of air in the cylinders changed?
12	Student Cuong	No, it didn't change.
13	Teacher T3	It didn't change, did it? So how does it work?
14	Student Cuong	It was kept in.
15	Student Ly	It was hardened.
16	Student Thao	It was compressed down.
17	Teacher T3	Good! The air was compressed down and what else?
18	Student Thao	It created air pressure that made the other cylinder go up.
19	Teacher T3	So… what does it mean? What do you learn from this?
20	Student Vy	Air can be compressed down or … expanded.
21	Student Hung	Air can create pressure.

As recognised in the above conversation between teacher T3 and her students in Lesson 3 (Source A), the teacher's questions were often developed from the students' initial answers. This indicates that the teacher sought elaboration of the students' answers and gradually developed the thinking of the students in the lesson about air pressure.

This was also confirmed by the students' reflections on the lesson (Sources B and C), as in the quotation below.

> Normally the teacher teaches very quickly but today she taught very thoroughly. (Student Thai about Lesson 8; Source C)

In summary, traditional Confucian heritage teaching remained dominant in the first three experimental lessons. The change from more traditional teaching to constructivist teaching occurred in Lessons 4 and 5. Social constructivist teaching was more explicit in the last four experimental lessons.

2. Perceptions of Confucian heritage teachers regarding the designed curriculum (sub-research question 2)

The teachers' perceptions of the designed curriculum are clustered in the three emerging themes: 1) the designed curriculum brings more benefits for students than the conventional science curriculum does; 2) the designed curriculum helps reconceptualise the teaching and learning of science; and 3) the designed curriculum needs to have a formulation of teacher activities corresponding with each of the phases.

2.1. Students' benefits

The teachers acknowledged differences between the designed curriculum and the conventional science curriculum. According to them, the designed curriculum could bring more benefits for primary students, as detailed in the following quotations:

> I see differences in teaching and learning between the two curricula. Within the current teaching methods applied in our conventional curriculum, what the teacher says can be "Silent!", "Quiet!", "Don't speak freely!" But with teaching and learning according to this curriculum, students are very free to pose ideas. (T1, Team discussion 6)

> According to conventional lessons, students have to remember a body of knowledge; the difference with these lessons is that students have the opportunity to remember knowledge and can remember it for a longer time. (T1, Team discussion 9)

The teachers affirmed that the students in the experimental lessons were more active than in their conventional science lessons. They acknowledged that the students were more curious, excited, and active in learning.

2.2. Reconceptualising science teaching and learning

According to the teachers, the involvement in co-designing and teaching the experimental lessons of the designed curriculum made them change their perceptions of teaching and learning science. The teachers acknowledged that the teaching and learning methods of the conventional science curriculum emphasised transmissive teaching and reproductive learning. By analyzing the differences between the experimental lessons and the conventional science lessons, the teachers showed their preference for social constructivist teaching methods for science lessons. This can be recognised in the quotations below:

> Good science learning involves the consideration that knowledge is not always precise and correct, and hence, we should not impose "correct knowledge" on students. Students have to explore and discover, and they assess knowledge by themselves. (T1, Team discussion 6)

> In this lesson, if a student does not know, thanks to her peers, she can know, right? If she knows already, thanks to her peers, she can know more. Hence, her knowledge becomes certain. Through exploring activities, she knows more again, so that she becomes more self-confident, courageous, and knowledgeable. However, in our conventional science lessons, the students depend on the teacher and they do not dare to ask the teacher to tell them more as they do when they work with their peers. (T3, Team discussion 9)

2.3. The formulation of teacher activities corresponding with each of the phases

Despite acknowledging advantages of the designed curriculum, the teachers pointed out its shortcomings and limitations. According to them, the designed curriculum did not provide enough instructive information or an instructional guideline specific enough for teachers to know with certainty what they should do when teaching the lessons. For example, the designed curriculum was structured with two main learning tasks for the Experience phase (APPENDIX A). However, the lack of a clear description of the teacher activities in relation to the designed student activities confused the teachers. The teachers formulated two alternatives for teaching this phase. The teachers chose Alternative 1 in the first six lessons; from Lesson 7 on, they decided to follow Alternative 2.

Alternative 1

Step 1. The teacher lets student groups complete both the predicting task and the experiment task (APPENDIX A) in the Experience phase.

Step 2. The teacher lets students present all of the group answers for both the predicting task and experiment task and postpones the discussion of the outcomes until the Exchange phase.

Alternative 2

Step 1. The teacher lets student groups complete the predicting task in the Experience phase.

Step 2. The teacher lets students present predicting answers and compare predicting answers with each other in the Experience phase.

Step 3. The teacher lets student groups do the experiment task in the Experience phase.

Step 4. The teacher lets student groups present experimental answers, compare the experimental answers, and discuss them in the Exchange phase.

Step 5. The teacher lets student groups compare the predicting answers to the experimental answers and discuss them in the Exchange phase.

According to the teachers, Alternative 1 confused students and they found it difficult to catch key ideas of other groups in order to assess answers because many of the answers were presented at the same time. This made the students feel bored and less motivated to share ideas. The teachers considered Alternative 1 (applied in the first six experimental lessons) as one of the explanations for a less active learning atmosphere in the Exchange phase than in the other phases. The Exchange phase could easily return to traditional teaching and learning.

The teachers preferred Alternative 2 because students had opportunities to find similarities and differences in group answers within and between the tasks. The teachers acknowledged that the comparisons meant that the teaching and learning was better structured and student groups were more motivated for the next learning step. The teachers could follow the students' learning step by step; hence, they could master their teaching in a better way and were able to assess the students' learning adequately.

In reflecting on the designed curriculum and their experimental lessons, the teachers stressed the need for explicit descriptions of the following teacher activities to avoid practical difficulties during teaching.

- Observing students and providing students with autonomy for their self-regulated learning
- Using open-ended elaborative questions to guide students

- Staying open-minded to interact with students

Based on their own experiences of co-designing, teaching, and reflecting on the experimental lessons in the spiral professional development programme, the teachers formulated a complete set of teaching activities to be applied to the design. These formulated teaching activities are summarized and presented in Table 5.

3. Challenges for the application of the designed curriculum (sub-research question 3)

The challenges experienced by the teachers are clustered in two themes: 1) challenges for teaching and 2) institutional challenges. The first set of challenges concerns a) the influences of habits and traditional methods, b) the need for understanding scientific subject matter, and c) the difficulty associated with teaching and learning argumentation. The second set of challenges is related to a) the issue of time, b) the measurement of learning results, and c) the difficulty associated with systemic change.

3.1. Teacher challenges

3.1.a. The influences of habits and traditional teaching methods

According to the teachers, when teaching the experimental lessons they were influenced by their existing habits and the traditional teaching and learning methods of the conventional science curriculum, especially in the first three experimental lessons. This was expressed in the following statements:

> To apply this curriculum, teachers are required to change their minds. In our usual lessons, the teacher is already provided with solid knowledge written in the textbooks; what she needs to do is to convey it to students. But for the lessons of this innovative curriculum, the teacher needs to self-prepare knowledge.... In the first, the knowledge source is available to the teacher and the teacher just fills the vase with it. The second one requires the teacher to have and select a suitable knowledge source and also know how to use it for teaching. This is difficult. (T1, Team discussion 6)

> Sometimes we might have used traditional methods unintentionally when teaching these lessons. This is because we have been deeply influenced by a traditional teaching method and used it for quite a long time. (T1, Team discussion 9)

Table 5. The teaching activities agreed on and proposed by the Confucian heritage teachers to apply to the designed curriculum

Phase	Teaching activity		
	Number	Repeated	Items
Engagement	i		Using a few key questions to reveal students' prior knowledge and curiosity
	ii		Staying open to students' responses
Experience			PREDICTING
	iii		Delivering the task and being sure that student groups know what to do and how to do the task
	iv		Establishing time for group discussion
	v		Observing and supervising groups while they do their group tasks
	vi		Encouraging students to present answers, and compare and assess answers
	vii	i	Staying open to students' responses
			HANDS-ON
	viii	iii	Delivering the task and being sure that student groups know what to do and how to do the task
	ix	iv	Establishing time for group discussion
	x	v	Observing and supervising groups while they do their group tasks
	xi		Using open-ended elaborative questions to guide students
	xii		Staying open-minded and friendly while interacting with students
Exchange	xiii	vi	Encouraging students to present answers, and compare and assess answers
	xiv		Stimulating groups to interact and argue with each other
	xv	xi	Using open-ended elaborative questions to guide students in grasping deeper knowledge
	xvi	xii	Staying open-minded and friendly while interacting with students
	xvii		Choosing representative questions formulated by students/groups for students to discuss and answer
Follow-up	xviii	xi	Providing open-ended sub-questions (if necessary) to guide students in answering/solving new questions/problems
	xix		Giving compliments to individual students and groups who have achieved successful learning

The teachers used these arguments to explain why they applied a transmissive teaching style and judged students based on a "correct or incorrect" standard in the first experimental lessons, although they were aware that they should not have done so. They acknowledged that habits of traditional teaching methods were considerable challenges for Confucian heritage teachers aiming to teach the designed science lessons.

3.1.b. The need for deep understanding of scientific content knowledge

The teachers acknowledged that one of the difficulties they had to cope with was that they did not have enough content knowledge about air pressure, plant roots, and CO_2 reaction to teach these scientific themes to their students, although they were provided with literature in the professional development programme. To teach these lessons, they had to look for information and knowledge on these scientific themes by searching the internet and consulting their science colleagues. They showed a need for deep understanding of scientific content knowledge when implementing the designed curriculum, as is illustrated in the following quotation:

> If the teacher does not have enough knowledge and information on scientific content, she cannot guide students to solve problems. (T3, Team discussion 9)

According to the teachers, it was difficult for them to formulate effective open-ended questions to guide students to grasp knowledge when they themselves did not understand the subject matter well enough. Therefore, they stressed that the teachers' understanding of content knowledge played a crucial role when teaching the lessons.

> With the [new] approach…, the teacher needs to know more about content knowledge, and she needs to search for knowledge to stay independent in her own thinking. (T3, Team discussion 6)

However, according to the teachers, Vietnamese primary teachers teach many subjects, of which the main ones are mathematics and Vietnamese, and they are overloaded with work. Pre- and in-service teacher education did not provide much content knowledge about science, which explains why primary teachers have insufficient content knowledge about science. It was therefore challenging to search for deeper content knowledge.

In the teachers' opinions, the designed curriculum requires teachers to have a higher capability in pedagogy to guide students and cope with problems and questions because the curriculum encourages students to pose questions and to raise conflicts in discussions and argumentation. To guide students in answering questions, resolving conflicts in discussions, and arguing with each other requires that teachers are well equipped with scientific content knowledge.

3.1.c. The difficulty of teaching and learning argumentations

Scientific argumentation was found to be challenging. According to the teachers, social conflicts in argumentation occurred during the experimental lessons. Then the students tended to wait for the teacher's interventions or let the group leader decide on the final answers rather than arguing with each other. However, the teachers found it difficult to help the students resolve such conflicts, because they did not have sufficient skill in scientific argumentation. In such a situation, the learning environment could easily return to passive learning as in traditional classrooms.

> It's difficult for teachers to teach students how to reason, argue, and defend their ideas. (T2, Team discussion 8)

We feel that it is difficult to teach the Exchange phase. It is not easy to promote argumentation among students in this phase. That's why I think in this phase the students' learning was less active than in the other phases. (T1, Team discussion 9)

3.2. Institutional challenges

3.2.a. The issue of time

Despite their appreciation for the new curriculum design, the teachers asserted that the issue of time could be a barrier to the application of the designed curriculum. According to the teachers, the experimental science lessons were time consuming.

> I thought these lessons took a lot of time. A current science lesson is taught for around 30 minutes. If it exceeds the time constraint, it will be assessed as a weak lesson. (T2, Team discussion 6)

> With respect to teaching methods, I think educational inspectors will appreciate these lessons. But with respect to lesson length, I think they will not like the lessons. (T1, Team discussion 6)

The teachers considered that the experimental lessons took more time than conventional science lessons, because inquiry and cooperative learning takes more time than listening and reproducing. Moreover, much lesson time was spent dealing with students' questions and the problems that arose during activities and discussions. The teachers anticipated it would be challenging to apply the designed curriculum to primary science education in Vietnam if the time amount for one lesson exceeded 35 minutes (Chapter 2).

3.2.b. The measurement of learning results

According to the teachers, the measurement of learning results for the conventional science curriculum was easier than for the designed curriculum. In the conventional science curriculum, the learning results are mainly measured based on the student's memorisation of factual knowledge. However, in the teachers' opinions, measuring the students' skills and attitudes as learning results, as emphasised by the designed curriculum, would be more difficult.

> It's easier to measure learning results about knowledge. That's what we do now for the conventional science curriculum. Mostly, we measure students' memorisation of knowledge. We can use tests to do it. However, this designed curriculum focuses on developing not only knowledge but also skills and attitudes for students…, but measuring skills and attitudes is very difficult. How to do it? We need to measure it, right? But how to measure it? (T3, Team discussion 8)

If they apply the criteria of classroom assessment used in the conventional curriculum to these [experimental] lessons, maybe these lessons will not satisfy. (T2, Team discussion 8)

The above quotations show that the application of the designed curriculum requires the development of corresponding materials to support teachers in assessing student learning in accordance with the designed curriculum.

3.2.c. The difficulty of a systemic change

The teachers affirmed that the designed curriculum could not be applicable to primary classroom practices in Vietnam without systemic changes.

> To apply this curriculum design in practice, there needs to be a change – systemic, consistent, and from top to bottom. (T1, Team discussion 8)

However, according to the teachers, it was difficult to initiate a systemic change in Vietnam, because of issues related to finance, educational policies, administrations, teacher training, teacher abilities, and so on.

Conclusions and Discussion

This study reveals that the Confucian heritage teachers who participated changed their attitudes and teaching activities considerably. They became more open-minded and friendly in interacting with students in the science lessons. In addition, they focused more on a) encouraging students to engage in inquiry, b) providing time and space for self-regulated learning, c) promoting social interactions among students, and d) seeking elaboration of students' initial responses.

With the changes in the teachers' attitudes and teaching activities, this study shows that although teaching is influenced by culture (Hofstede et al., 2010), teachers are highly adaptive. The study therefore supports and promotes the application and adaptation of social constructivist theories to Confucian heritage culture. Moreover, given the considerable changes observed in the Confucian heritage teachers, this study shows that the adapted and combined spiral programme of teacher professional development (Figure 1), which is consistent with a social constructivist approach, was effective in facilitating the Confucian heritage teachers in their interaction with the designed curriculum and in helping them change attitudes and activities toward a social constructivist perspective of science teaching and learning. With these findings, this study strengthens the assertion that "we need to consider redeveloping a curriculum for teacher education more consistent with what we value" (Sosniak, 1999, p. 200).

This study can be situated within a larger research programme on developing a framework for professional development with three main stages – preparation for teaching, teaching and observing, and reflection – and, as Stolk et al. (2012) and Dolfing (2013) have recommended, with quite a number of small iterations (nine in this case; Figure 1). The importance of general strategies, such as collaboration, sharing experiences, co-designing, and reflection are acknowledged by many studies on professional development (Dolfing, 2013; Stolk, 2013). This study also builds on the knowledge of the establishment of learning communities with a facilitator and the teachers as critical co-designers (Agung, 2013), and builds on design knowledge of curriculum frameworks and units (Bulte et al., 2006; Meijer, 2011; Prins, 2010) which was synthesised and adapted to the programme (Figure 1) used for teacher professional development. With the adapted and combined spiral programme, this study reinforces the research results of those former studies.

The teachers in this study perceived that the designed curriculum brings more benefits for students than does the conventional science curriculum (Chapter 2). They acknowledged that the designed curriculum helped reconceptualise the teaching and learning of science, bringing it closer to a social constructivist perspective and the "nature of science" education. Also, the teachers proposed the formulation of teacher activities corresponding with each of the phases of the designed curriculum. With the concrete teaching activities (Table 5) achieved from the heuristic knowledge of the Confucian heritage teachers, this study can provide a response to the call from social constructivist researchers for "teacher presentation of concepts and skills and tighter structuring and scaffolding of students' activities than most social constructivists envision" (Brophy, 2006, p. 536). Moreover, this study creates the possibility of developing the design through a formulation of the concrete teaching activities that were acknowledged by the Confucian heritage teachers to be helpful in practice. A curriculum design with concrete teaching activities is also supported by the claim that the construction and critical discussion of detailed content-specific justifications of teaching-learning sequences, as the core business of science education research, are only effective when firmly grounded in detailed accounts of concrete teaching-learning activities (Klaassen & Kortland, 2013).Concrete teaching-learning activities with general considerations that involve theoretical frameworks can be meaningfully clarified, discussed, and compared (Klaassen & Kortland, 2013). The design embedded with concrete teaching-learning activities can bridge the gaps between the ideal curriculum and the experiential and attained curriculum (Van den Akker, 2003).

In terms of the challenges for the teachers, three major challenges were mentioned: a) the influences of habits and traditional teaching methods, b) the need for deep understanding of scientific content knowledge, and c) the difficulty of teaching and learning argumentations for Vietnamese primary teachers and students. The institutional challenges mentioned were: a) the issue of time, b) the measurement of learning results, and c) the difficulty of a systemic change. To a certain extent, these challenges perceived by the teachers are predictable difficulties with social constructivist approaches (Brophy, 2006) and underpin the claim that sustaining a constructivist classroom culture involves dealing with teacher challenges, as well as logistical and political challenges to effective implementation (Airasian & Walsh, 1997; Windschilt, 1999).The teacher challenges may be the main problems that make educational researchers pessimistic about the application of a social constructivist perspective to teaching (Nuthall, 2002; Tobias & Duffy, 2009). In our consideration, however, the teacher challenges in applying the designed social constructivism-based curriculum leave room for further research. They show that the design should be improved in order to be a better teaching guideline for teachers to use. In this way, the teaching activities agreed and proposed by the Confucian heritage teachers are valuable sources of practical knowledge that can be used to improve the design. Also, they show that teacher input has a major role within a social constructivist framework (Beck & Kosnik, 2006; Nuthall, 2002) that requires an emphasis on professional development and teacher education in order to facilitate Confucian heritage teachers in overcoming the challenges more successfully. Further programmes of teacher professional development and teacher education may "need to integrate knowledge from different disciplines, diverse procedures, and attitudes" (Bulte et al., 2006, p. 1084).

The institutional challenges perceived by the teachers show that the designed curriculum needs to include certain conditions to make the approach applicable in the educational practice of Confucian heritage culture. Therefore, to apply the designed curriculum in practice, it needs to accommodate not only the involvement of Confucian heritage teachers as direct actors but also the involvement of educational policy makers, who should primarily consider the coherency of educational policy and practice (Agung, 2013) for the application of a science curriculum. Policy makers, stakeholders, and curriculum designers need to coordinate with each other in order to create a facilitative ground that supports the application of a social constructivist perspective to primary science education and promotes the growth of an innovative curriculum (Bulte & Seller, 2011). With the findings presented and discussed here, the study therefore contributes to a knowledge base about teacher professional development for the application of a social constructivist perspective to primary school science education in Confucian heritage culture.

Endnote

All names of the teachers and students used in this study are pseudonyms.

References

Abd-El-Khalick, F., & Lederman, N. G. (2000). Improving science teachers' conceptions of nature of science: A critical review of the literature. *International Journal of Science Education*, *22*(7), 665–701.

Agung, S. (2013). *Facilitating professional development of Madrasah chemistry teachers*. Doctoral dissertation. Utrecht University, the Netherlands.

Airasian, P., & Walsh, M. (1997). Constructivist cautions. *Phi Delta Kappan*, *78*, 444–449.

Anderson, R. D. (1996). *Study of curriculum reform*. (Volume I of the final report of research conducted under contract no.RR91182001 with the Office of Educational Research and Improvement, U.S. Department of Education). Washington, DC: U.S. Government Printing Office.

Anderson, R. D. (2007). Inquiry as an organizing theme for science curricula. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 807–830). Oxford, UK: Taylor & Francis.

Beck, C., & Kosnik, C. (2006). *Innovations in teacher education – A social constructivist approach*. Albany, NY: State University of New York Press.

Brooks, J., & Brooks, M. (1993). *In search of understanding: The case for constructivist classrooms*. Alexandria, VA: Association for Supervision and Curriculum Development.

Brophy, J. (2006). Graham Nuthall and social constructivist teaching: Research-based cautions and qualifications. *Teaching and Teacher Education*, *22*, 529–537.

Bulte, A. M. W., & Seller, F. (2011). Making an innovation grow: On the shared learning within and between communities. In C. Lindner, L. Östman, D. A. Roberts, P.-O. Wickman, G. Erickson, & A. MacKinnon (Eds.), *Exploring the landscape of scientific literacy* (pp. 236–254). New York, NY: Taylor & Francis.

Bulte, A. M. W., Westbroek, H. B., De Jong, O., & Pilot, A. (2006). A research approach to designing chemistry education using authentic practices as contexts. *International Journal of Science Education, 28*(9), 1063–1086.

Calderhead, J., & Robson, M. (1991). Images of teaching: Student teachers' early conceptions of classroom practice. *Teaching and Teacher Education*, *7*(1), 1–8.

Chan, S. (1999). The Chinese learning – A question of style. *Education and Training*, *41*(6/7), 294–304.

Clarke, D., & Hollingsworth, H. (2002). Elaborating a model of teacher professional growth. *Teaching and Teacher Education*, *18*(8), 947–967.

Coenders, F. (2010). *Teachers' professional growth during the development and class enactment of context-based chemistry student learning*

material. Doctoral dissertation. University of Twente, Enschede, the Netherlands.
Coll, R. K., & Taylor, N. (2012). An international perspective on science curriculum development and implementation. In B. J. Fraser, K. G. Tobin, & C. J. McRobbie (Eds.), *Second international handbook of science education* (Vol. II, pp. 771–782). Dordrecht, the Netherlands: Springer.
Cotton, D. R. E. (2006). Implementing curriculum guidance on environmental education: The importance of teachers' beliefs. *Journal of Curriculum Studies*, *38*, 67–83.
Couchman, J. (1997). Making sense: Cross-cultural variation in the organisation of academic texts by Taiwanese and Australian undergraduate students. In Z. Golebiowski & H. Borland (Eds.), *Academic communication across disciplines and cultures* (pp. 64–76). Melbourne, Australia: Victoria University of Technology.
Creswell, J. W. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches* (3rd ed.). Thousand Oaks, CA: Sage Publications.
Dekkers, P. (2006). Reconstructing the creature – Exploring design criteria for teaching NOS. In E. Van den Berg, T. Ellermeijer, & O. Stooten (Eds.), *Proceedings of the GIREP Conference Modelling in Physics and Physics Education* (pp. 459–464). Amsterdam, the Netherlands: University of Amsterdam.
Dewey, J. (1933). *How we think: A restatement of the relation of reflective thinking to the educative process*. Chicago, IL: Henry Regnery.
Dolfing, R. (2013). *Teacher's professional development in context-based chemistry education: Strategies to support teachers in developing domain-specific expertise.* Doctoral dissertation. Utrecht University, the Netherlands.
Duffee, L., & Aikenhead, G. (1992). Curriculum change, student evaluation, and teacher practical knowledge. *Science Education,* 76(5), 493–506.
Duit, R., & Treagust, D. (1998). Learning in science – From behaviorism towards social constructivism and beyond. In B. L. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (pp. 3–25). Dordrecht, the Netherlands: Kluwer Academic Publishers.
Đạm, Q. (1994). *Nho giáo xưa và nay [Confucianism: Past and present].* Hanoi, Vietnam: Culture Publisher.
Fullan, M. G. (1991). *The new meaning of educational change* (2nd ed.). New York, NY: Teachers College Press.
Gess-Newsome, J. (1999). Pedagogical content knowledge: An introduction and orientation. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining pedagogical content knowledge* (pp. 3–17). Dordrecht, the Netherlands: Kluwer Academic Publishers.

Glatthorn, A. (1995). Teacher development. In L. Anderson (Ed.), *International encyclopedia of teaching and teacher education* (2nd ed., pp. 41–45). London, UK: Pergamon Press.
Guskey, T. R. (2002). Professional development and teacher change. *Teachers and teaching: Theory and practice*, *8*(3/4), 381–391.
Hand, B. (2011). An immersion approach to argument-based inquiry – Does it look the same in different countries? In Y. Kim, J. Park, H. E. Seo, J. A. Lee, & J. Kim (Eds.), *Proceeding of the 2011 EASE International Conference – Lighting the world with science* (pp. 45–54). Gwangju, Korea: Chosun University.
Hand, B., Treagust, D. F., & Vance, K. (1997). Student perceptions of the social constructivist classroom. *Science Education*, *81*(5), 561–575.
Hofstede, G., Hofstede, G. J., & Minkov, M. (2010). *Cultures and organizations: Software of the mind: Intercultural cooperation and its importance for survival* (3rd ed.). New York, NY: McGraw-Hill.
Irvin, J. (2008). Social constructivism in the classroom: From a community of learners to a community of teachers. In M. Goos, R. Brown, & K. Makar (Eds.), *Proceedings of the 31st Annual Conference of the Mathematics Education Research Group of Australasia* (pp. 287–293). Sydney, Australia: MERGA Inc.
Kang, I., Choi, J. I., & Chang, K. (2007). Constructivist research in educational technology: A retrospective view and future prospects. *Asia Pacific Education Review*, *8*(3), 397–412.
Keys, C. W., & Bryan, L. A. (2001). Co-constructing inquiry-based science with teachers: Essential research for lasting reform. *Journal of Research in Science Teaching*, *38*(6), 631–645.
Kim, M., & Tan, A. L. (2011). Rethinking difficulties of teaching inquiry-based practical work: Stories from elementary pre-service teachers. *International Journal of Science Education*, *33*(4), 465–486.
Klaassen, K., & Kortland, K. (2013).*The role and nature of theory in design research*. Paper presented at the 13th ESERA Conference: Science education research for evidence-based teaching and coherence in learning. Cyprus University, Cyprus.
Le Cornu, R., & Peters, J. (2005). Towards constructivist classrooms: The role of the reflective teacher. *Journal of Educational Enquiry*, *6*(1), 50–64.
Lee, K. W., Tan, L. L., Coh, N. K., Chia, L. S., & Chin, C. (2000). Science teachers and problem solving in elementary schools in Singapore. *Research in Science and Technological Education*, *18*(1), 113–126.
Lieberman, A. (1995). Practices that support teacher development: Transforming conceptions of professional learning. *Phi Delta Kappan*, *51*(8), 221–227.

Liu, N. F., & Littlewood, W. (1997). Why do many students appear reluctant to participate in classroom learning discourse? *System*, *25*(3), 371–384.
Loughran, J., Mulhall, P., & Berry, A. (2004). In search of pedagogical content knowledge in science: Developing ways of articulating and documenting professional practice. *Journal of Research in Science Teaching*, *41*(4), 370–391.
McComas, W. F., Almazroa, H., & Clough, M. (1998). The nature of science in science education: An introduction. *Science and Education*, *7*(6), 511–532.
Meijer, M. (2011). *Macro-meso-micro thinking with structure-property relations for chemistry education: An explorative design-based study*. Doctoral dissertation. Utrecht University, the Netherlands.
Neuman, Y., & Bekerman, Z. (2000). Cultural resources and the gap between educational theory and practice. *Teachers College Record, 103*(3), 471–484.
Nguyen, M., Elliott, J., Terlouw, C., & Pilot, A. (2009). Neocolonialism in education: Cooperative learning, Western pedagogy in an Asian context. *Comparative Education*, *45*(1), 109–130.
Nuthall, G. (2002). Social constructivist teaching and the shaping of students' knowledge and thinking. In J. Brophy (Ed.), *Social constructivist teaching: Affordances and constraints* (pp. 43–79). New York, NY: Elsevier.
Osborne, J. (1996). Beyond constructivism. *Science Education*, *80*(1), 53–82.
Prins, G. (2010). *Teaching and learning of modelling in chemistry education: Authentic practices as contexts for learning*. Doctoral dissertation. Utrecht University, the Netherlands.
Serpell, R. (2007). Bridging between orthodox western higher educational practices and an African sociocultural context. *Comparative Education*, *43*(1), 23–51.
Sosniak, L. A. (1999). Professional and subject matter knowledge for teacher education. In G. A. Griffin (Ed.), *The education of teachers: 98th NSSE Yearbook, Part I* (pp. 185–204). Chicago, IL: National Society for the Study of Education.
Stolk, M. (2013). *Empowering chemistry teachers for context-based education.* Doctoral dissertation. Utrecht University, the Netherlands.
Stolk, M. J., Bulte, A. M. W., De Jong, O., & Pilot, A. (2009). Towards a framework for a professional development programme: Empowering teachers for context-based chemistry education. *Chemistry Education Research and Practice*, *10*, 164–176.
Stolk, M. J., Bulte, A. M. W., De Jong, O., & Pilot, A. (2011). Exploring a framework for professional development in curriculum innovation:

Empowering teachers for designing context-based chemistry education. *Research in Science Education*, *41*, 369–388.
Stolk, M. J., Bulte, A. M. W., De Jong, O., & Pilot, A. (2012). Evaluating a professional development framework to empower chemistry teachers to design context-based education. *International Journal of Science Education*, *34*(10), 1487–1508.
Tao, Y., Oliver, M., & Venville, G. (2013). A comparison of approaches to the teaching and learning of science in Chinese and Australian elementary classrooms: Cultural and socioeconomic complexities. *Journal of Research in Science Teaching*, *50*(1), 33–61.
Thêm, T. N. (1997). *Tìm về bản sắc văn hóa Việt Nam [Research on Vietnamese cultural distinctions].* Ho Chi Minh, Vietnam: Ho Chi Minh Publisher.
Tobias, S., & Duffy, T. (2009). *Constructivist instruction: Success or failure.* New York, NY: Routledge.
Van den Akker, J. J. H. (2003). Curriculum perspectives: An introduction. In J. J. H. Van den Akker, W. Kuiper, & U. Hameyer (Eds.), *Curriculum landscape and trends* (pp. 1–10). Dordrecht, the Netherlands: Kluwer Academic Publisher.
Van Driel, J. H., Beijaard, D., & Verloop, N. (2001). Professional development and reform in science education: The role of teachers' practical knowledge. *Journal of Research in Science Teaching*, *38*(2), 673–695.
Van Driel, J. H., Verloop, N., & De Vos, W. (1998). Developing science teachers' pedagogical content knowledge. *Journal of Research in Science Teaching*, *35*(6), 673–695.
Volet, S., & Renshaw, P. (1996) Chinese students at an Australian university: Adaptability and continuity. In D. A. Watkins & J. B. Biggs (Eds.), *The Chinese learner: Cultural, psychological and contextual influences* (pp. 205-220). Hong Kong: The Central Printing Press.
Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.
Watson, J. (2001). Social constructivism in the classroom. *Support for Learning*, *16*(3), 140–147.
Windschitl, M. (1999). The challenges of sustaining a constructivist classroom culture. *Phi Delta Kappan*, *80*(10), 751–755.
Zemplén, G. (2009). Putting sociology first – Reconsidering the role of the social in "nature of science" education. *Science and Education, 18*(5), 525–559.

APPENDIX A The designed framework of the social constructivism-based curriculum for primary science education in Confucian heritage culture

PHASE	FUNCTION	LEARNING SETTING		EDUCATIONAL EXPECTATIONS
		Activity	Form	
Engagement	A. To provide students with the motivation to learn	1. Doing a small hands-on task with a relevant example related to scientific subject matter 2. Answering *What*, *How*, and *Why* questions about a relevant example related to scientific subject matter	1. In small groups and/ or in the class as a whole	a. Students are interested in scientific subject matter
Experience	B. To evoke attitudes toward science C. To acquire procedural knowledge D. To acquire conceptual knowledge E. To acquire argumentative skills	3. Predicting: Observe and discuss in order to answer questions: *What do you observe? What will happen if…? Why do you think so?* 4. Hands-on: Do experiment and discuss in order to answer questions: *What did you observe? How can you explain it? Why do you think so?* 5. Questioning: Formulate questions related to scientific subject matter	2. In small groups	b. Students are curious about representative examples of scientific subject matter c. Students are active in learning about representative examples of scientific subject matter d. Students use their intuitive knowledge to learn about scientific subject matter e. Students argue with each other to attain consensually agreed knowledge on representative examples of scientific subject matter

PHASE	FUNCTION	LEARNING SETTING		EDUCATIONAL EXPECTATIONS
		Activity	Form	
Exchange	F. To build on attitudes toward science G. To build on procedural knowledge H. To build on conceptual knowledge I. To build on argumentative skills	6. Presenting results to other groups 7. Discussing results with other groups 8. Answering formulated questions related to scientific subject matter	3. In the class as a whole and/or in combined groups	f. Students are interactive in learning scientific subject matter g. Students argue with each other to attain consensually agreed knowledge on scientific subject matter
Follow-up	J. To acquire cognitive flexibility K. To further learning motivation	9. Providing answers and/or solutions for new questions and/or problems related to scientific subject matter	4. In the class as a whole	h. Students can provide appropriate answers and/or solutions i. Students show their desire to learn more about scientific subject matter

APPENDIX B The designs of exemplary curriculum units

Phase	Unit Air Pressure	Unit Plant Roots	Unit CO_2 Reaction
Engagement	1. Answering: *What will happen if we blow air into the inflated balloon? Why do you think so? What will happen if the inflated balloon is released at once? Why do you think so?* 2. Blowing air into the inflated balloon and releasing it, and answering: *What happened? How can you explain what was observed?*	1. Drawing a complete plant 2. Answering: *What did you draw? Why did you draw the plant root like that? How did you know it?*	1. Answering: *What will happen if we blow air through a straw into a water bottle? Why do you think so?* 2. Blowing air through a straw into a water bottle and answering: *What happened? How can you explain what was observed?*
Experience	3. Predicting (Exercise 1): Connect two cylinders with a plastic tube. Discuss with your peers and answer the following questions: *a. What will happen if one cylinder is pressed down?* *b. Why do you think so?* 4. Hands-on (Exercise 2): Press one of the connected cylinders down. Discuss in the group answers to the following questions:	3. Predicting (Exercise 1): Choose a wild plant in the school garden to observe. Discuss in the group the answers to the following questions: *a. What do you think the plant root looks like? Draw it.* *b. Why do you think so?* 4. Hands-on (Exercise 2): Pull out the wild plant in the school garden. Discuss in the group the answers to the following questions:	3. Predicting (Exercise 1): Given a Coca Cola bottle and some Mentos. Discuss in your group the answers to the following questions: *a. What will happen if all the Mentos are dropped into the coke bottle?* *b. Why do you think so?* 4. Hands-on (Exercise 2): Drop all the Mentos into the coke bottle. Discuss in the group the answers to the following questions:

Phase	Unit Air Pressure	Unit Plant Roots	Unit CO_2 Reaction
Experience	*a. What did you observe?* *b. How can you explain what was observed?* 5. Questioning (Exercise 3): Write down questions or ideas related to the subject matter that you want to discuss.	*a. What does the plant root system look like? Draw it.* *b. Why does this plant have a root system like that?* *c. What are the functions of the plant root system? Why do you think so?* 5. Questioning (Exercise 3): Write down questions or ideas related to the subject matter that you want to discuss.	*a. What did you observe?* *b. Why did it happen?* 5. Questioning (Exercise 3): Write down questions or ideas related to the subject matter that you want to discuss
Exchange	6. Presenting results to other groups 7. Discussing results with other groups 8. Answering formulated questions related to subject matter	6. Presenting results to other groups 7. Discussing results with other groups 8. Answering formulated questions related to subject matter	6. Presenting results to other groups 7. Discussing results with other groups 8. Answering formulated questions related to subject matter
Follow-up	9. Answering the questions: *What did you learn from the lesson today? Can you provide some examples related to air pressure and explain why you think what you do about them? How can you relate this knowledge to a natural phenomenon, for example, the wind?*	9.a. Answering questions: *What did you learn from the lesson today? Can you provide some examples of root types and explain why you think those plants have such root types?* 9.b. Determining type of root for some plants	9. Answering questions: *What did you learn from the lesson today? Can you provide some examples of carbon dioxide reaction and explain why you think what you do about them?*

Chapter 1. Introduction and Research Overview

What is the design of curriculum for primary science education that has social constructivist characteristics and is appropriate with Confucian heritage culture?

PROBLEM ANALYSIS

Chapter 2. The implementation of a social constructivist perspective in primary science education in Confucian heritage culture: the case of Vietnam

RQ1. To what extent is a social constructivist perspective implemented in primary science education in Confucian heritage culture?

RQ2. How can this implementation be explained from a Confucian cultural perspective and what are fostering and hindering cultural factors to the implementation?

DESIGN CYCLE 1

Chapter 3. Designing a formal curriculum based on a social constructivist perspective for primary science education in Confucian heritage culture

RQ. What is the design of formal curriculum for primary science education that has social constructivist characteristics and is appropriate with Confucian heritage culture?

Chapter 4. Teacher professional development: The interaction of Confucian heritage teachers with a social constructivism-based curriculum for primary science education

RQ. In what way do Confucian heritage teachers interact with a primary science curriculum, which is based on a social constructivist perspective and made appropriate with Confucian heritage culture, in a program of professional development?

Chapter 5. Scientific argumentation as bottleneck for implementing a social constructivism-based science curriculum in Confucian heritage culture

RQ. To what extent does the unit of the curriculum design for primary science education in Confucian heritage culture meet the social constructivist expectations in the practice of the classroom?

DESIGN CYCLE 2

Chapter 6. Improving scientific argumentation through a social constructivism-based curriculum for primary science education in Confucian heritage culture

RQ1. To what extent does the unit of the adjusted design of social constructivism-based curriculum for primary science education in Confucian heritage culture support students to practice scientific argumentation in a science lesson?

RQ2. To what extent does the unit of the adjusted design of social constructivism-based curriculum for primary science education in Confucian heritage culture support students to attain consensually agreed knowledge on scientific subject-matter?

Chapter 7. Conclusions, Reflection and Recommendations

RQ. What is the design of curriculum for primary science education that has social constructivist characteristics and is appropriate with Confucian heritage culture?

CHAPTER 5 Scientific Argumentation as a Bottleneck for Implementing a Social Constructivism-Based Science Curriculum in Confucian Heritage Culture[1]


[2]

Abstract The implementation of a social constructivist perspective in primary science education in Confucian heritage countries remains challenging and problematic. Addressed to solve problems of primary science education in Confucian heritage culture, a curriculum based on a social constructivist perspective was designed that took cultural divergences between Confucian heritage culture and Western educational philosophy of the "nature of science" education into consideration. In applying this curriculum to the practice of primary science education in Confucian heritage culture, a programme of professional development was offered to teachers. It provided Confucian heritage teachers with opportunities to co-design and teach social constructivist science lessons. The analysis of a specific experimental lesson reveals that the designed curriculum can encourage Confucian heritage students to be interested in scientific subject-matter, active and interactive in learning of science. However, the designed curriculum was not effective enough in supporting students in scientific argumentation. The findings of the study require the designed curriculum to be revised and adjusted in order to support Confucian heritage students in practicing scientific argumentation, which was considered as the salient element that might make a social constructivist perspective remain challenging in primary science education in Confucian heritage culture. The study suggests that the harmony valued as a feature of Confucian heritage culture needs to be addressed in adjusting the designed curriculum.

---

1 This chapter is submitted as: Hằng, N. V. T., Bulte, A. M. W., & Pilot, A. *Scientific Argumentation as a Bottleneck for Implementing a Social Constructivism-Based Science Curriculum in Confucian Heritage Culture.*

2 A student drawing of the analysed experimental science lesson (from the data source of post-questionnaires of this study).

Introduction

Despite increasing applications, the implementation of a social constructivist perspective (Beck & Kosnik, 2006) has remained problematic and challenging in Confucian heritage culture. It was found in Chapter 2 that in Confucian heritage culture, teaching and learning are textbook-based and teacher-centred, while hands-on complex tasks are absent, students' personal perspectives, emotions, attitudes, and values are discounted, and hierarchical interactions remain the norm in science classrooms.

It is considered as difficult to apply a constructivist approach for a community where students had been passive of receiving information (Neuman & Bekerman, 2000). Confucianism has acknowledged to influence teaching and learning by rote learning, the application of quoting and examples, and students' avoidance of confrontations and argumentation in discussion (Chapter 2; Chan, 1999; Hofstede et al., 2010). A social constructivist perspective in primary science education has not been very well implemented, reasonably because of Confucian heritage culture and its divergences from Western educational philosophy of the "nature of science" education (Abd-El-Khalick & Lederman, 2000) and from a social constructivist perspective (Chapter 2). Three main divergences between Confucian heritage culture and Western educational philosophy are:

(1) Confucian heritage culture emphasises stability and harmony among its human values, whereas Western educational philosophy emphasises the rationality (Totten, Sills, Digby, & Russ, 1991) that supports argumentation and conflict in discussion and helps students be prepared for citizenship (Kolstø, 2001). In the "nature of science" education (Abd-El-Khalick & Lederman, 2000; Dekkers, 2006), conflicts and argumentation are preferred over harmony.

(2) Confucian heritage culture emphasises theoretical knowledge, considering "classical" knowledge and theory as universally correct, whereas Western educational philosophy emphasises empirical knowledge and well-substantiated scientific claims, believing that there is no complete truth and that every aspect of theoretical knowledge is changeable (Abd-El-Khalick & Lederman, 2000; Dekkers, 2006).

(3) Confucian heritage culture emphasises hierarchical order in which the teacher is considered superior and the transmitter of the body of knowledge to students, whereas Western educational philosophy

emphasises equitability: the teacher is considered a more advanced learner (Vygotski, 1978) who facilitates students to learn in order to achieve not only knowledge but also the skills and attitudes used to study science (Bybee, McCrae, & Laurie, 2009; Hofstede, 1986).

These cultural divergences are considered to have caused cultural mismatch and practical difficulties in applying Western social constructivist theories to educational contexts in Confucian heritage culture (Örtenblad, Babur, & Kumari, 2012). In order to improve the application of a social constructivist perspective, thereby enhancing primary science education in Confucian heritage culture, a new curriculum has been designed that takes characteristics of Confucian heritage culture and its cultural divergences with Western educational philosophy into consideration. The curriculum design used a social constructivist perspective as a theoretical foundation and referred to the "nature of science" education (Abd-El-Khalick & Lederman, 2000). The well-supported formal curriculum provided a curriculum framework for the design of specific science units for use in classroom practice in Confucian heritage culture (Chapter 3).

In the design process, the importance of the role of the teacher and his or her professional development (Coll & Taylor, 2012; Fullan, 1991) has been taken into account. Concurrent with the design of the social constructivism-based curriculum, a programme of teacher professional development was carried out, providing Confucian heritage teachers with the opportunity to co-design and teach science lessons (Chapter 4). The programme of teacher professional development aimed to help Confucian heritage teachers, who have been influenced by the culture and are accustomed to the traditional teaching of science, to adapt to and accommodate the designed curriculum. In this way, Confucian heritage teachers were expected to teach science lessons in accordance with the designed curriculum. Thereby, scientific lessons taught by them could be used to analyse and evaluate the designed curriculum according to a design-based research approach (Bulte, Westbroek, De Jong, & Pilot, 2006).

Through the programme of teacher professional development and the implementation of the designed curriculum in Confucian heritage culture, a specific lesson considered as the best functioning was selected for an in-depth analysis. This was necessary because an in-depth analysis of a specific lesson could provide details about both the achievements and problems of the designed curriculum. Based on this, the designed curriculum could be evaluated adequately, providing a basis for appropriate adjustment or improvement for a further application. Also, by thoroughly analysing a specific lesson in practice, a better understanding of not only theoretical but also practical knowledge about a social constructivist perspective for primary science education could be attained. Such knowledge was considered helpful in reducing the gaps which often exist between the ideal and formal curriculum, and the experiential and attained curriculum (Van Berkel, De Vos, Verdonk, & Pilot, 2000; Van den Akker, 2003). The knowledge provided in this study contributes to the knowledge base about designing and applying a social constructivism-based curriculum for primary science education in Confucian heritage culture.

The Formal Science Curriculum Based on a Social Constructivist Perspective

The formal curriculum was designed based on the key features of a social constructivist perspective, including: 1) Learning is social; 2) Knowledge is experience based; 3) Knowledge is constructed by learners; 4) All aspects of a person are connected; and 5) Learning communities should be inclusive and equitable (Beck & Kosnik, 2006). The curriculum aims to develop scientific skills (i.e., observing, hypothesising, experimenting, explaining, arguing, and questioning), attitudes (i.e., curiosity and interest in and response to science), and knowledge relevant to daily life in a comprehensive way for Confucian heritage students. Derived from these learning aims, a curriculum framework was established with the alignment of learning functions, learning settings, and educational expectations for each of the learning phases, which were labelled *Engagement*, *Experience*, *Exchange*, and *Follow-up* (Chapter 3). The framework was underpinned with knowledge of the "nature of science" education and Confucian cultural knowledge that could make it appropriate for Confucian heritage culture. In the curriculum framework, educational expectations, defined as important predictors of educational attainment (Duncan, Featherman, & Duncan, 1972; Sewell, Haller, & Ohlendorf, 1970; Sewell & Hauser, 1972), were also determined and considered as the link between the formal curriculum and the operational curriculum (Bulte et al., 2006; Van den Akker, 2003).

Based on the framework of the designed curriculum, curriculum units were designed to illustrate the ideas of the formal curriculum (Chapter 3). The framework of the formal curriculum is presented in Table 1. The learning activities of the formal curriculum are specifically illustrated by the activities for the curriculum unit called *Plant Roots*.

The educational expectations (Table 1) are considered as hypotheses on the students' learning processes when the designed curriculum is applied to the practice of the science classroom in Confucian heritage culture. These expectations are described in more detail in the following paragraphs.

Students' interest in scientific subject matter (Expectation a in Table 1) is important because of its relationship with learning achievements and lifelong learning (Bybee et al., 2009). This interest can be recognised through students' curiosity, their active and attentive engagement in learning, and their willingness to provide responses for questions or problems which are posed to help them acquire scientific knowledge and skills.

Students' curiosity (Expectation b) is a manifestation of students' interest in science. It can be recognised by students' attentive and concentrative engagement in recognising problems while learning science. It promotes students to generate actions to answer questions and solve problems, and also brings wonder and new questions (Minstrell & Van Zee, 2000).

The activeness of students in learning (Expectation c) is considered a typical characteristic of social constructivist learning (Pitsoe, 2007). It can be recognised by students' taking up various activities to learn science and by students' involvement in learning through all of the personal aspects, such as emotions, values, and actions (Beck & Kosnik, 2006). Specifically, students are expected to show their excitement, enthusiasm, and concentration in their learning of science.

Students' intuitive knowledge (Expectation d) reflects students' beliefs and prior knowledge which are attained by personal experiences. It is important and valuable for students to learn science (Driver, Guesne, & Tiberghien, 1998). Students' intuitive knowledge is considered a raw and primary source that can be recognised and found in students' daily life-related and metaphorical expressions (due to students' limited ability in language), in which the relevance to and grounds for scientific subject matter exist.

Arguing (Expectation e and g) is not only a learning goal but also a crucial activity in learning science. The nature of scientific argumentation is understood to contain a personal aspect and a social aspect (Driver, Newton, & Osborne, 2000; Ryu & Sandoval, 2012). The personal aspect refers to the content of argument, in which data, evidence,

Table 1. The curriculum framework with the learning activities illustrated by the curriculum unit *Plant Roots*

PHASE	FUNCTION	LEARNING SETTING		EXPECTATION
		Activity	Form	
Engagement	A. To provide students with the motivation to learn	1. Drawing a complete plant 2. Answering: *What did you draw? Why did you draw the plant root like that? How did you know it?*	1. In small groups and/or in the class as a whole	a. Students are interested in scientific subject matter
Experience	B. To evoke attitudes toward science C. To acquire procedural knowledge D. To acquire conceptual knowledge E. To acquire argumentative skills	3. Predicting (Exercise 1): Choose a wild plant in the school garden to observe. Discuss in the group the answers to the following questions: *a. What do you think the plant root looks like? Draw it.* *b. Why do you think so?* 4. Hands-on (Exercise 2): Pull out the wild plant in the school garden. Discuss in the group the answers to the following questions: *a. What does the plant root system look like? Draw it.* *b. Why does this plant have a root system like that?* *c. What are the functions of the plant root system? Why do you think so?* 5. Questioning (Exercise 3): *Write down questions or ideas related to the subject matter that you want to discuss.*	2. In small groups	b. Students are curious about representative examples of scientific subject matter c. Students are active in learning about representative examples of scientific subject matter d. Students use their intuitive knowledge to learn about scientific subject matter e. Students argue with each other to attain consensually agreed knowledge on representative examples of scientific subject matter

Exchange	F. To build on attitudes toward science G. To build on procedural knowledge H. To build on conceptual knowledge I. To build on argumentative skills in science	6. Presenting results to other groups 7. Discussing results with other groups 8. Answering formulated questions related to subject matter	3. In the class as a whole or in combined groups	f. Students are interactive in learning scientific subject matter g. Students argue with each other to attain consensually agreed knowledge on scientific subject matter
Follow-up	J. To acquire cognitive flexibility K. To further learning motivation	9.a. Answering questions: *What did you learn from the lesson today? Can you provide some examples of root types and explain why you think those plants have such root types?* 9.b. Determining type of root for some plants	4. In the class as a whole	h. Students can provide appropriate answers and/or solutions i. Students show their desire to learn more about scientific subject matter

and a casual structure (Hand, 2011; Ryu & Sandoval, 2012) are found. The social aspect refers to social interactive activities, such as evaluating, judging, questioning, qualifying, justifying, and rebutting in argumentations. The social activities of scientific argumentations can be detected in statements such as *I agree/disagree with you (because…); My opinions are the same/different on the point (…); Your opinions are interesting/weird/good; I don't think so; Your opinions are not plausible/acceptable (because…)*, and so on. These activities can help to elaborate and clarify personal explanations and arguments. By participating in these activities, students can attain consensually agreed knowledge (Expectation e & g). In this study, consensually agreed knowledge refers to the (best) possible answers rather than correct answers (see Dekkers, 2006) arrived at through negotiations among students. The expectation of achieving consensually agreed knowledge is considered to be suitable for Confucian heritage culture because this culture values collectivity, solidarity, and harmony (Chapter 2) that supports consensus in communication.

Interaction (Expectation f) is also considered a typical characteristic of social constructivist learning which is characterised by students' interactive activities, such as sharing and exchanging ideas, and discussing and negotiating with each other about knowledge of the subject matter (Hand, Treagust, & Vance, 1997). The social activities of scientific argumentation can be part of students' social interaction.

Appropriate answers and/or solutions (Expectation h), as expected to be provided by students in the Follow-up phase, are considered outcomes of the negotiations and scientific argumentation implemented in the previous phases, including Engagement, Experience, and Exchange. They can be derived from consensually agreed knowledge that students achieve in the previous phases. Therefore, appropriate answers are about possible or acceptable answers that are provided by students. Although the design focuses on formative assessment, this expectation is partially about summative assessment as it regards learning results.

The desire to learn (Expectation i) is considered to be the development of an interest in learning that can support students in lifelong learning (Bybee et al., 2009). A desire to learn reveals that students recognise the significance and meaningfulness of learning, and the issues associated with scientific subject matter as well. It stimulates them to pursue learning consciously and passionately. Students' desire to learn desire is shown by their willingness to continue their learning and their expectation to learn more about the specific scientific subject matter that is introduced in the lesson.

Research Question

This study focuses on an in-depth analysis of the lesson constructed from the social constructivism-based curriculum design. In this way, this study aims to achieve a proof of principle in relation to the design of the curriculum. According to Freudenthal (1991), a proof of principle involves two elements: (i) showing that the idea can be worked out by designing at least one unit in such a way that is convincing in itself, and (ii) demonstrating that the intended teaching-learning process can be implemented with a quality sufficient to meet the expectations of the designers. Specifically, this study focuses on providing the answer to the following research question:

To what extent does a unit of the curriculum design for primary science education in Confucian heritage culture meet social constructivist expectations in classroom practice?

Strategy

Setting up a programme of professional development for Confucian heritage teachers

For the implementation of the designed curriculum in the practice of primary science education in Confucian heritage culture, a 6-month programme of teacher professional development was carried out in Vietnam (Chapter 4). The programme was implemented on a small scale through the participation of three experienced Vietnamese teachers in an immersion approach to the social constructivist learning and teaching of the designed units (see Appendix A). In this programme, the teachers closely collaborated with the researcher who set up a work team. In the team, the researcher acted as the trainer and the leader, whilst the participating teachers acted as co-designers, observers, active teachers, and reflectors of the experimental lessons. In total, nine science lessons were prepared and co-designed, taught and observed, and intensively reflected on and discussed in the team (see Appendix A for an overview of the lessons).

Selection of the best-functioning lesson for an in-depth analysis

The best-functioning lesson was considered by the research team to provide educational achievements that the other experimental lessons in the programme could not provide. Therefore, the best-functioning lesson is better than the other lessons to be used for an in-depth analysis in order to evaluate the curriculum design.

For the selection of the best-functioning lesson, key selection criteria were established based on social constructivist features (Beck & Kosnik, 2006). The selection criteria used appear below:

i. The lesson is implemented in accordance with the designed lesson and consistent with the designed curriculum;

ii. The teacher implements attitudes and activities as a social constructivist teacher;

iii. Students are active and autonomous in learning;

iv. Social interactions are dominant in classroom practice and interactions among students are dominant for cooperative learning;

v. Knowledge is constructed by students through social negotiations.

The extent to which these criteria were satisfied was different among the nine experimental lessons. The work team agreed that the sixth lesson of the curriculum unit *Plant Roots* (Appendix A) was the best functioning because the students in this lesson were involved in learning more actively, cooperatively, and effectively than in the other experimental lessons.

Description of the best-functioning lesson of the science unit *Plant Roots*

The curriculum unit on *Plant Roots* is one of the three units (Appendix A) that were pre-designed by the research team to illustrate the ideas of the designed curriculum (Chapter 3). To apply this unit in practice, a learning card with specific written tasks was developed for students to use (Appendix B). The pre-designed curriculum unit on *Plant Roots* was later used for the teachers to rely on in order to co-design and develop the lesson plans of *Plant Roots* before they taught these lessons in the science classroom.

In the sixth lesson of *Plant Roots*, the Engagement and Experience phases took place outdoors, and the other phases took place indoors. The students interacted with real plants (wild ones) grown in the school garden in order to answer inquiry questions written on the learning card

(Appendix B). The teacher pre-determined various plants for the student groups to study. This was to ensure that each of the student groups would have an opportunity to study plant roots different from those studied by the other groups. The teachers organised the students to work in five small groups of six students each in the Engagement and Experience phases. Then the students worked in combined groups in the Exchange phase, in which individual students went to other groups to exchange ideas from the knowledge that they had discovered after carrying out inquiries. After that, the students were involved in learning in the class as a whole in the Follow-up phase, in which they were asked to answer new questions aimed to help them apply their achieved knowledge.

Participants

The sixth lesson of *Plant Roots* was taught by Vietnamese teacher T1, who was considered a competent teacher. Teacher T1 was 38 years old and had 18 years of experience teaching in primary school. Her practices in the science classroom had been observed by the first researcher in a previous study (Chapter 2). She was traditional in her teaching and influenced by Confucian heritage culture.

Thirty Vietnamese students at age ten were involved in this experimental lesson. The numbers of male and female students were relatively equal. These students had no experience with a social constructivist approach in their conventional science curriculum.

Data collection

Data from multiple sources were collected, including classroom observation, student questionnaires, post-interviews, and learning materials. The details of data collection for this lesson are presented below.

A. Classroom observation. Classroom observation allowed the researchers to develop a holistic perspective on the implementation of the designed social constructivism-based curriculum in science classroom practice in Confucian heritage educational settings. This is to say that they were able to characterise teachers' and students' activities and evaluate teaching and learning activities.

The lesson was observed by the researcher and the other teachers of the team. The classroom observation was implemented with the activities of note taking, video recording, and audio recording. One video camera was located in a convenient place either in the classroom or in the school garden, depending on where the teaching and learning took place in order to have the best overview of the lesson. Photos of the main activities of each of the learning phases in the lesson were taken by the researcher (see Figure 1). All of the discussions of the groups in the lesson were audio recorded to help the researcher obtain data which cannot be grasped by observing student learning from a distance. To record discussions of the groups, audio recorders were held by one of the students in each group (for outdoor activities) and set in the middle of the student tables (for indoor activities). The videotape and the audiotapes were later watched and listened to carefully, and transcribed verbatim.

B. Student questionnaires. Student questionnaires were employed to obtain information from a large population of students, who could provide their thoughts on the implementation of the designed science unit in classroom practice. Pre-questionnaires and post-questionnaires were employed for the study. The pre-questionnaires were distributed two months before the lesson took place; the post-questionnaires were distributed after the lesson. In both of the questionnaires, the students were asked to illustrate lessons in drawings (about a conventional science lesson and about the experimental lesson on *Plant Roots*). In the post-questionnaires, the students were asked to answer closed-ended questions and open-ended questions that aimed to elicit their reflections on and evaluations of the lesson. The questions for students to answer about the lesson *Plant Roots* in the post-questionnaires appear below:

1. To what extent did you like the lesson? (a likert-scaled question with a range of answers: 1 = *not at all* to 10 = *very much*). Why?

2. Was the lesson different from or similar to your conventional science lessons? Please specify differences or similarities.

3. What do you think about the learning involvement of your peers in this lesson?

4. Write down your thoughts about this lesson.

5. Please illustrate the lesson in a drawing.

C. Post-interview. To have elaborative feedback from the students, a semi-structured interview with the students was conducted after the lesson. Three students were randomly selected by the researcher. They were involved in a face-to-face group interview for about 30 minutes.

All of them were encouraged to be free in answering the questions, which were aimed at attaining their impressions of the lesson and testing their acquisition of knowledge on plant roots as introduced in the lesson. The main questions asked in the interview were:

1. What do you think about the lesson? Why do you think so?
2. What do you think about the learning involvement of your peers in this lesson? Why do you think so?
3. What did you learn from the lesson?
4. What are main functions of the root systems of plants?
5. What is the root type of kohlrabi? Why do you think so?

These questions were elaborated in more detail in the interview. The interview was audio recorded and transcribed verbatim afterwards.

D. Learning materials. All of the plant drawings and learning cards completed by the students were collected and used for the analysis of the lesson.

Data Analysis

The analysis was implemented in two cycles and sub-cycles. In the first cycle, the analysis was accomplished by the researcher. To answer the research question – *To what extent does the unit meet the expectations?* – the expectations (Table 1) were used as the organising elements to analyse the lesson and provide the leading themes for presenting the findings. Classroom observation was used as the main data source, the findings of which were verified and triangulated by data from the other sources. The analysis of the lesson led the researcher to formulate the main conclusions about the attainments of the expectations. Then the analysis and the corresponding conclusions to the attainments of the expectations of the lesson were discussed with the teachers in the team. Team discussion provided the consensus on the first cycle for the analysis and the conclusions about the lesson.

The second cycle of the analysis was carried out by the researchers of the research team (researcher and both supervisors) with several sub-cycles. Firstly, the researcher presented the analysis and the conclusions agreed upon by the teachers about the lesson to a second researcher (supervisor-2). Both the analysis and the conclusions about the attainments of the expectations were discussed thoroughly between the researcher and this second researcher several times.

They both then came to a consensus about the analysis and the conclusions. After that, this analysis was carefully discussed between the first researcher and a third researcher (supervisor-1). The in-depth discussions between the researcher and the third researcher helped both of the researchers obtain a deep analysis of the attainments of the expectations of the lesson. The analysis was then discussed among the entire research team to come to the final consensus. The discussions in two cycles with many sub-cycles and with the involvement of the participating teachers and the researchers provided opportunities to cross-check and validate the findings thoroughly (Creswell, 2009). In this way, the analysis and the corresponding conclusions about the attainments of the expectations were recorded in the format of a thick description of the lesson *Plant Roots*.

Findings

Overall, the students in this lesson were involved in learning actively, excitedly, and autonomously. The main activities for each of the learning phases carried out in the lesson are illustrated by the photos presented in Figure 1.

Engagement Phase

Expectation a: students are interested in scientific subject matter. In this phase, all five groups of six students were attentive in listening to the teacher's instruction. All of the students in the five groups were highly involved and concentrative in doing the practical task of drawing a complete plant as the main activity of this phase (Source A). This could be recognised by the students' actions, speech, and expressions, such as knitting the brows and furrowing the forehead (e.g., the male student in the sporty shirt in Photo 1 of Figure 1). Five drawings of plants were presented by the five groups (Source A and D). The students remained rather timid in presenting their work in front of the teacher and the class, and in providing answers for questions (Source A). Nevertheless, they looked curious and attentive in attitude while listening to answers and observing drawings. Based on their concentrative and attentive attitudes and their high involvement in learning in this phase, the classroom observation showed that the students were interested in learning about plant roots. This observation is consistent with the views of the students on the lesson shared in the post-interview. The interviewed students expressed that they enjoyed the activity of drawing a complete plant because it made them want to know what the other groups drew for a complete plant and why they drew the plant with the root system they did (Source C). The conclusion therefore is that the students were interested in plant roots.

1. *Engagement.* Drawing a complete plant in small groups

2. *Experience*. Examining real plant roots in the school garden

3. *Exchange*. Exchanging ideas in the combined group

4. *Follow-up*. Applying knowledge to answer new questions

Figure 1. Main learning activities of the students in the lesson (Source A)

Experience Phase

Expectation b: students are curious. In this phase, all students of the five groups were highly involved in implementing the two learning tasks: (i) providing predictions about the root systems of the pre-determined plants grown in the school garden and providing explanations of their predictions, and (ii) pulling the real plants out, observing their root systems, and providing explanations of the observed root systems (Source A). Fifty-six questions regarding plant roots were posed by the students personally during their discussions in the five groups (Source A). Twenty-two of the 56 questions were "Why" questions which were often elaborated from previous answers and focused on the specific plant root examined by each group (Source A). The following transcription shows an example of a discussion in one group.

1	Student A	What is the plant root for?
2	Student B	To absorb nutrients from underground.
3	Student C	To convey nutrients to the plant body that helps the plant to grow healthily.
4	Student A	*Why like that?*
5	Student C	Because the root grows downwards into the ground so it can absorb nutrients under the ground.
6	Student A	I don't think so. Because the fern lives in exhausted ground but it can still stay alive.
7	Student C	But it still needs nutrients to live.
		(*Group 2, Source A*)

Line 4 of this discussion records a question that Student A posed to justify the explanation of Student C. This question shows the curiosity and wonder of Student A that can be interpreted as wondering why student C thought the root would convey nutrients to the plant body even though some plants, such as the fern, can stay alive in exhausted ground where there are no (or very few) nutrients. This kind of question was often asked by individual students during their discussion. In addition to individual questions, eight questions were formulated cooperatively by the five groups and presented on the completed learning cards, such as *Why do big old trees have their root systems rising to the surface?* (Group 1)*; How many root types are there in total?* (Group 2)*; How will the tree be if it has no root?* (Group 3); *Why do small plants often have fibrous roots and big plants have tap roots?* (Group 4); *Why can plants live in the water?* (Group 5) (Source D). These questions showed that the students were curious about plant roots in the Experience phase.

In addition, practical actions, such as touching the plant (which two students are doing in Photo 2 of Figure 1), spreading the soil out at the foot of the plant to observe the root part better, bringing the root part closer to the eyes to observe details, and looking thoroughly at the root part (e.g., the middle student in Photo 2 of Figure 1), often took place while the students discussed the plant and its root system (Source A).

We therefore conclude that the students were curious about the root systems of the real plants.

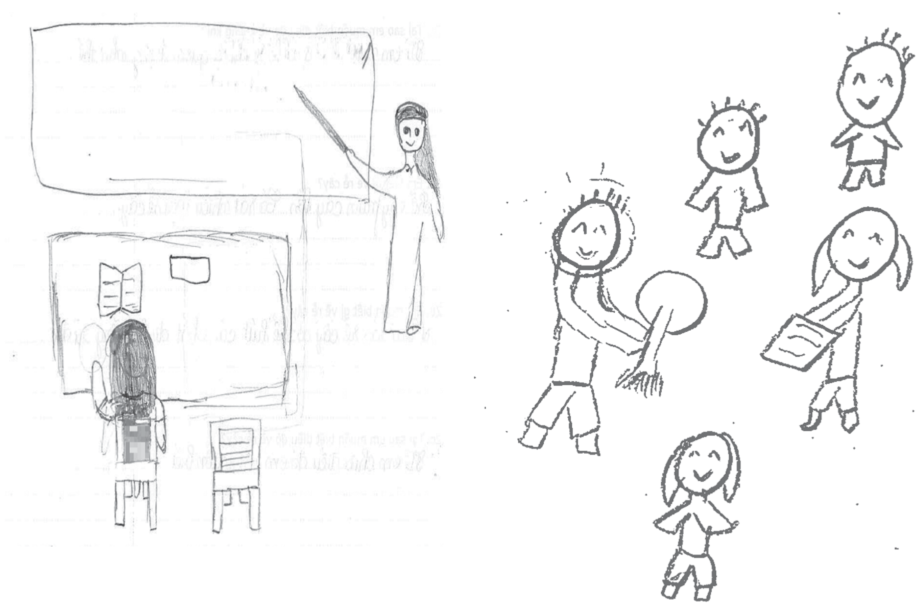
Expectation c: students are active in learning. All five groups discussed their plants noisily and actively while interacting with the real plants in the school garden (Source A). They looked highly enthusiastic and excited about learning, as could be recognised through their voices, their body language, their smiles (e.g., the leftmost student in the foreground group in Photo 2 of Figure 1), and their laughter (Source A). The various scientific activities, such as observing real plants, predicting what their root systems will look like, pulling the plants out of the ground, describing the root part, and discussing and explaining why the plants have such root systems were observed in all five groups (Source A). In addition, all of the five groups of students wrote about and provided drawings of the plant roots they examined (Source D). This active learning was also obvious in the students' thoughts about the lesson (Source B & C). All thirty students referred to the lesson in a positive way (Source B). The active learning that the students showed in the lesson was recognised in their description of the lesson, as summarised and presented in Table 2 (Source B).

Table 2. Students' description of the lesson (Source B)

	Written ideas	Students (N = 30)
1	Their peers as enthusiastic	23
2	The lesson as joyful	17
3	The lesson as interesting	15
4	The lesson as useful	12
5	Their peers as passionate	12
6	Their peers as active	9
7	Their peers full of ideas	7
8	The lesson as engaging	3
9	Their peers as cooperative	3
10	Satisfied with the lesson	2

The students' descriptive ideas (Table 2) reflect the active learning of the students. Moreover, all of the students acknowledged that the experimental lesson was significantly different than their conventional science lessons (Sources B & C). They preferred the experimental lesson because they had opportunities to work with real plants, stay in small groups, learn outdoors, discuss and cooperate with each other, and speak freely regardless of wrong answers (Sources B & C).

The active learning of the students in this lesson was also shown in the students' drawings to illustrate the lesson (Source B). There are explicit differences in the students' activities in this experimental lesson when compared to their conventional science lesson. Twenty-two of 27 drawings in the student pre-questionnaires illustrated static, individualistic learning or teacher-centred learning. This was shown by the images presented in the drawings, such as that of a student sitting neatly, alone or separately beside her peer(s), looking at the blackboard or reading a textbook (20 of 22 drawings), or that of only the teacher teaching (2 of 22 drawings). Such static learning can be represented by drawing 1 in Figure 2 (Source B). In the post-questionnaires, a very different picture of learning emerges: 20 of the 28 drawings illustrate student learning in action and cooperation in various learning activities, as represented by drawing 2 in Figure 2 (Source B).



1. In a conventional science lesson

2. In the (sixth) experimental lesson *Plant Roots*

Figure 2. The students' drawings of their learning activities (Source B)

As shown in drawing 2 (Figure 2), the students in the experimental lesson *Plant Roots* are engaged in learning through cooperative, active and practical activities, with joyful expressions on their faces. This was shown in their activities as well, such as gathering in a group, working with a real plant, writing, and smiling in an open environment of learning. The conclusion, therefore, is that the students were active in learning about the root systems of the real plants.

Expectation d: students use their intuitive knowledge. Intuitive knowledge was used by the students when they worked on the predicting and hands-on tasks on plant roots (Source A). Since the students could not at first see the root systems of the given plants (because the root systems were under the ground), they often referred to their prior knowledge to describe the plant roots (Source A). When interacting with the real plant roots for the hands-on task, the students in the five groups used everyday knowledge to describe the forms of the root systems and to provide explanations (Source A). This was recognised in the students' informal and metaphorical statements and expressions as in the discussion below.

1	Student D	This root has a white colour at its under part.
2	Student E	Spreading into many sides.
3	Student F	Falling down like a bunch.
4	Student G	Like a willow tree.
5	Student F	Like leaves of the willow tree hanging down.
6	Student H	What else?
7	Student I	Small as a finger.
8	Student E	Like thinly threaded meat.
9	Student D	Like an octopus.

In this conversation, students used the phrases *spreading into many sides* (Line 2), *falling down like a bunch* (Line 3), *like a willow tree* (Line 4), *like leaves of the willow tree hanging down* (Line 5), *small as a finger* (Line 7), *like thinly threaded meat* (Line 8), and *like an octopus* (Line 9) to describe the root system of the plant they studied. All of these expressions show the intuitive knowledge regarding plant roots that the students used to learn about plant roots. Such comparative phrases and expressions were also used in the other discussions, in which students compared the root to a snake, determined sizes of roots by comparing them with the span of one group member, and referred to their non-scientific prior knowledge (Source A). In the post-interview, the interviewed students also acknowledged that many "funny" words and expressions were used by their peers when they were discussing the root systems of the given plants (Source C). The "funny" expressions noted by the interviewed students reflected intuitive knowledge that the students applied to learning about plant roots in this lesson. The conclusion, therefore, is that the students used their intuitive knowledge to learn about the plant roots.

Expectation e: students argue with each other to attain consensually agreed knowledge. Various personal scientific arguments and explanations about plant roots were raised by the individual students in all five groups for answering the given question *Why do you think the plant has the root system like that?* (Source A). All of these personal arguments and explanations were simple in general and often used the relation-indicating linking word *because*: for example, *because this plant is small; because its leaves are large; because its shape is bent*; *because its foot has many small bodies growing up; because the plant is smaller than the others;* and *because it has serrated leaves* (Source A). The personal arguments were constructed with data and evidence which often relied on the outer characteristics of the plant, such as small body, large leaves, bent shape, serrated leaves, or plant foot with small bodies (Source A).

In total, ten scientific arguments were made cooperatively in the five groups and written on the learning cards (Source D). These group arguments were constructed by the linking word *because* or *therefore* and supported with data and evidence which also relied on the outer characteristics of the plant, for instance: *The root system of the plant is small fibrous roots huddled together, because the plant has a small and curved body* (Group 4). In this case, we interpret that "*a small and curved body*" was used as data and evidence in the argument of Group 4 in order to explain the form of the root system of the group's plant (which was described to be small fibrous roots huddled together).

Despite being active in providing personal explanations and arguments, the students hardly argued with each other. This can be illustrated by the transcription of a group discussion presented below.

1	Student K	What do you think about the root of this plant?
2	Student L	It is sinuous.
3	Student M	It is dry, sinuous, and thrusts deeply into ground.
4	Student N	It is not big but somewhat small.

5	Student O	It is sinuous, dry, small, and thrusts deeply into ground.
6	Student K	Anything else?
7	Student L	Nope.
8	Student K	Let's think!
9	Student M	It spreads out into many branches.
10	Student N	Like a ginseng. It has many clods at its foot.
11	Student O	A fibrous root!
12	Student K	How do you know it is fibrous root?
13	Student O	Because it is small and low.
14	*Teacher T1*	Why do you think it is a fibrous root? How do you know it? Tell us!
15	Student O	Because I see its leaf canopy is in a clump shape.
16	Student M	Because I see this plant has many branches and its foot spreads out into fibre.
17	Student L	Because… it is natural.

In the discussion quoted above, the students mainly provided single explanations and arguments, most of which were not evaluated, judged, qualified, or rebutted by their peers, though questioning was implemented by the students (e.g., Line 12). This continued even when opposing ideas were presented, such as *It has many clods at its foot* (Line 10) and *Its foot spreads out into fibre* (Line 16). Although many personal explanations and arguments were provided as answers for the given questions, the groups' final answers were often found to have been decided personally by the individuals who were the group leaders or the most competent students in the groups (Source A). The conclusion, therefore, is that the students argued with each other to a small extent and they attained imposed knowledge rather than consensually agreed knowledge on plant roots.

Exchange Phase

Expectation f: students are interactive. To inspire the exchange of ideas, the students were encouraged to take up the roles of the questioner and the answerer by reusing the questions introduced for the hands-on task in their exchanging dialogues (Source A). At the beginning of this phase, the students exchanged ideas with rather passive attitudes (Source A). In the later part of this phase, the students became more active and involved in exchanging ideas (Source A). The activity of questioning was taken up by one or two of the students in the combined groups. These students used the questions given in the Experience phase as the leading questions. All of the students in the combined groups in turn provided their answers for the questions asked by their peers (Source A). In this way, the students presented the results of the inquiries carried out in the former phase to those from different groups. The conclusion, therefore, is that the students were interactive in learning in this phase.

Expectation g: students argue with each other to attain consensually agreed knowledge. The occurrence of argumentation in this phase was no better than in the Experience phase. This can be illustrated by a representative exchange from a combined group discussion as presented below.

1	Student Q	Can you describe the root system of your group's plant?
2	Student R	The root system of our group's plant is fibrous roots. The roots are short, small, and grow in wet grounds.
3	Student Q	Why do you think that the root system is fibrous roots?
4	Student R	Because I find its body is curved, small, and soft.
5	Student Q	What are the functions of the plant root?
6	Student R	The plant root absorbs nutrients from underground and conveys them up to the plant body in order to help the plant stay healthy.
7	Student Q	Why do you think the plant has that function?
8	Student R	Because the root system digs into the ground.

As seen in the above conversation, two students from two different groups played two roles: one as a questioner and the other giving answers. Many personal explanations were expressed by Student R (e.g., Lines 1, 4, 6, and 8), but they were not evaluated, judged, qualified, or rebutted by Student Q. The *Why* questions asked by Student Q in the conversation (Lines 3 & 7) could be understood as the way in which Student Q justified the explanation of Student R, however, these questions were originally introduced on the learning card (Appendix B). Questions developed from the at-hand conversational explanations, e.g. *How do you know the plant growing in wet ground has a fibrous root system?* or *Why do some plants with its root system not pitch into the ground but into water instead and still stay healthy*?, were not asked by Student Q. The lack of such kinds of interactive questions show that social argumentation between these students was low.

The way in which the students exchanged ideas in the conversation quoted above was similar to the exchanges of the other combined groups (Source A). The students often reproduced explanations and arguments that had been formulated in their small groups in the Experience phase (Source A). They neither evaluated explanations and arguments nor elaborated them by justifying, judging, qualifying, and rebutting while they were exchanging ideas (Source A). Although the students provided many answers and presented results for students from different groups, the knowledge the students achieved in this phase remained separate rather than being consensually agreed. The conclusion, therefore, is that the students argued with each other to a small extent in this phase.

Follow-Up Phase

Expectation h: students can provide appropriate answers and/or solutions. In this phase, overall, the students provided appropriate answers for new questions asked by the teacher. Nevertheless, a few answers given by the students were inappropriate. When the teacher asked the students to determine the root type of a prepared plant, for instance, the students acknowledged that the prepared plant had a fibrous root system and explained that they knew this because the plant had many small roots sprouting out from one main root (Source A). However, the root system of that plant was taproot because its characteristics match the characteristics of the taproot system: one large main root from which sprout many lateral small roots.

This happened again in the post-interview, in which the students were asked to answer some questions of a test made by the researcher (Source C). Four of 13 answers given by the students were inappropriate. Examples include: *There were three types of root system, including: the fibrous root, the taproot, and the smaller lateral root* and *Kohlrabi has a fibrous root system* (Source C). The first answer was considered inappropriate because the smaller lateral root is a part of the taproot system, so it is not in the same category as the taproot and fibrous root as a type of plant root. The second answer was also considered inappropriate because the root system of the kohlrabi is taproot, since it has one large main root which grows downward into the ground. Notably, in the lesson, the students were provided with a picture of kohlrabi and they characterised its parts. Given the inappropriate answers of the students in the Follow-up phase and in the testing, the conclusion is that the expectation about students providing appropriate answers by applying attained knowledge was not completely satisfied.

Expectation i: students show their desire to learn science. Despite inappropriate answers, in this phase the students were highly active and involved in applying the knowledge of plant roots conveyed in the lesson to answer questions asked by the teacher (Source A). Twenty-nine of 30 students were attentive and focussed on learning in this phase (Source A). More than half of the class actively volunteered to provide answers to the teacher's questions (Source A). Only one student, whose seat was backside to the blackboard, was inattentive during the majority of this learning time (Source A).

The students' desire to learn through this lesson can be partly revealed by their answers in the questionnaires. Twenty-seven of 30 students circled 10, 2 of 30 students circled 9, and only one student circled 8 to indicate the extent to which they liked the lesson (Source B). The students' desire to learn was expressed in a direct or indirect way in their answers to the open-ended question asking them to reflect on the lesson (Source B), as in the comment below:

> I liked this lesson very much…. I wish I and my peers would have more science lessons like this. (Student T, Source B).

This is consistent with the findings in the post-interview. All three of the interviewed students revealed their expectation of having more opportunities to learn science as they did in the experimental lesson (Source C). We therefore conclude that the lesson was effective in inspiring students to have a greater desire to learn science.

Conclusions and Discussion

In providing the answer for the research question, *To what extent does a unit of the curriculum design for primary science education in Confucian heritage culture meet social constructivist expectations in classroom practice?,* this study shows that the newly designed curriculum unit can encourage Confucian heritage students to be interested in scientific subject matter (Expectation a), curious in learning about scientific examples (Expectation b), and active in learning science (Expectation c). Also, the findings show that the curriculum unit could help students use intuitive knowledge to learn science (Expectation d), be interactive in learning (Expectation f), and have the desire to learn science

(Expectation i). With these educational attainments of the curriculum unit, the study shows that the designed curriculum can be a possibility for applying to primary science education in Confucian heritage culture in order to overcome the analysed problems associated with primary science education (Chapter 2). Specifically, the designed curriculum can help Confucian heritage students change from passive learning to more active and interactive learning.

With the majority of the expectations met by the unit, this study shows that the research question receives a positive answer and the study delivers a proof of principle (Freudenthal, 1991; Westbroek, Klaassen, Bulte, & Pilot, 2010). The lesson analysed in this study was the best-functioning lesson in the programme of teacher professional development that provided Confucian heritage teachers with opportunities to interact with the designed curriculum by co-designing, observing, teaching, and reflecting on the experimental lessons. The teacher in this lesson had attained considerable experience of social constructivist approaches to science education through the programme designed to help teachers adapt to such approaches (Chapter 4). The attainments of the expectations in implementing the unit on *Plant roots* could be different if the unit were taught in different conditions, such as by a teacher whose professional capability and experiences of social constructivist teaching are lower. The proof of principle delivered by this study shows that the designed curriculum and curriculum units can be feasible and promising under certain conditions in which the skill and experience of the teacher, as well as teacher professional development play a crucial role.

With the positive answer to the above research question, the study shows that Western educational philosophy, particularly a social constructivist perspective and the "nature of science" education, can be applied to primary science education in Confucian heritage culture. In this way, the study reinforces the proposition that teaching and learning are highly contextual and teachers and learners are highly adaptive (Biggs, 1996; Volet & Renshaw, 1996), and if the curriculum is designed in a culturally appropriate way, it can avoid a "false universalism"(Nguyen, Elliott, Terlouw, & Pilot, 2009).

Nevertheless, the study showed that the newly designed curriculum was not effective enough in encouraging Confucian heritage students to practice scientific argumentation in a science lesson. This is evident in the modest attainments of Expectations e, g and h (Table 1). On the one hand, these modest attainments can be related to the limitations of a social constructivist perspective, which has been criticised as resulting in relative content knowledge (Benson, 2001). According to Brophy (2006), a social constructivist approach can lead lessons to stray from lesson goals and content, and has the potential to expose the class as a whole to numerous incorrect ideas. These limitations of a social constructivist perspective have made some educators pessimistic about the application of a social constructivist approach to teaching and learning (see Nuthall, 2002; Tobias & Duffy, 2009). On the other hand, these modest attainments show that scientific argumentation can be the most difficult and challenging problem for the application of a social constructivist perspective to primary science education in Confucian heritage culture. The low implementation of scientific argumentation (Expectations e and g) could be the influential factor that led the students to have the modest attainment of consensually agreed knowledge and to provide inappropriate answers when applying knowledge (Expectation h).

The finding of the low level of scientific argumentation in the lesson applying a social constructivist approach to the subject of science is an emergent contribution of the study. In the other words, the study shows that scientific argumentation is the bottleneck in the implementation of a social constructivism-based curriculum in primary science education in Confucian heritage culture. This identification can be related to the dramatic challenge and the stumbling block involved in applying inquiry-based approaches and constructivist theories to the practice of science education in Confucian heritage countries such as Taiwan, Korea, Singapore, and China (see Abd-El-Khalick et al., 2004; Kim & Tan, 2011; Lee, Tan, Coh, Chia, & Chin, 2000; Tao, Oliver, & Venville, 2013).

To promote a social constructivist approach in primary science education in Confucian heritage culture, this study shows that scientific argumentation needs to become a focus for design-based research about applying constructivist views to science education in Confucian heritage culture. Promoting scientific argumentation for Confucian heritage students through science education is necessary. This is due to the crucial role scientific argumentation is thought to play in science education (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Millar & Osborne, 1998). Scientific argumentation can help students think critically, logically, and creatively about world phenomena (Kuhn, 1993;

Jiménez-Aleixandre, Bugallo Rodríguez, & Duschl, 2000), understand a core aspect of scientific practice (Driver et al., 2000; Duschl, 2008), and be prepared for citizenship (Kolstø, 2001).

The need for promoting and supporting scientific argumentation for Confucian heritage students is more considerable when it is related to the characteristic of harmony preference found in Confucian heritage culture. This cultural characteristic is considered to hinder argumentation in the teaching and learning of science.

Although not all of the expectations were met by the unit enacted in practice and despite the limitations of a social constructivist perspective in teaching and learning, it should not be thought that the limitations of a social constructivist perspective cannot be overcome or that such an approach cannot be applied to primary science education in Confucian heritage culture. Rather, in a more positive view, the low level of scientific argumentation among Confucian heritage students found in this study shows that the curriculum design needs to be reviewed and adjusted so that it can help support Confucian heritage students in practicing scientific argumentation in science lessons through a social constructivist approach. Also, it provides new directions for further research about applying a social constructivist perspective in Confucian heritage contexts. Confucian cultural characteristics (Chapter 2), for instance, and especially the harmony preference, need to be taken into consideration. Therefore, the next step is that designers should search for appropriate pedagogical solutions to support scientific argumentation that can be compatible with the feature of harmony in Confucian heritage culture.

In addition to the issue of adjusting the curriculum design, the role of teachers in encouraging Confucian heritage students to practice scientific argumentation is stressed as crucial. To do that, Confucian heritage teachers need to be equipped not only with content knowledge of science and pedagogical knowledge of social constructivist teaching but also the knowledge and skills associated with scientific argumentation. Programmes of teacher professional development, therefore, are needed. In this way, a social constructivist approach can be applied as an immersion approach for teacher professional development. The previous study (Chapter 4) proved that Confucian heritage teachers could gradually change toward a social constructivist approach to teaching science through a programme of teacher professional development in which the teachers acted as co-designers and teachers of social constructivist lessons. With all of the findings presented in this study, this study contributes to a knowledge base about the design and application of a social constructivism-based curriculum for primary science education in Confucian heritage culture.

Endnote

All names of the teachers and students used in this study are pseudonyms.

References

Abd-El-Khalick, F., Boujaoude, S., Duschl, R., Lederman, N. G., Mamlok-Naaman, R., & Hofstein, A. (2004). Inquiry in science education: International perspectives. *Science Education, 88*(3), 397–419.

Abd-El-Khalick, F., & Lederman, N. G. (2000). Improving science teachers' conceptions of nature of science: A critical review of the literature. *International Journal of Science Education*, *22(7)*, 665–701.

Beck, C., & Kosnik, C. (2006). *Innovations in teacher education – A social constructivist approach*. Albany, NY: State University of New York Press.

Benson, G. D. (2001). Science Education from a social constructivist position: A worldview. *Studies in Philosophy and Education*, *20*, 443–452.

Biggs, J. (1996). Western misperceptions of the Confucian-heritage learning culture. In D. Watkins & J. Biggs (Eds.), *The Chinese learner: Cultural, psychological and contextual influences* (pp. 45–67). Hong Kong: The University of Hong Kong Comparative Education Research Centre.

Brophy, J. (2006). Graham Nuthall and social constructivist teaching: Research-based cautions and qualifications. *Teaching and Teacher Education*, *22*, 529–537.

Bulte, A. M. W., Westbroek, H. B., De Jong, O., & Pilot, A. (2006). A research approach to designing chemistry education using authentic practices as contexts. *International Journal of Science Education, 28*(9), 1063–1086.

Bybee, R., McCrae, B., & Laurie, R. (2009). PISA 2006: An assessment of scientific literacy. *Journal of Research in Science Teaching, 46*(8), 865–883.

Coll, R. K., & Taylor, N. (2012). An international perspective on science curriculum development and implementation. In B. J. Fraser, K. G. Tobin, & C. J. McRobbie (Eds.), *Second international handbook of science education* (Vol. II, pp. 771–782). Dordrecht, the Netherlands: Springer.

Creswell, J. W. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches* (3rd ed). Thousand Oaks, CA: Sage Publications.

Dekkers, P. (2006). Reconstructing the creature – Exploring design criteria for teaching NOS. In E. Van den Berg, T. Ellermeijer, & O. Slooten (Eds.), *Proceedings of the GIREP Conference Modelling in Physics and Physics Education* (pp. 459-464). Amsterdam, the Netherlands: University of Amsterdam.

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher*, *23*(7), 5–12.

Driver, R., Guesne, E., Tiberghien, A. (1998). *Children's ideas in science*. Milton Keynes, UK: Open University Press.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education, 84*, 287–312.

Duit, R., & Treagust, D. (1998). Learning in science – From behaviorism towards social constructivism and beyond. In B. L. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (pp. 3–25). Dordrecht, the Netherlands: Kluwer Academic Publishers.

Duncan, O. D., Featherman, D. L., & Duncan, B. (1972). *Socioeconomic background and achievement.* New York, NY: Seminar Press.

Duschl, R. A. (2008). Science education in three-part harmony: Balancing conceptual, epistemic and social goals. *Review of Research in Education*, *32*(1), 268–291.

Freudenthal, H. (1991). *Revisiting mathematics education.* Dordrecht, Netherlands: Kluwer Academic Publishers.

Fullan, M. G. (1991). *The new meaning of educational change* (2nd ed). New York, NY: Teachers College Press.

Hand, B. (2011). An immersion approach to argument-based inquiry – Does it look the same in different countries? In Y. Kim, J. Park, H.E. Seo, J.A. Lee, & J. Kim (Eds.), *Proceedings of the 2011 EASE International Conference – Lighting the world with science* (pp. 45-54). Gwangju, Korea: Chosun University,

Hand, B., Treagust, D. F., & Vance, K. (1997). Student perceptions of the social constructivist classroom. *Science Education*, *81*(5), 561–575.

Hofstede, G. (1986). Cultural difference in teaching and learning. *International Journal of Intercultural Relations*, *10*, 301–320.

Jiménez-Aleixandre, M. P., Bugallo Rodríguez, A., & Duschl, R. A. (2000). "Doing the lesson" or "doing science": Argument in high school genetics. *Science Education*, *84*(6), 757–792.

Kim, M., & Tan, A. L. (2011). Rethinking difficulties of teaching inquiry-based practical work: Stories from elementary pre-service teachers. *International Journal of Science Education*, *33*(4), 465–486.

Kolstø, S. D. (2001). Scientific literacy for citizenship: Tools for dealing with the science dimension of controversial socioscientific issues. *Science Education*, *85*(3), 291–310.
Kuhn, D. (1993). Science as argument: Implications for teaching and learning scientific thinking. *Science Education*, *77*(3), 319–337.
Lee, K. W., Tan, L. L., Coh N. K., Chia, L. S., & Chin, C. (2000). Science teachers and problem solving in elementary schools in Singapore. *Research in Science and Technological Education*, *18*(1), 113–126.
Millar, R., & Osborne, J. F. (Eds.). (1998). *Beyond 2000: Science education for the future*. London, UK: King's College.
Minstrell, J., & Van Zee, E. H. (Eds.). (2000). *Inquiring into inquiry learning and teaching in science.* Washington, DC: American Association for the Advancement of Science.
Neuman, Y., & Bekerman, Z. (2000). Cultural resources and the gap between educational theory and practice. *Teachers College Record, 103*(3), 471–484.
Nguyen, M., Elliott, J., Terlouw, C., & Pilot, A. (2009). Neocolonialism in education: Cooperative learning, Western pedagogy in an Asian context. *Comparative Education*, *45*(1), 109–130.
Nuthall, G. (2002). Social constructivist teaching and the shaping of students' knowledge and thinking. In J. Brophy (Ed.), *Social constructivist teaching: Affordances and constraints* (pp. 43–79). New York, NY: Elsevier.
Örtenblad, A., Babur, M., & Kumari, R. (2012). Learning in Asia, *Asia Pacific Journal of Education*, *32*(2), 131–136.
Pitsoe, V. J. (2007). *A conceptual analysis of constructivist classroom management.* University of Pretoria.
Ryu, S., & Sandoval, W. A. (2012). Improvements to elementary children's epistemic understanding from sustained argumentation. *Journal of Science Education*, *96*(3), 488–526.
Serpell, R. (2007). Bridging between orthodox western higher educational practices and an African sociocultural context. *Comparative Education*, *43*(1), 23–51.
Sewell, W. H., Haller, A. O., & Ohlendorf, G. W. (1970). The educational and early occupational attainment process: Replication and revision. *American Sociological Review, 35*, 1014–1027.
Sewell, W. H., & Hauser, R. M. (1972). Causes and consequences of higher education: Models of the status attainment process. *American Journal of Agricultural Economics*, *54*, 851–861.
Tao, Y., Oliver, M., & Venville, G. (2013). A comparison of approaches to the teaching and learning of science in Chinese and Australian elementary classrooms: Cultural and socioeconomic complexities. *Journal of Research in Science Teaching*, *50*(1), 33–61.

Tobias, S. & Duffy, T. (2009). Constructivist Instruction: Success or Failure, New York: Routledge.

Totten, S., Sills, T., Digby, A., & Russ, P. (1991). *Cooperative learning: A guide to research*. New York, NY: Garland.

Van Berkel, B., De Vos, W., Verdonk, A. H., & Pilot, A. (2000). Normal science education and its danger: The case of school chemistry. *Science & Education, 9*, 123–159.

Van den Akker, J. J. H. (2003). Curriculum perspectives: An introduction. In J. J. H. Van den Akker, W. Kuiper, & U. Hameyer (Eds.), *Curriculum landscape and trends* (pp. 1–10). Dordrecht, the Netherlands: Kluwer Academic Publisher.

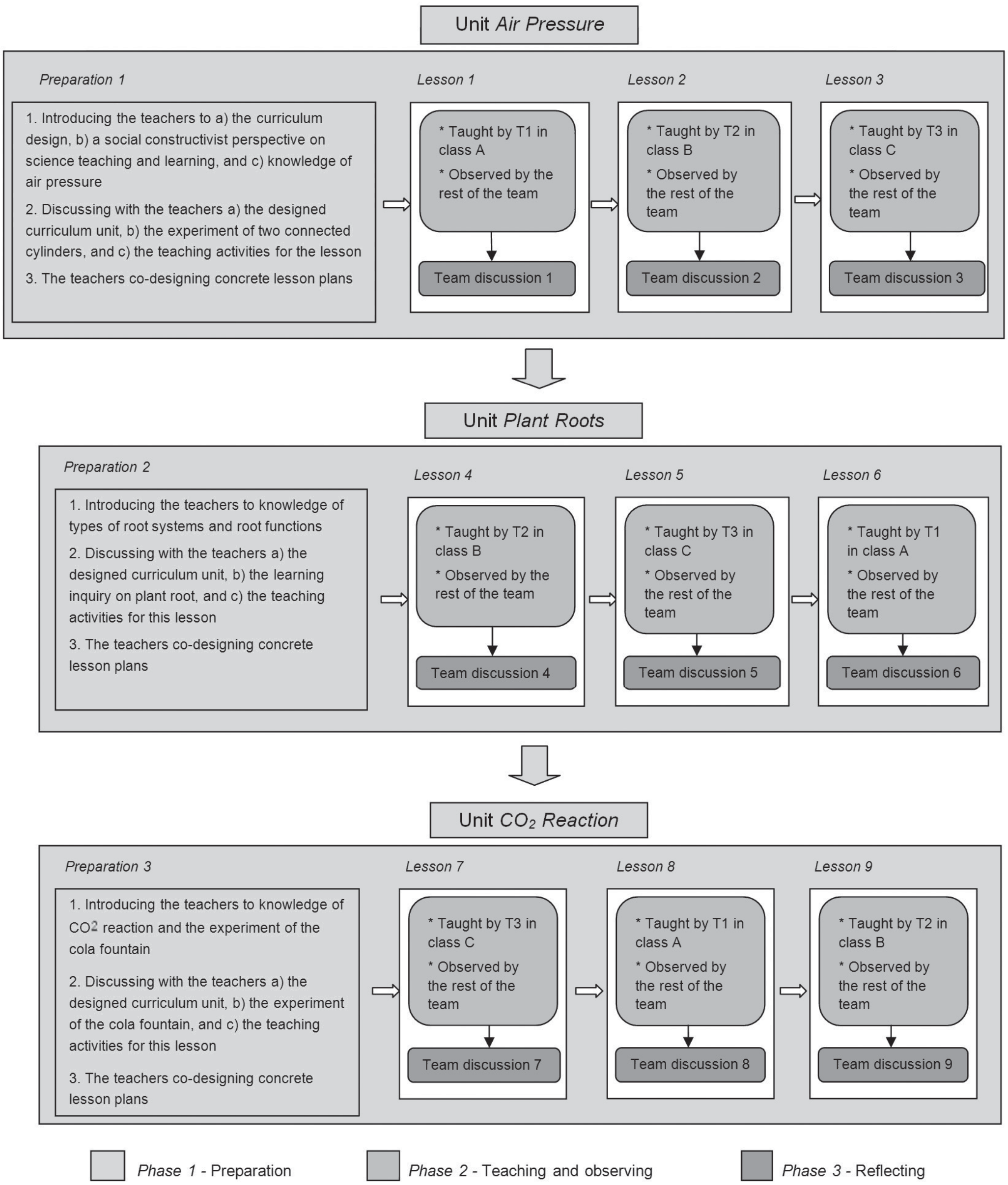
Volet, S., & Renshaw, P. (1996). Chinese students at an Australian university: Adaptability and continuity. In D. A. Watkins & J. B. Biggs (Eds.), *The Chinese learner: Cultural, psychological and contextual influences* (pp. 205-220). Hong Kong: The Central Printing Press.

Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Watson, J. (2001). Social constructivism in the classroom. *Support for Learning*, *16*(3), 140–147.

Westbroek, H. B., Klaassen, K., Bulte, A., & Pilot, A. (2010). Providing students with a sense of purpose by adapting a professional practice. *International Journal of Science Education*, *32*, 603–627.

Appendix A - The implementation of the teacher professional development programme



Appendix B - Learning card of the lesson *Plant Roots*

Exercise 1. *Predicting:* *Observe a wild plant. Discuss it with peers in your group in order to answer the following questions:*

a. What do you think the root system of the plant will look like? Draw it.

....

....

b. Why do you think so?

....

....

Exercise 2. *Hands-on:* *Pull out the wild plant. Discuss it with peers in your group in order to answer the following questions:*

a. What does the root system of the plant look like? Draw it.

....

....

b. Why do you think this plant has a root system like that?

....

....

c. What do you think the functions of the root system of the plant are? Why do you think so?

....

....

Exercise 3. *Questioning:* *Do you have any questions to ask or to discuss with the whole class?*

....

....

Chapter 1. Introduction and Research Overview

What is the design of curriculum for primary science education that has social constructivist characteristics and is appropriate with Confucian heritage culture?

PROBLEM ANALYSIS

Chapter 2. The implementation of a social constructivist perspective in primary science education in Confucian heritage culture: the case of Vietnam

RQ1. To what extent is a social constructivist perspective implemented in primary science education in Confucian heritage culture?

RQ2. How can this implementation be explained from a Confucian cultural perspective and what are fostering and hindering cultural factors to the implementation?

DESIGN CYCLE 1

Chapter 3. Designing a formal curriculum based on a social constructivist perspective for primary science education in Confucian heritage culture

RQ. What is the design of formal curriculum for primary science education that has social constructivist characteristics and is appropriate with Confucian heritage culture?

Chapter 4. Teacher professional development: The interaction of Confucian heritage teachers with a social constructivism-based curriculum for primary science education

RQ. In what way do Confucian heritage teachers interact with a primary science curriculum, which is based on a social constructivist perspective and made appropriate with Confucian heritage culture, in a program of professional development?

Chapter 5. Scientific argumentation as bottleneck for implementing a social constructivism-based science curriculum in Confucian heritage culture

RQ. To what extent does the unit of the curriculum design for primary science education in Confucian heritage culture meet the social constructivist expectations in the practice of the classroom?

DESIGN CYCLE 2

Chapter 6. Improving scientific argumentation through a social constructivism-based curriculum for primary science education in Confucian heritage culture

RQ1. To what extent does the unit of the adjusted design of social constructivism-based curriculum for primary science education in Confucian heritage culture support students to practice scientific argumentation in a science lesson?

RQ2. To what extent does the unit of the adjusted design of social constructivism-based curriculum for primary science education in Confucian heritage culture support students to attain consensually agreed knowledge on scientific subject-matter?

Chapter 7. Conclusions, Reflection and Recommendations

RQ. What is the design of curriculum for primary science education that has social constructivist characteristics and is appropriate with Confucian heritage culture?

CHAPTER 6 Improving Scientific Argumentation through a Social Constructivism-Based Curriculum for Primary Science Education in Confucian Heritage Culture[1]


2

Abstract This study describes the improvement of a social constructivism-based curriculum in order to support Confucian heritage primary students in practicing scientific argumentation in a science lesson. The former design is adjusted by the application of an adapted model of the learning placemat for argumentation and by the formulation of concrete teaching-learning activities which are articulated with the application of the adapted learning placemat. The practice of a designed curriculum unit reveals that the designed curriculum can support Confucian heritage students in practicing scientific argumentation and in attaining consensually agreed knowledge. Nevertheless, the study also shows that Confucian heritage teachers and students do not pay much attention to the activities of qualifying and rebutting in scientific argumentation. The study recommends that further developmental research needs to deal with the refined problem of how to improve qualifying and rebutting in scientific argumentation in the practice of science lessons in Confucian heritage culture.

1 This chapter is submitted as: Hằng, N. V. T., Bulte, A. M. W., & Pilot, A. *Improving Scientific Argumentation through a Social Constructivism-Based Curriculum for Primary Science Education in Confucian Heritage Culture.*

2 A photo of the analysed experimental science lesson (from the data source of classroom observations of this study)

Introduction

The teaching and learning of science in Confucian heritage culture maintains a traditional approach which is teacher-centred, while students remain passive in constructing knowledge (Chapter 2; Tao, Oliver, & Venville, 2013; Xiao, 2009). Meanwhile, it is considered difficult to apply a constructivist approach to a community in which students have been passive in receiving information (Neuman & Bekerman, 2000). Culture is known to influence education (Hofstede, 1986; Hofstede, Hofstede, & Minkov, 2010) and Confucianism has influenced teaching and learning with rote learning, the application of quotations and examples, and students' avoidance of confrontations and argumentation in discussion (Chapter 2; Chan, 1999; Hofstede, 2003). Yet there is a need for change and for policies to make advanced educational theories applicable in Confucian heritage countries. The changes aim to help students be active and autonomous in constructing and grasping knowledge and skills; thereby, they can be well educated to be future labourers who can cope with the challenges of modern times and contribute to the development of countries (see Ministry of Education [China], 2010; Ministry of Education [Taiwan], 1999; Ministry of Education and Human Resources [Korea], 2007; Ministry of Education and Training [Vietnam], 2006). Coping with these issues, researchers call for curriculum development that takes cultural resources and local experiences into consideration (Coll & Taylor, 2012; Neuman & Bekerman, 2000) so that culturally appropriate pedagogies can be developed (Phuong-Mai, Terlouw, & Pilot, 2005).

Derived from the above issues, a new curriculum framework for primary science education was designed, which was based on a social constructivist perspective (Chapter 3). This curriculum design took the cultural divergences between Confucian heritage culture and Western educational philosophy into account (Chapter 2) and focussed on the "nature of science" with an emphasis on an inquiry-based approach (Abd-Al-Khalick & Lederman, 2000). According to Anderson (2007), what is called inquiry learning is very similar to what others call constructivist learning and as with inquiry, the constructivist label can be applied to the nature of science learning and teaching (Anderson, 2007, p. 809). A social constructivist approach is considered to create a learning community, providing students with strong social and emotional support that enables them to take risks and develop ownership (Beck & Kosnik, 2006). It can thereby help students develop not only knowledge but also critical thinking (Totten, Sills, Digby, & Russ, 1991) and communication skills (Confrey, 1985).

The designed curriculum was put into practice through a programme of teacher professional development in Vietnam (Chapter 4). The analysis of the first design cycle showed that the lessons could support Confucian heritage students in becoming interested in science, curious about scientific subject matter, and both active and interactive in learning science (Chapter 5). However, despite considerable positive achievements, the first cycle curriculum design was not effective enough in supporting Confucian heritage students in scientific argumentation (Chapter 5). Specifically, Confucian heritage students tended not to argue with each other while carrying out argumentative tasks. The study revealed that scientific argumentation was the core problem, and could be considered a bottleneck for implementing a social constructivist perspective in primary science education in Confucian heritage culture (Chapter 5).

Meanwhile, scientific argumentation is a core aspect of science education (Driver, Newton, & Osborne, 2000; Hand, 2011). It is stressed as important and necessary to students' learning of science (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Driver, Leach, Millar & Scott, 1996; Millar & Osborn, 1998). Argumentation is described as the process of thinking scientifically, logically, and creatively about phenomena (Jiménez-Aleixandre, Bugallo Rodríguez, & Duschl, 2000; Van Gelder, Bissett, & Cumming, 2004), and it is understood as a core aspect of science practice (Driver et al., 2000; Duschl, 2008). In addition, through argumentation students become better prepared for citizenship (Kolstø, 2001). However, there is a lack of studies on curriculum innovations designed to support Confucian heritage students in practicing scientific argumentation.

This study is the next step of a design-based research on designing a social constructivism-based curriculum for primary science education in Confucian heritage culture. It focuses on the issue of how to support Confucian heritage students in practicing scientific argumentation through a social constructivism-based curriculum. To do that, there is a need to revise the former design of the framework and its corresponding science lessons with reference to the nature of scientific argumentation and the Confucian cultural characteristic of harmony preference. This study aims to determine the extent to which the adjusted design supports Confucian heritage students in practicing scientific argumentation in a science lesson and attaining consensually agreed knowledge. By doing this, the study contributes to the development of a knowledge base for designing a social constructivism-based curriculum that supports scientific argumentation in primary science education in Confucian heritage culture.

Understanding the Nature of Scientific Argumentation

There is often a confusing overlap between the words *argumentation* and *argument*. According to Siegel (1995), "argumentation – whatever else it may be – aims at rational resolution of questions, issues and disputes" (cited in Driver et al., 2000, p.292). In this paper, the word *argumentation* is used to denote an interactional process of constructing an argument. The word *argument* is used to refer specifically to the content of the constructed argument (Duschl & Osborne, 2002; Ryu et al., 2012). In this way, scientific argumentation can be perceived as a human practice that takes place as an individual activity through thinking and writing, and as a social activity within a group – a negotiated social act within a specific community (Driver et al., 2000). Scientific argumentation involves the joining of two aspects – the personal and the social – and participants are required to construct and negotiate the meaning of the argument both privately and publicly (Hand, 2011), or personally and interpersonally. In this study, these two aspects are used to set up a framework that is utilised to analyse the practice of scientific argumentation among the students in a science lesson of the social constructivism-based curriculum designed for primary science education in Confucian heritage culture.

Regarding the *personal aspect of scientific argumentation*, the focus lies on arguments with the "solid" elements, such as data, evidence, causal structure, and causal coherence, which are used to formulate explanations and claims. These elements are synthesised from epistemic understandings of argumentation (Hand, 2011; Lehrer, Schauble, & Lucas, 2008; Ryu & Sandoval, 2012; Sandoval, 2005). According to Hand (2011), data do not speak (p.46). Data are defined as facts that are involved in the argument to support the claim (Toulmin, 1958) and to provide evidence used for reasoning (Hand, 2011). Both data and evidence cannot formulate explanations and arguments (Hand, 2011). To construct explanations in reasoning, causal structure and causal coherence are needed (Ryu & Sandoval, 2012; Sandoval, 2005). Causal structure and causal coherence refer to the basic structure of an argument in sentences. According to Ryu and Sandoval (2012), science aims at understanding the causes of natural phenomena. This requires scientific arguments to be formulated in causal structures as represented in sentences containing linking words such as *because*, *since*, *on account of*, and *therefore* (Toulmin, 1958). *Causal coherence* indicates the advancement of chains or networks of causal inferences in the scientific argument (Ryu & Sandoval, 2012). It requires that the evidence and the epistemic claims in scientific arguments be connected coherently and consistently with each other.

Regarding the *social aspect of scientific argumentation*, the focus lies on the interpersonal activities that take place within a group of participants. In this sense, science is considered a process "in which scientific knowledge is socially constructed, and in which discursive activity is central to the process of science" (Driver et al., 2000, p.290). Therefore, an argument is perceived to be socially situated (Driver et al., 2000) through argumentative activities such as evaluating, judging, qualifying, justifying, questioning, and rebutting. In this study, the definitions of these activities are as follows (Free Dictionary by Farlex, 2013; Toulmin, 1958):

Evaluating: To ascertain or fix the value or worth of the claim or argument.

Judging: To form an opinion or estimation of the claim or argument after careful consideration.

Qualifying: To modify, limit, or restrict the claim or argument by giving exceptions or specifying the conditions under which the claim can be taken as true.

Justifying: To demonstrate or prove the claim or argument to be right or valid.

Questioning: To examine, analyse (a witness, for example), or interrogate the claim or argument; to express doubt about the claim or argument; to dispute the claim; or to show wonder or curiosity.

Rebutting: To refute the claim by evidence or argument, or to oppose the claim by contrary proof or by specifying the conditions under which the claim will not be true.

The use of argumentative activities in a science class can support science teaching and learning that accomplishes much more than simply detailing *what we know*; it also teaches students *how we know* and *why we believe* (Driver et al., 1994; Driver et al., 1996; Millar & Osborne, 1998). This also aligns with the "nature of science" education (Abd-El-Khalick & Lederman, 2000), which emphasises the values of scepticism and open communication, as well as the interaction between personal beliefs in the generation of scientific knowledge (p.668).

These aspects of scientific argumentation and their indicators are summarised in Table 1. Each of the indicators is illustrated with an example taken from the specific scientific theme of plant roots.

Table 1. The aspects, indicators, and examples of scientific argumentation

Aspect	Indicator	Example
Personal (arguments in content)	Data	The root system of the mango has *one big long root* and *many smaller thin roots.*
	Evidence	The big long root can enable the plant to anchor firmly into the ground; the mango can anchor firmly into the ground because *it has one big long root*.
	Causal structure	*Since* the taproot system is defined as a big long root from which other roots sprout laterally, *therefore* the root system of the mango is a taproot type *because* the mango has one big long root from which other thin smaller roots sprout out.
	Causal coherence	A network of causal inferences: a taproot is inferred to be a big long root from which many lateral roots sprout; the root system of the mango is a big long root from which many lateral roots sprout and it is inferred that the root system of the mango is taproot.
Social (arguments in interactions)	Evaluating/Judging	The explanation/argument is clear, interesting, weird, good, plausible, acceptable, convincing, or illogical.
	Qualifying	Your explanation/argument is true/right but not enough/complete (because…).
	Justifying	Why/On what basis do you think that it has many roots?
	Questioning	Why does the mango have a root system like that? What will happen if the mango has no root system?
	Rebutting	I don't agree with you/I don't think that this plant has a fibrous root system (because I see it has only *a few* smaller roots but not *many* small roots as you said).

It is difficult in practice to separate the activity of evaluating from the activity of judging and the activity of justifying from the activity of questioning. Therefore, in this study, to identify the students' practice of scientific argumentation, the activities of evaluating and judging are combined into one category called "evaluating and judging," and the activities of justifying and questioning are combined into another category called "justifying and questioning."

The practice of both the personal and social aspects of scientific argumentation in a science lesson can help students achieve *consensually agreed knowledge* more than can a traditional approach in which a body of factual knowledge is imposed on students. This is because through arguing with each other, students' scientific arguments and claims can be tested, justified, qualified, questioned, and rebutted. In this way, scientific knowledge is expected to find *the best possible answers* for students (Dekkers, 2006) rather than "correct" answers. Such learning of science is compatible with the "nature of science" education, which is defined as complex and subtle and contains no absolute truth (Abd-El-Khalick & Lederman, 2000; Dekkers, 2006). The expectation of achieving consensually agreed knowledge is considered to be suitable for Confucian heritage culture, because this culture values the collectivity, solidarity, and harmony (Chapter 2) that support consensus in communication.

The personal and social aspects of scientific argumentation are considered two sides of a coin. Both of them need to be promoted in the practice of scientific argumentation (McComas, Almazroa, & Clough, 1998). According to Driver et al. (2000), science teaching has paid little attention to the practice of argumentation although it lies at the heart of science. This was considered as failing to "empower students with the ability to critically examine the scientific claims generated by the plethora of socio-scientific issues that confront them in their everyday lives" (Driver et al., 2000, p.288).

Adjusting the Curriculum Design to Support Scientific Argumentation

One of the learning aims of the designed curriculum is to help Confucian heritage students acquire and develop argumentative skills (Chapter 3). This is accomplished through the design of argumentative tasks as learning activities (Chapter 3). Nevertheless, the implementation of the designed curriculum in practice revealed that this learning aim was not sufficiently achieved, since the students did not argue actively with each other although they were actively involved in the other learning activities (Chapter 5). Specifically, in the Exchange phase, in which interactive and argumentative practices are emphasised (Chapter 3), the students were less active than in the other phases of learning (Chapter 5). In this phase, the students focussed on presenting and sharing their personal explanations and claims. However, the social activities of scientific argumentation such as evaluating, judging, qualifying, justifying, and rebutting (Table 1) were seldom carried out in the students' discussions. This low level of scientific argumentation in a social constructivist science lesson runs the risk of causing Confucian classrooms to return to the traditional approach in which the teacher transmits knowledge to students and students learn to reproduce "correct" answers.

The low level of scientific argumentation in the practice of the science lesson, especially with respect to its social aspect, was explained by two primary causes: a) the absence of a formulation of concrete teaching activities in the design that can serve as a specific guideline for teachers to implement teaching appropriately and support students in practicing scientific argumentation (Chapter 3); and b) strong influences of Confucian heritage culture, which supports the harmony, stability, and hierarchy (Berthrong & Berthrong, 2000) that cause students to avoid argumentation and conflicts in discussions (Chapter 3). These explanations were taken into consideration to adjust the design so that it can support Confucian heritage teachers and students in the practice of a social constructivist science class.

In thinking of adjusting the design, the designers searched for a pedagogical tool that could function as an intermediary between the designed formal curriculum and the teacher and students. Such a pedagogical tool should meet two primary criteria: i) supporting scientific argumentation in the practice of the science classroom, and ii) remaining appropriate within Confucian heritage culture, which values the stability and harmony that cause students to avoid arguing with each other (Chapter 2). The pedagogical tool should effectively reconcile the divergences between Western educational philosophy and Confucian heritage culture (Chapter 2). Based on these criteria, the learning placemat (Bennett & Rolheiser, 2001; Lissen, 2004) was selected and adapted to the design in a way that supports scientific argumentation in the practice of science lessons (see Figure 1).

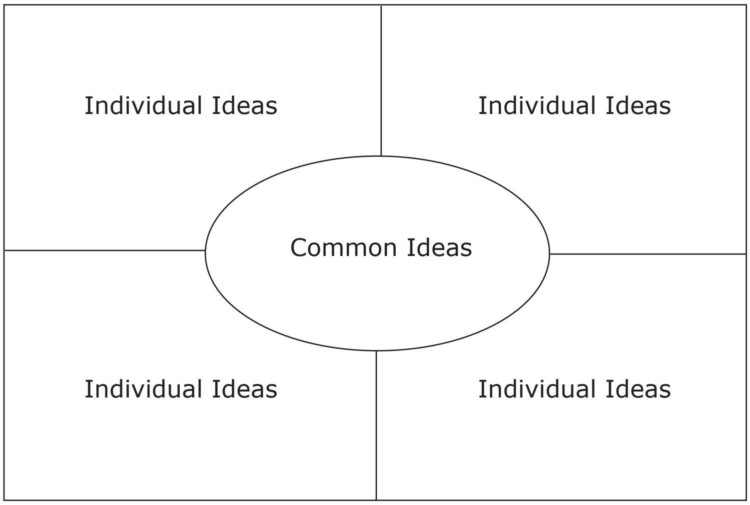


Figure 1. Common model of learning placemat

The learning placemat is a sheet of paper with a space in the middle where students can write their common ideas. Around this middle space, the paper has empty areas in which students can first write their individual ideas. The learning placemat can involve groups of students working both alone and together to think about, record, and share their ideas, and to learn from each other in small group discussions. It combines writing and dialogue to ensure the accountability and participation of all students. The learning placemat has been used for active cooperative learning approaches (Bennett & Rolheiser, 2001).

Adapting the Model of the Learning Placemat to the Design in order to Support Scientific Argumentation

The learning placemat was chosen to be used for the cooperative hands-on task. Specifically, the argumentative activities of the hands-on task of the Experience phase were structured and written on the learning placemat (see Figure 2).

The Use of the Adapted Model of the Learning Placemat

The adapted model of the learning placemat is used in several steps.

Step 1. Students in groups think independently and write down separate answers to the questions in the individual areas of the adapted learning placemat.

Step 2. Students share individual answers written on the adapted learning placemat with other members in the group as a whole.

Step 3. Students discuss individual answers in the group as a whole.

Step 4. Students select appropriate ideas from individual answers for the group's answers.

Step 5. Students write down the group's answers in the common area of the adapted learning placemat.

Individual ideas Name:	*Individual ideas* Name:	*Individual ideas* Name:	Group:
Hands-on 1. What do you observe? .... 2. How can you explain your observation? / Why is it like that? .... 3. Do you have any questions?			
Name: *Individual ideas*	Name: *Individual ideas*	Name: *Individual ideas*	

Figure 2. Adapted model of the learning placemat used in the design

Step 1 can support and stimulate passive students to be more active and involved in learning. Step 2 can provide quiet and passive students with an easy way to share ideas, especially since their thoughts are visualised in written answers that these students can rely on to read and share with the group. In this way, the adapted model of the learning placemat can help reduce difficulties for students in expressing and arguing, and thus support them in becoming more confident in front of their peers and teacher. The last four steps of using the adjusted learning placemat can help students be more interactive and argumentative in the discussion, because they themselves have prepared their own answers.

With all of the steps of using the adapted learning placemat as described above, the adapted model of the learning placemat is considered to foster not only the personal aspect but also the social aspect of scientific argumentation (Table 1). In addition, it can help teachers monitor the process of learning more smoothly and assess learning more conveniently. Through students' answers written on the adapted learning placemat, the teacher is provided with useful information to intervene appropriately when facilitating and assessing the learning individuals and groups.

Formulation of Concrete Teaching-Learning Activities

In adjusting the design, the teaching activities that Confucian heritage teachers proposed (Chapter 4) were used along with the students' learning activities. In addition, both the teaching and learning activities for the use of the adapted model of the learning placemat were articulated. In this way, the adjusted curriculum design provided a specific instructional framework (see Table 2) for primary science education in Confucian heritage culture to support students in practicing scientific argumentation. Consequently, the adjusted design is considered a convenient teaching guideline for Confucian heritage teachers to design and teach science lessons in accordance with a social constructivist perspective and to foster students' scientific argumentation. The framework formed a basis on which to develop corresponding curriculum units and science lessons.

The iterative teaching and learning activities presented in Table 2 show a spiral process of teaching and learning. In this way, the designed curriculum is considered to help Confucian heritage students gradually acquire scientific knowledge, attitudes, and skills, especially argumentative skills.

Differences between the Former Design (Cycle 1) and the Adjusted Design (Cycle 2)

The first design only focussed on student activities and did not provide guidelines for teacher activities. This caused practical difficulties for Confucian heritage teachers in teaching the experimental lessons (Chapter 4). Secondly, the first design was developed without the use of the model of the learning placemat. The adapted model of the learning placemat (Figure 2) was used in the adjusted design in order to foster argumentative interaction among students and enable them to learn argumentative skills. The third difference is that student activities in the adjusted design were more concrete and better organised due to the articulation with the concrete teaching activities and the use of the adapted model of the learning placemat. In the former design, the activities of presenting and discussing for both the predicting task and the hands-on task took place in the Exchange phase. However, in the adjusted design, the activities of presenting and discussing for the predicting task took place in the Experience phase before the hands-on task began (Table 2). This was done to avoid confusing students because it can be difficult to catch key ideas of other groups when predictions and observations are presented at the same time. This confusion could make students passive in learning and lead to a return to traditional teaching and learning methods (Chapter 4).

By separating the activities of presenting and discussing the predictions from the observations of the hands-on task, the adjusted design provides students with opportunities to find similarities and differences in group answers within the same tasks and between the different tasks (Student activities 3.4, 7, & 8 in Table 2). The comparisons can provide student groups with informative grounds that they can rely on for the next step in their learning process. Moreover, they can also help the teacher follow the students' learning step by step and better master teaching from a social constructivist perspective (Chapter 4).

Research Questions

This study was situated in Vietnam, a country deeply influenced by Confucianism (Phuong-Mai et al., 2005) that has recently implemented curriculum reform in primary education (Hoan, 2002). Based on the arguments in the previous section, this study aims at answering the two interrelated research questions that appear below.

1. *To what extent does the adjusted design of the social constructivism-based curriculum for primary science education in Confucian heritage culture support students in practicing scientific argumentation in a science lesson?*
2. *To what extent does the adjusted design support Confucian heritage students in attaining consensually agreed knowledge on scientific subject matter?*

Research Strategy

Collaboration with Confucian heritage teachers

This study is part of a research that applies a design-based approach (Bulte, Westbroek, De Jong, & Pilot, 2006). It describes the second cycle of the design and research process. In this cycle, the preparation of the teachers was implemented collaboratively in a way rather similar to that used in the first cycle (Chapter 4).

Three Vietnamese primary teachers who were involved in the first cycle of the design process (Chapter 4) continued to be involved in the second cycle one year later. The collaboration with the same teachers saved time and training because through the first cycle these teachers had already gained an understanding of ideas of the design and had adapted to some degree to social constructivist teaching after co-designing and teaching the experimental science lessons (Chapter 4). With their existing knowledge and experiences, these teachers could more easily adapt to and accommodate the adjusted design. In this cycle, the teachers were informed about the adapted model of the learning placemat (Figure 2) and the concrete teaching-learning activities formulated in the design (Table 2).

The close collaboration between the researcher and the teachers took place in a work team in which the researcher acted as a leader. Much as they did with the original design in the first cycle, the teachers interacted with the adjusted design by co-designing and teaching science lessons based on curriculum units predesigned by the researcher. They were also involved in post-lesson discussions to reflect on the adjusted design and the experimental lessons.

The enactment of the experimental lessons

Based on the curriculum framework (Table 2), three science curriculum units were designed for this cycle: *Solutions*, *CO_2 Reaction*, and *Plant Roots*. The use of the units *Solutions* and *CO_2 Reaction* aimed to provide the teachers with trial lessons. Although the teachers had already changed their approaches considerably toward the social constructivist teaching of science (Chapter 4), they needed time and experience to familiarise themselves with the changes to the adjusted design. In this way, they could teach the experimental lessons smoothly for the analysis of the adjusted design.

Table 2. The adjusted framework of the social constructivism-based curriculum for primary science education in Confucian heritage culture (Cycle 2)

Phase	Function	Teacher activity	Student activity	Learning form	Expectation
Engagement	A. To provide students with motivation to learn scientific subject matter	i. Using a few key questions to reveal students' prior knowledge and curiosity related to scientific subject matter ii. Staying open to students' responses	1. Doing a small hands-on task with a relevant example related to scientific subject matter 2. Answering What, How, and Why questions about a relevant example related to scientific subject matter	In small groups and/or in class as a whole	a. Students are interested in scientific subject matter
Experience	B. To evoke attitudes toward science C. To acquire procedural knowledge D. To acquire	iii. Delivering the task and being sure that student groups know what to do and how to do the task iv. Establishing time for group discussion v. Observing and supervising groups while they do their group tasks	3. PREDICTING 3.1. Observing and discussing in order to answer questions: What do you observe? What will happen if…? Why do you think so? 3.2. Writing down answers (on the group small boards)	In small groups	b. Students are curious about representative examples of scientific subject matter c. Students are active in learning about representative examples of scientific subject matter

Experience	conceptual knowledge E. To acquire argumentative skills	vi. Encouraging students to present answers, and to compare and assess answers vii. Staying open to students' responses	3.3. Presenting these answers (3.1 & 3.2.) to other groups 3.4. Clarifying similarities and differences in answers for predicting questions among groups 3.5. Discussing the predicting answers with other groups	In small groups	d. Students use their intuitive knowledge to learn about scientific subject matter e. Students argue with each other to attain consensually agreed knowledge on representative examples of scientific subject matter
		viii. Delivering the task and being sure that student groups know what to do and how to do the task ix. Establishing time for group discussion x. Observing and supervising groups while they do their group tasks	4. HANDS-ON 4.1. Doing the experiment and discussing the results in order to answer the questions: What did you observe? How can you explain your observations? Why do you think so?		

			4.2. Writing down answers in the individual ideas area of the adapted learning placemat 4.3. Sharing the written individual ideas in the group	
		xi. Using open-ended elaborative questions to guide students		
		xii. Staying open-minded and friendly to interact with students	4.4. Selecting ideas for the common answers and writing then down in the common ideas area of the adapted learning placemat	
			5. QUESTIONING: Formulating questions related to scientific subject matter	
Exchange	F. To build on attitudes toward science G. To build on procedural knowledge	xiii. Encouraging students to present answers, and to compare and assess answers	6. Presenting results of hands-on activities to other groups 7. Clarifying similarities and differences in answers (6) 8. Clarifying similarities and differences between predicting answers and hands-on answers within groups	f. Students are interactive in learning scientific subject matter

	H. To build on conceptual knowledge	xiv. Stimulating groups to interact and argue with each other	9. Discussing results of the hands-on activities with other groups	In class as a whole and/or in combined groups	g. Students argue with each other to attain consensually agreed knowledge on scientific subject matter
	I. To build on argumentative skills	xv. Using open-ended elaborative questions to guide students to grasp deeper knowledge			
		xvi. Staying open-minded and friendly to interact with students			
		xvii. Choosing representative questions formulated by students/groups for students to discuss and answer	10. Answering formulated questions related to scientific subject matter		
Follow-up	J. To acquire cognitive flexibility	xviii. Providing open-ended sub-questions (if necessary) to guide students to answer/ solve new questions/problems	11. Providing answers/ solutions for new questions/ problems related to scientific subject matter	In class as a whole	h. Students can provide apprpriate answers and/ or solutions on applying attained knowledge
	K. To further learning motivation	xix. Giving compliments to individual students and groups who have achieved successful learning			i. Students show their desire to learn more about scientific subject matter

The unit *Solutions* was used to replace the unit *Air Pressure* in the first cycle, because mixing sugar, salt, and sand into water to learn about solutions was considered to be more interesting for students than pressing the connected cylinders to learn about air pressure (Chapter 3). The curriculum unit *Plant Roots* was chosen for an in-depth analysis because the results of the first cycle of the design process showed that the experimental lesson of the curriculum unit *Plant Roots* was the best functioning among the experimental lessons (Chapter 5). The sequence in which the teachers taught the adjusted design's lessons is presented in Figure 3.

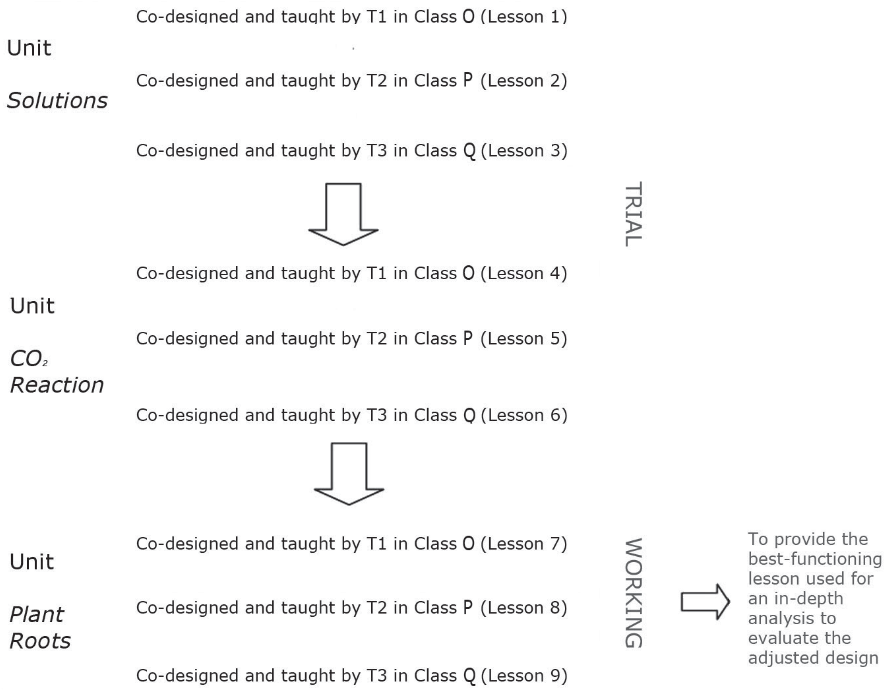


Figure 3. The sequence in which the teachers taught the experimental lessons

In total, nine experimental science lessons were co-designed, taught and observed, and discussed in the collaborative team. Each of the experimental lessons was intensively discussed and evaluated by the team after being enacted in classroom practice. The main themes of the discussions were determined by the following questions:

1. What do you think about the lesson? Why do you think so?
2. What do you think about each of the phases in the lesson? Why do you think so?
3. What do you think about the teacher and students in this lesson? Why do you think so?
4. What should be done to improve the next lesson?

These questions were often elaborated in the discussions. By teaching and reflecting on the experimental lessons, each of the teachers could apply what was learned in the previous lesson to the next experimental lesson. Overall, the teachers made progress in the next lessons. On average, the enactment of the designed lessons was implemented in the span of a week.

The selection of the best-functioning experimental lesson for an in-depth analysis

In order to find the best-functioning experimental lesson (Figure 3), key measuring criteria based on social constructivist features (Beck & Kosnik, 2006) and used in the first cycle (Chapter 5) were used again in this cycle. In addition, one more criterion was established that focussed on scientific argumentation as the focal issue of the second cycle of the design process. These criteria were:

i. The lesson is implemented in accordance with the designed lesson and consistent with the designed curriculum.

ii. The teacher implements attitudes and activities as a social constructivist teacher.

iii. Students are active and autonomous in learning.

iv. Social interactions are dominant in classroom practice and interactions among students are dominant for cooperative learning.

v. Knowledge is constructed by students through social negotiations.

vi. Students are argumentative in their interaction.

Based on these criteria, the team agreed that the ninth lesson of *Plant Roots* (Figure 3) was the best-functioning of the experimental lessons. This lesson (APPENDICES A & B) was therefore chosen for an in-depth analysis to answer the research questions.

The *Plant Roots* lesson was taught by Vietnamese teacher T3, who was considered a competent teacher in a public primary school in Bacninh, a suburban area in Vietnam (Chapter 5). Teacher T3 was thirty years old and had eight years of experience teaching in primary school. The twenty-four Vietnamese students of Class Q at the age of 10 were involved in this experimental lesson. The numbers of male and female students in this class were close to equal.

Data collection

Data from two sources – classroom observations and learning materials – were collected. The details of data collection for this lesson are presented below.

A. Classroom observation. Classroom observation allowed the researcher to develop a holistic perspective on the implementation of the adjusted social constructivism-based curriculum. In this way, the researcher could see how scientific argumentation (for the first research question) was implemented by the students, and the extent to which the students attained consensually agreed knowledge in the lesson (for the second research question).

The researcher took photographs of the main activities taking place in the lesson for each of the phases of the adjusted design (see section Findings). One video camera was located at a convenient place in the classroom to have the best overview of how teaching and learning took place in the lesson. All of the students' group discussions in the lesson were recorded by audiotape to provide the researcher with data which were difficult to detect by observing the class from a distance. Voice recorders were put in the middle of the student tables to record discussions of the groups.

All of the videotapes and audiotapes were thereafter observed and listened to; subsequently, they were carefully transcribed verbatim if necessary and possible.

B. Learning materials. Learning materials were collected with the products completed by the students, including i) the groups' small boards (for the Engagement and Experience phases), ii) the learning placemats (for the Experience phase), and iii) the post-learning tests. In the post-learning tests, the students were asked to answer the following questions:

1a. Can you provide some examples of taproot plants?

1b. What is the taproot system? Make a drawing of the taproot system.

2a. Can you provide some examples of fibrous root plants?

2b. What is the fibrous root system? Make a drawing of the fibrous root system.

The post-learning tests were delivered to the students and answered by them one month after the lesson.

Data analysis

To answer the first research question – *To what extent does the adjusted design support students in practicing scientific argumentation?* – the indicators of scientific argumentation (Table 1) were used as organising elements to cluster the students' utterances (Sources A & B). The analysis mainly focussed on the Experience and Exchange phases, because scientific argumentation is the main expectation of these phases (Chapter 3) that was not satisfied by the former design (Chapter 5). The students' practice of the personal aspect of scientific argumentation was analysed relied on the students' arguments written on the learning placemats (Source B). The students' practice of the social aspect of scientific argumentation was analysed relied on the data source of classroom observation (Source A), taken from either the video tape or the audio tapes. To analyse the way in which the students reasoned about root systems in their arguments, the designer's perspective of form and function in biology (Boerwinkel, Waarlo, & Boersma, 2009) was used. Accordingly, the question of the form-function relation (Figure 4) *Why plant X has root Y and not Z'?* was a central focal point in analysing the reasoning in the students' arguments.

To answer the second research question – *To what extent does the adjusted design support Confucian heritage students in attaining consensually agreed knowledge on scientific subject matter?* – the answers and solutions provided by the students in the Exchange and Follow-up phases (Source A), as well as in the post-learning tests (Source B) were collected and assessed. To determine the students' consensually agreed knowledge on the plant roots, the assessment focussed on appropriate solutions and answers rather than "scientifically correct" answers.

The analysis of data sources was implemented in two cycles with many steps to validate the findings. The initial data analysis of the first cycle was accomplished by the researcher. In this cycle, the researcher provided the main findings of the lesson. Then the findings of the lesson were discussed with the teachers in the team. The discussion in the team provided a work-team consensus for the findings. After that, the second cycle of the analysis was carried out with the involvement of the research team.

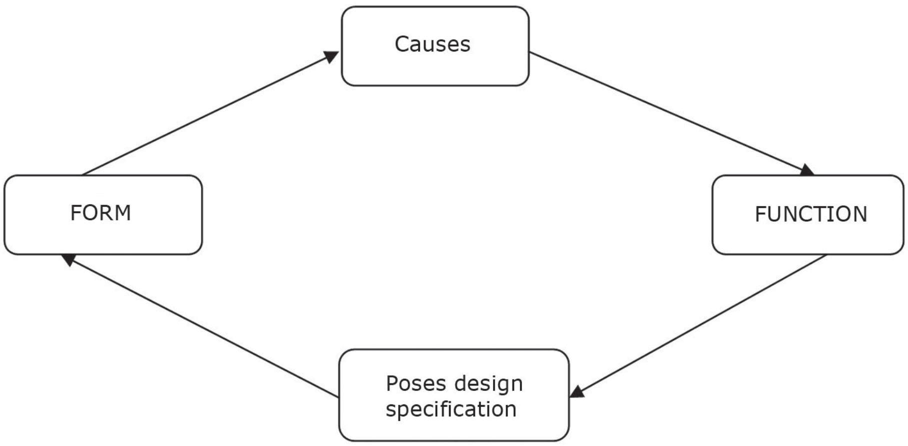


Figure 4. Basal model of the perspective of form and function according to Boerwinkel et al. (2009)

In the second cycle, the data analysis was implemented in three main steps. Firstly, the researcher discussed the first analysis and the findings which were agreed on by the teachers with a second researcher (supervisor 1) several times. After that, the researcher and supervisor 1 came to the first consensus on the analysis. Next, this analysis was discussed again between the researcher and supervisor 2. Their thorough discussions focussed on specific parts of the analysis and provided a deeper analysis of the lesson. The analysis was then carefully discussed in the entire research team to come to the final consensus. These discussions provided opportunities to cross-check and validate the findings thoroughly (Creswell, 2009). In this way, the thick description of the analysis of the lesson *Plant Roots* in practice was completed.

Findings

Overall Description

In the lesson *Plant Roots,* the students were divided into four small groups of six. They were highly active, concentrative, and comprehensive in learning in all of the learning phases. The students' learning in this lesson is illustrated in Figure 5.

 1. *Engagement*. Discussing and drawing a complete plant in small groups	 a b 2. *Experience*. Interacting with a) the real plants and b) the prepared learning placemat after doing predictions in groups
 3. *Exchange*. Presenting and discussing the results in the class as a whole	 4. *Follow-up*. Applying knowledge to answer new questions

Figure 5. The main learning activities of the students in classroom practice

Scientific argumentation of the students (research question 1)

<u>Personal aspects of scientific argumentation (Table 1)</u>

In total, 64 arguments were written by 24 students, individually or in groups. Specifically, for the prediction task, eight arguments were co-constructed by the four student groups; for the hands-on task, eight arguments were co-constructed by the four student groups and 48 arguments were constructed by individual students.

Data and *evidence* were provided in all of the students' arguments. They can be recognised in the students' arguments by the quantitative words, such as *one* and *many*, and the qualitative words, such as *big*, *small*, *thin*, and *long*, that the students used in their arguments related to the root systems of the mango and grass plants. Evidence is also recognised through the students' references to the shapes of the plant bodies or to the root functions to explain the forms of the root systems, as illustrated by the following examples:

> The mango has such a root system because it is suitable for the body of the mango which is straight, hard, and long. (Group 4)

> The mango has such a big root so that it can anchor the tree body stably on the ground. (Student Ha)

The body of the mango which is straight, hard, and long (in the argument of Group 4) and *can anchor the tree body stably on the ground* (in the argument of student Ha) are considered evidence that the students used to provide explanations for their arguments.

Causal structure was found in 63 of the students' 64 arguments. This is presented by relationship-indicating causal words that the students used to construct their arguments. Specifically, the word *because* was used in 41 of the 64 arguments, the word *therefore* was used in 3 of the 64 arguments, and the words *so that* were used in 19 of the 64 arguments. For instance:

> The mango has such a root system [with the small roots attached to one long root] because it helps to convey nutrients for the tree. (Group 2)

> The grass has such a root system [many small and short roots] so that it can develop well. (Group 3)

Causal coherence was found in 47 of the students' 64 arguments. In these arguments, the students used relationship-indicating causal words plausibly. The students referred to the characteristics of the forms of the bodies of the mango and the grass in order to explain the forms of the root systems of these plants. For instance:

> The grass has a root system (many thin small roots) like that because it is suitable for its body which has many culms. (Student Hanh)
>
> The mango has a long and big root system because its body is big and tall. (Student Hanh)

Also, the students referred to the functions of the root systems in order to explain the forms of the root systems of the mango and the grass. For instance:

> The grass's root system is many thin small roots so that it can help the plant reproduce well. (Student Lan)
>
> The mango has a root system with one big long root and a few small roots around the big main root. This is because the big main root can help the mango not be blown down by a storm when it is growing. (Group 3)

Both of the above arguments are considered as functional arguments in which the students referred to the functions of the root systems, such as the function of reproducing (in the argument of student Lan) or the function of anchoring (in the argument of Group 3), to explain the forms of the root systems.

In 17 of the 64 arguments presented by the students, the causal coherence was weak because of the use of inappropriate relationship-indicating words, the improper use of causal relationship-indicating words (i.e., the causal words were put in the wrong places), and mismatches between the subjects of inferences in the arguments. For instance:

> The root system of the mango has one big root and many small roots, long and sinuous, because the body of the mango is small so that the root system is also small. (Student Duy)

The above argument is not coherent in its content. It is not consistent with the form of the mango's root system described in the argument. In the first (pre-*because*) part of the sentence, the root system of the mango is described as having *one big root* and *small roots* but this does not claim that the mango has a small root system. However, in the second (post-*because*) part of the sentence (*the body of the mango is small so that the root system is also small*), which is used to explain the idea presented in the first part (*the root system of the mango has one big root and many small roots, long and sinuous*), the student claims that the root system of the mango is small. There is no logical relation between the ideas presented before *because* and those presented after it. The argument is therefore obscure.

Social aspects of scientific argumentation (Table 1)

The students discussed and interacted with each other so enthusiastically and noisily in the group tasks that it was difficult to catch their ideas when listening to the voice recorders. Nevertheless, some of the audible conversations in the group discussions and classroom observations do reveal that the social aspect of scientific argumentation was implemented in this lesson.

Evaluating and judging were implemented by the students in all four of the groups in the Experience phase, especially when the students worked on the adapted learning placemats. It was observed that the common sequence of achieving group answers was generally implemented in a certain order. Firstly, each of the members in the group presented his/her personal answers (written in one of the individual areas on the learning placemat) to the questions. After that, ideas that differed from each other were evaluated and negotiated in the groups. Then the ideas the students agreed upon were written as the group's answers in the common area of the learning placemat. It was found that to formulate common answers to the questions, one group used nonverbal activities to indicate their agreement and disagreement with the personal ideas. This took place spontaneously when group members raised their hands if they agreed with an idea and did not raise their hands if they disagreed. The ideas consensually agreed upon were then written in the common area on the group's placemat. The nonverbal activity of raising hands is interpreted as the way in which the students evaluated the personal arguments to construct the argumentative answers of the group. Through this evaluation method, the students in the group achieved a consensus for the group's answers.

Words and phrases such as *nice*, *right* or *not correct* were heard on listening to conversations during the group discussions while students provided answers to the questions related to the hands-on activity. These words and phrases were interpreted as the activities of evaluating and judging when the students were arguing with each other. These activities are illustrated by the statements *I think so too* (Line 2), *It's funny* (Line 6), and *Yes, I agree* (Line 12) in Quotation 1 below.

In the overall class activity in the Exchange phase, the students demonstrated the activities of evaluating and judging. When asked to evaluate the answers of the groups, the students acknowledged that Group 4 formulated the best predictions: the outcomes of the hands-on activity were closest to their predictions.

Justifying and questioning were implemented by the students in all four of the groups. The activity of justifying was carried out when the students accomplished the hands-on task to justify their predictions about the root systems of the mango and the grass. This can be illustrated by an example from Group 2. The students in this group had two different kinds of ideas when they predicted the root system of the grass: one asserted that the grass has a big main root to help it adhere to the ground and the other asserted that the grass has many roots. After observing the root system of the grass, the student who held the idea that the grass has a big main root agreed that the grass has no big main root but many small thin roots.

In the discussion of Group 4, the students' activities of justifying and questioning were implemented in the expressions of student C (Line 4) and student A (Line 5) in Quotation 1 below.

Quotation 1. A discursive dialogue (Group 4)

1	Student A	The mango has few roots.
2	Student B	I think so too.
3	Student C	But I think it has many roots.
4		Here you can see…small roots…much smaller and shorter than the main root.
5	Student A	Like this…many roots?
6		It's funny.
7		I don't think so.
8		It only has a few roots.
9	Student C	I see it has small roots around the main big root.
10		These roots are very small, thin, and short.
11	Student D	If we compare it with the grass, the mango has fewer roots.
12	Student C	Yes, I agree.
13		It has fewer roots than the grass.
14		The grass has many roots, much more than the mango.

Along with justifying, questioning was implemented by the students. In total, 13 questions were formulated and written by the students on the learning placemats. Five questions were asked cooperatively and eight questions were asked individually, including: *Could the mango live if it had the same root system as the grass?* (Group 1); *What would happen if the plant had no root system?* (Group 2); *Why does the mango have one root bigger than the root of the grass?* (Group 3); *and What do you think about the root system of an apple tree?* (Group 4).

Rebutting was also implemented by the students when they argued with each other, as was recognised in the dialogue presented in Quotation 1. It was shown in the statement *But I think it has many roots* (Line 3) that student C offered to oppose the idea that the mango has few roots as asserted by students A and B (Lines 1 & 2), and again in the statement *I don't think so* (Line 7) that student A offered to deny student C's idea that the mango has many roots.

Qualifying was implemented as well, and can be seen in the expression of student D (Line 11) and those of student C (Lines 13 & 14) in Quotation 1.

Although Quotation 1 shows *rebutting and qualifying*, these activities could not be found in the conversations of the other groups in the Experience phase. In addition, in the whole class discussion in the Exchange phase, *rebutting and qualifying* could not be observed at all. Compared to the others activities of social argumentation, the students and teacher did not pay much attention to this.

Students' attainment of consensually agreed knowledge (research question 2)

The Exchange phase

Through discussing, arguing with each other, and answering the elaborative questions asked by the teacher in the Exchange phase, which was organised in a spiral learning process with the other phases, the students could attain consensually agreed knowledge on plant roots. This can be recognised in Quotation 2 below.

Quotation 2. A teacher-student dialogue

Q1	Teacher T3	How many big roots does this mango have?
A1	The class	One.
Q2	Teacher T3	What appears from this big root? (shows it by hand to the students)
A2	The class	Small roots.
Q3	Teacher T3	What is this big root called?
A3	The class	The main root.

Q4	Teacher T3	So…what is this type of root system called? ... Who knows?
A4	Student E	Taproot.
Q5	Teacher T3	Why is it called taproot?
A5	Student G	It is called the taproot system because its root system has few roots and is not exuberant.
Q6	Teacher T3	Can you describe it more clearly?
A6	Student E	It has one long and big root with small roots surrounding it.
Q7	Teacher T3	Do you agree with her?
A7	The class	Yes.
Q8	Teacher T3	So…what is the taproot system?
A8	Student H	The taproot system is the one having a main root, hard, long, and sticking deeply into the ground.
Q9	Teacher T3	Anything else?
A9	Student I	And having many small roots surrounding it.

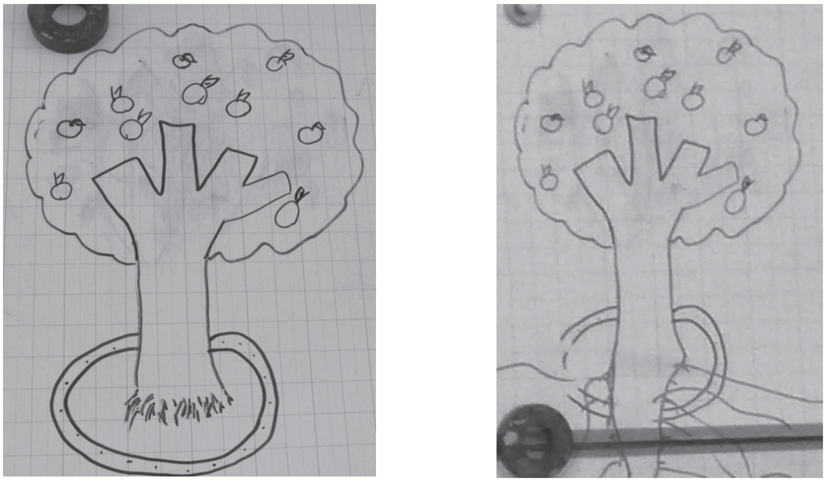
As in the conversation quoted above, the teachers asked many questions for the students to answer. The questions could be developed and elaborated from students' initial answers (as, for instance, in Q5, Q6, Q7, Q8, & Q9). This enabled students' answers to be interconnected with each other (in, for instance, A4, A5, A6, A7, & A8). In this way, the students gradually came to a conceptualisation of the taproot and fibrous root systems.

The Follow-Up phase

The findings in the Exchange phase are consistent with the findings in the Follow-up phase, in which the students were asked by the teacher to assess the drawings made in the Engagement phase. The students recognised the inappropriateness of the root systems in the drawings of the plants they had made before being involved in the inquiry activities of the Experience phase and the discussions of the Exchange phase. In the Follow-up phase, they proposed solutions to adjust the drawings, as shown by the example drawings presented in Figure 6.

As seen in Figure 6, the root system of the apple tree that the students drew at the beginning of the lesson in the Engagement phase was very short and thin (Figure 6.1). However, at the end of the lesson, in the Follow-up phase, the drawing of the root system of the apple tree was adjusted by the students: the root system was drawn with a bigger and longer root and many small and thin sub-roots (Figure 6.2).

Moreover, when asked to determine the root type of the real radish provided by the teacher, the students were enthusiastic in providing answers and all of the answerers acknowledged that the radish had a taproot system because they saw that the radish had one big root at the foot of the plant with a few small roots sprouting from the main root. The appropriate answers of the students in the Follow-up phase showed that they had attained consensually agreed knowledge on the types of plant roots.



1. *Before* – in the Engagement phase 2. *After* – in the Follow-up phase

Figure 6. The drawings of a complete plant made by the students

In the post-learning test

The findings from class observation were consistent with the students' answer sheets in the post-learning test. On the day of doing the post-learning test, twenty-two of the 24 students were available in the classroom and took the post-learning test.

Twenty-two of the 22 students who completed the test provided 79 examples of the taproot system using 17 different plants. Seventy-seven of the 79 examples are the kind of trees that have large, tall straight bodies, including apple (18 times in the examples), mango (16 times), orange (16), flamboyant (6), jackfruit (3), Malabar almond (3), guava (3), mandarin (3), khaya senegalensis (African mahogany, 2), star apple (2), grapefruit, mandarin orange tree, pear, mangosteen, and durian (once each). The two other examples provided for the taproot system were grape and kohlrabi. This is consistent with 17 of the 22 answers provided by students for the test question *What is the taproot system?* These answers were simple conceptualisations of the taproot system but nonetheless reflected the main characteristics of the taproot system, as in the following quotation:

> The taproot system consists of one main root and many lateral roots. The main root is bigger and longer than the lateral roots. It helps to anchor the plant to the ground. (Student Hoang)

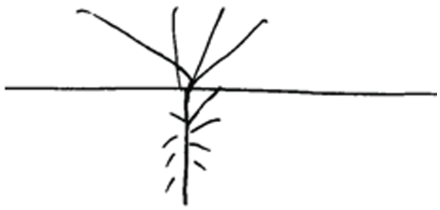
Such a conceptualisation of the taproot system aligns with all of the drawings of the taproot system made by the 22 students, as represented by drawing 1 in Figure 7.

The 22 students also provided 58 examples of the fibrous root system using 16 different plants. Twenty-six of these 58 examples are the kind of plants that have small short bodies, including grass (14 times in the examples), rice (5 times), water spinach (3), salad greens (3), and onion (once). Thirty of the 58 examples provided for the fibrous root system are large, tall trees, including the banian tree (18 times), Benjamin fig (4), khaya senegalensis (African mahogany, (2), flamboyant, papaya, Malabar almond, rubber tree, cardamom, and grapefruit (once each). The two remaining examples indicated "luffa" and "flower." Although the students provided examples of the fibrous root system using plants with large, tall bodies that were also considered by them to belong to the taproot system – namely, khaya senegalensis (African mahogany), flamboyant, Malabar almond, and grapefruit – 18 of the 22 answers for the test question *What is the fibrous root system?* provided by the students can reflect the main characteristics of the fibrous root system, despite simple conceptualisations, as illustrated in the following quotation:

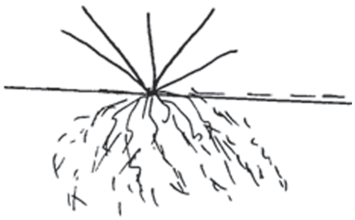
> The fibrous root system consists of many roots sprouting from the foot of the plant; the majority of them are similar to one another. (Student An)

Such a conceptualisation of the fibrous root system aligns with all of the drawings of the fibrous root system made by the 22 students, as represented by drawing 2 in Figure 7.

Based on the way in which the students conceptualised the taproot and fibrous root systems and on their illustrative drawings, considered as the appropriate answers on applying knowledge of the students, the researcher considered that the students attained consensually agreed knowledge of the taproot and fibrous root systems.



1. Taproot system



2. Fibrous root system

Figure 7. Students' drawings of root systems

Conclusions and Discussion

This study shows that the adjusted design can substantially support Confucian heritage students in practicing scientific argumentation (research question 1) and attaining consensually agreed knowledge (research question 2). Thereby, this study delivered *a proof of principle* (Freudenthal, 1991; Westbroek, Klaassen, Bulte, & Pilot, 2010) for the adjusted curriculum. In this way, the study shows that the design with its concrete teaching-learning activities can indeed be a possibility for application to primary science education in Confucian heritage culture. It can be used to activate student learning and support students in practicing scientific argumentation, and seems a promising contribution to the improvement of primary science education that addresses the problems analysed in Chapter 2 and the refined problem analysis presented in Chapter 5. Moreover, this study shows that the adapted model of the learning placemat (Figure 2) is a culturally appropriate teaching-learning tool that is useful in facilitating Confucian heritage students to interact with each other and practice scientific argumentation. Although specifically designed for Confucian heritage culture, the adapted model of the learning placemat (Figure 2) could be useful for learning scientific argumentation in other cultures as well because it is so easy to use. Therefore, the adapted model of the learning placemat (Figure 2) is recommended for use in facilitating students to practice scientific argumentation.

Although the adjusted curriculum substantially supported Confucian heritage students in practicing scientific argumentation, this study revealed that regarding the personal aspect of scientific argumentation, the causal coherence of an argument needs attention in instruction, because causal coherence was less effectively implemented by the students compared to the other indicators of the personal aspect. Regarding the social aspect of scientific argumentation, this study showed that Confucian heritage students seldom practiced the argumentative activities of *qualifying and rebutting.* The low level of implementation with respect to *qualifying and rebutting* emerged as the refined problem in the second cycle design. It can be considered as the core problem of applying a social constructivist perspective in primary science education in Confucian heritage culture, and needs further research, because *qualifying and rebutting* are essential activities of scientific argumentation (Hand, 2011; Toulmin, 1958). The findings of this study reinforce the proposition that scientific argumentation is difficult in science education (Driver et al., 2000). Further research is recommended to deal with the problem of how to embed the activities of *qualifying and rebutting* in scientific argumentation in a social constructivist science lesson.

<table>
<tr><td>Individual ideas

Name:</td><td>Individual ideas

Name:</td><td>Individual ideas

Name:</td><td>Group:</td></tr>
<tr><td colspan="4">What are your group’s arguments to qualify and/or rebut the given argument?
....
....</td></tr>
<tr><td>Name:

Individual ideas</td><td>Name:

Individual ideas</td><td colspan="2">Name:

Individual ideas</td></tr>
</table>

Figure 8. The adapted model of the learning placemat for supporting *qualifying* and *rebutting*

In thinking of supporting the activities of *qualifying and rebutting* in science lessons, it is possible to use the learning placemat as a pedagogical tool. The recommendation is to extend the learning placemat with scaffolding questions that specifically focus on *qualifying and rebutting*, as shown in Figure 8.

Along with the use of the learning placemat, to support students in practicing the activities of *qualifying and rebutting*,, teachers are recommended to pose the following reassuring and challenging questions:

> You are intelligent/smart/bright if you can rebut/show the limitations of this argument. Who can do it?
>
> Who can add to the incomplete argument/statement?
>
> Can you show an example of why this claim is not completely correct?
>
> I expect that one of you can provide an argument which is more coherent/persuasive.
>
> You are welcome to provide rebuttals to arguments.
>
> It is a difficult job, but who can rebut this argument convincingly?
>
> Student A demonstrates his intelligence/cleverness through his answer, which is well argued, and I think you are also a smart student, or maybe smarter, if you can provide a plausible rebuttal to or a limitation in his argument.
>
> Rebutting and showing limitations of an argument are difficult jobs and you are a good scientist if you can do such difficult jobs. Can you do this with the last argument?

The above questions and statements can be considered to encourage and motivate students to provide more coherent arguments and practice *qualifying and rebutting* in their argumentation in science classes. If these questions and statements are emphasised and regularly expressed by the teacher in a social constructivist science class, students can gradually become more familiar with the activities of *qualifying and rebutting*; hence, their argumentative skills can be enhanced. In addition, the analysis of the quality of arguments plays an essential role and needs to have appropriate frameworks for analysis. Lakatos' scientific research programmes (Chang & Chiu, 2008), may add to the theoretical framework for representing and evaluating informal argumentation, and could offer an alternative in supporting the improvement of quality of scientific arguments.

With its adjusted design of a social constructivism-based curriculum incorporating concrete teaching-learning activities, this study is a response to the call for "tighter structuring and scaffolding of students' activities than most social constructivists envision" (Brophy, 2006, p.536). Concrete teaching-learning activities can meaningfully clarify theoretical frameworks, which can then be discussed and compared (Klaassen & Kortland, 2013). Klaassen and Kortland (2013) argue that the nature of theory in connection with curriculum design is often unclear. With the concrete teaching-learning activities as an application of a social constructivist perspective, this study aligns with the implications many authors have formulated for a design-based research approach (see Barab & Squire, 2004; Kortland & Klaassen, 2010; Méheut & Psillos, 2004). Moreover, the design with its concrete teaching-learning activities makes a social constructivism-based curriculum easier to use in the practice of primary science education in Confucian heritage culture. It bridges a gap between the ideal and formal curriculum and the experiential and attained curriculum (Van den Akker, 1998, 2003).

With the educational achievements of the adjusted design of the curriculum, this study shows that Western educational philosophy, specifically a social constructivist perspective and the "nature of science" education, can be appropriately applied in primary science education in Confucian heritage culture. In this way, this study reinforces the propositions that teaching and learning is highly contextual and teachers and learners are highly adaptive (Biggs, 1996; Volet & Renshaw, 1996). For example, it has been reported that the longer students study in Australia, the more likely they are to adapt to the Australian style of teaching and learning (Wong, 2004). In addition, this study shows that when a curriculum is designed in a culturally appropriate way, it can avoid a false universalism (Nguyen, Elliott, Terlouw, & Pilot, 2009) and bring changes to primary science education. This study aligns with the "perspectives on Asian learning" approach through its "focus on applying and refining theories developed elsewhere to an Asian context" (Örtenblad, Babur, & Kumari, 2012, p.132).

Although this study provides a specific and effective framework of the curriculum with its concrete teaching-learning activities, two limitations need to be discussed. First, the curriculum design involves three teachers who were well acquainted with the approach. If the curriculum is to be effective for a larger population of teachers, it is recommended that the innovation be allowed to grow (Bulte & Seller,

2011) by facilitating a growing number of communities of teachers to become involved. In this way, the three teachers who were involved in this study could, for example, act as a core nucleus from which an increasing number of new learning communities could be formed. Secondly, the number of lessons necessary to form a core curriculum needs to be increased, and lessons for younger children should become subject to investigation.

By providing the specific design with concrete teaching-learning activities and identifying which elements of scientific argumentation are key issues, the study provides a first and essential step to a knowledge base about designing and implementing a science curriculum based on a social constructivist perspective that supports scientific argumentation in primary science education in Confucian heritage culture.

Acknowledgements

The researcher would like to thank Dirk-Jan Boerwinkel for his discussion on the perspective of form and function and functional arguments that has been extremely useful for this study.

Endnotes

All names of the teachers and the students used in this study are pseudonyms.

References

Abd-El-Khalick, F., & Lederman, N. G. (2000). Improving science teachers' conceptions of nature of science: A critical review of the literature. *International Journal of Science Education*, *22*(7), 665–701.

Anderson, R. D. (2007). Inquiry as an organizing theme for science curricula. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 807-830). Oxford, UK: Taylor & Francis.

Barab, S., & Squire, K. (Eds.) (2004). Special issue on design-based research. *The Journal of the Learning Sciences, 13*(1).

Beck, C., & Kosnik, C. (2006). *Innovations in teacher education – A social constructivist approach*. Albany, NY: State University of New York Press.

Bennett, B., & Rolheiser, C. (2001). *Beyond Monet: The artful science of instructional integration*. Toronto, ON: Bookation.

Berthrong, J. H., & Berthrong, E. N. (2000). *Confucianism: A short introduction*. Oxford, UK: Oneworld.

Biggs, J. (1996). Western misperceptions of the Confucian-heritage learning culture. In D. Watkins & J. Biggs (Eds.), *The Chinese learner: Cultural, psychological and contextual influences* (pp. 45–67). Hong Kong: The University of Hong Kong Comparative Education Research Centre.

Boerwinkel, D. J., Waarlo, A. J., & Boersma, K. (2009). A designer's view: The perspective of form and function. *Journal of Biological Ed*ucation, *44*(1), 12–18.

Brophy, J. (2006). Graham Nuthall and social constructivist teaching: Research-based cautions and qualifications. *Teaching and Teacher Education*, *22*, 529–537.

Bulte, A. M. W., & Seller, F. (2011). Making an innovation grow: On the shared learning within and between communities. In C. Lindner, L. □stman, D. A. Roberts, P.-O. Wickman, G. Erickson, & A. MacKinnon (Eds.), *Exploring the landscape of scientific literacy* (pp. 236-254). New York, NY: Taylor & Francis.

Bulte, A. M. W., Westbroek, H. B., De Jong, O., & Pilot, A. (2006). A research approach to designing chemistry education using authentic practices as contexts. *International Journal of Science Education, 28*(9), 1063–1086.

Chang, S. & Chiu, M. (2008). Lakatos' scientific research programmes as a framework for analyzing informal argumentation about socio-scientific issues. *International Journal of Science Education*, 30(13), 1753–1773.

Coll, R. K., & Taylor, N. (2012). An international perspective on science curriculum development and implementation. In B. J. Fraser, K. G. Tobin, & C. J. McRobbie (Eds.), *Second international handbook of science education* (Vol. II, pp. 771–782). Dordrecht, Netherlands: Springer.

Confrey, J. (1985). Towards a framework for constructivist instruction. In L. Streefland (Ed.), *Proceedings of the Ninth Conference of the International Group for the Psychology of Mathematics Education* (pp. 477-483). Noordwijkerhout: Netherlands.

Creswell, J. W. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches* (3rd ed.). Thousand Oaks, CA: Sage Publications.

Creswell, J. W., & Clark, V. L. P. (2007). *Designing and conducting mixed methods research*. Thousand Oaks, CA: SAGE Publications.

Dekkers, P. (2006). Reconstructing the creature – Exploring design criteria for teaching NOS. In E. V. Den Berg, T. Ellermeijer, & O. Stooten (Eds.), *Proceedings of the GIREP Conference Modelling in Physics and Physics Education* (pp. 459–464). Amsterdam, Netherlands: University of Amsterdam.

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher*, *23*(7), 5–12.

Driver, R., Leach, J., Millar, R., & Scott, P. (1996). *Young people's images of science*. Buckingham, UK: Open University Press.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education, 84*, 287–312.

Duit, R., & Treagust, D. (1998). Learning in science – From behaviorism towards social constructivism and beyond. In B. L. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (pp. 3–25). Dordrecht, Netherlands: Kluwer Academic Publishers.

Duschl, R. A. (2008). Science education in three-part harmony: Balancing conceptual, epistemic and social goals. *Review of Research in Education*, *32*, 268-291.

Duschl, R. A., & Osborne, J. (2002). Supporting and promoting argumentation discourse in science education. *Studies in Science Education*, *38*, 39–72.

Free Dictionary by Farlex. (2013). Retrieved from http://www.thefreedictionary.com/

Freudenthal, H. (1991). *Revisiting mathematics education.* Dordrecht, Netherlands: Kluwer Academic Publishers.

Hand, B. (2011). An immersion approach to argument-based inquiry – Does it look the same in different countries? In Y. Kim, J. Park, H. E. Seo, J. A. Lee, & J. Kim (Eds.), *Proceedings of the 2011 EASE International Conference – Lighting the world with science* (pp.45-54). Chosun University, Gwangju, Korea.

Hoan, Đ. Đ. (2002). *Một số vấn đề cơ bản của chương trình tiểu học mới [Some basic issues of the new primary curricula]*. Hanoi, Vietnam: Education Publisher.

Hofstede, G. (1986). Cultural difference in teaching and learning. *International Journal of Intercultural relations*, *10*, 301–320.

Hofstede, G. (2003). *Cultures and organization - Software of the minds*. London: Profile Books Ltd.

Hofstede, G., Hofstede, G. J., & Minkov, M. (2010). *Cultures and organizations: Software of the mind: Intercultural cooperation and its importance for survival* (3rd ed.). New York: McGraw-Hill.

Jiménez-Aleixandre, M. P., Bugallo Rodríguez, A., & Duschl, R. A. (2000). "Doing the lesson" or "doing science": Argument in high school genetics. *Science Education*, *84*, 757–792.

Klaassen, K., & Kortland, K. (2013). The role and nature of theory in design research. Paper presented at the 13th ESERA Conference: Science education research for evidence-based teaching and coherence in learning. Cyprus University, Cyprus.

Kolstø, S. D. (2001). Scientific literacy for citizenship: Tools for dealing with the science dimension of controversial socioscientific issues. *Science Education*, *85*, 291–310.

Kortland, J., & Klaassen, K. (Eds.). (2010). *Designing theory-based teaching-learning sequences for science education*. Utrecht, Netherlands: CDβ Press. Retrieved from http://www.staff.science.uu.nl/~kortl101/book_sympPL.pdf

Kuhn, D. (1993). Science as argument: Implications for teaching and learning scientific thinking. *Science Education*, *77*(3), 319–337.

Lehrer, R., Schauble, L., & Lucas, D. (2008). Supporting development of the epistemology of inquiry. *Cognitive Development*, *23*(4), 512–529.

Lissen, L. (2004). Co-operative learning, a 'tool' for both students and teachers. In R. Schollaert (Ed.), *The keys to the treasure within: Learning and leadership in schools* (pp. 101–110). Antwerp, Belgium: Garant-Uitgevers.

McComas, W. F., Almazroa, H., & Clough, M. (1998). The nature of science in science education: An introduction. *Science and Education*, *7*, 511–532.

Méheut, M., & Psillos, D. (Eds.) (2004). Special issue: Teaching-Learning sequences: Aims and tools for science. *International Journal of Science Education, 26*(5).

Millar, R., & Osborne, J. F. (Eds.). (1998). *Beyond 2000: Science education for the future*. London, UK: King's College.

Ministry of Education [China] (2010). *National Outline for Medium and Long-term Education Reform and Development 2010-2020*. Retrieved from http://www. cov.cn/jrzg/2010-07/29/content-1667143.htm

Ministry of Education [Taiwan] (1999). *Curriculum outline for "Nature science and living technology"*. Taipei: Ministry of Education.

Ministry of Education and Human Resources [Korea] (2007). *Science Education Curriculum*. Seoul, Korea.

Ministry of Education and Training [Vietnam] (2006). *Chương trình dạy học - Dành cho bậc tiểu học [Schooling curricular – For Primary Education Level].* Hanoi, Vietnam: Education Publisher.

Neuman, Y., & Bekerman, Z. (2000). Cultural resources and the gap between educational theory and practice. *Teachers College Record, 103*(3), 471–484.

Nguyen, M., Elliott, J., Terlouw, C., & Pilot, A. (2009). Neocolonialism in education: Cooperative learning, Western pedagogy in an Asian context. *Comparative Education*, *45*(1), 109–130.

Phuong-Mai, N., Terlouw, C., & Pilot, A. (2005). Cooperative learning vs Confucian heritage culture's collectivism: Confrontation to reveal some cultural conflicts and mismatch. *Asia-Europe Journal, 3*(3), 403–419.

Ryu, S., & Sandoval, W. A. (2012). Improvements to elementary children's epistemic understanding from sustained argumentation. *Science Education*, *96*(3), 488–526.
Sandoval, W. A. (2005). Understanding students' practical epistemologies and their influence on learning through inquiry. *Science Education*, *8*9, 634–656.
Tao, Y., Oliver, M., & Venville, G. (2013). A comparison of approaches to the teaching and learning of science in Chinese and Australian elementary classrooms: Cultural and socioeconomic complexities. *Journal of Research in Science Teaching*, *50*(1), 33–61.
Totten, S., Sills, T., Digby, A., & Russ, P. (1991). *Cooperative learning: A guide to research*. New York, NY: Garland.
Toulmin, S. (1958). *The uses of argument*. Cambridge, UK: Cambridge University
Press.
Van den Akker, J. (1998). The science curriculum: Between ideals and outcomes. In B. Fraser & K. Tobin (Eds.), *International handbook of science education* (pp. 421–447). Dordrecht, the Netherlands: Kluwer Academic Publishers.
Van den Akker, J. J. H. (2003). Curriculum perspectives: An introduction. In J. J. H. Van den Akker, W. Kuiper, & U. Hameyer (Eds.), *Curriculum landscape and trends* (pp. 1–10). Dordrecht, the Netherlands: Kluwer Academic Publishers.
Van Gelder, T., Bissett, M., & Cumming, G. (2004). Cultivating expertise in informal reasoning. *Canadian Journal of Experimental Psychology*, *58*(2), 142–152.
Volet, S., & Renshaw, P. (1996). Chinese students at an Australian university: Adaptability and continuity. In D. A. Watkins & J. B. Biggs (Eds.), *The Chinese learner: Cultural, psychological and contextual influences* (pp. 205-220). Hong Kong: The Central Printing Press.
Westbroek, H. B., Klaassen, K., Bulte, A., & Pilot, A. (2010). Providing students with a sense of purpose by adapting a professional practice. *International Journal of Science Education*, *32*, 603–627.
Wong, J. K. K. (2004). Are the learning styles of Asian international students culturally or contextually based? *International Education Journal*, *4*(4), 154–166.
Xiao, L. (2009). What can we learn from a learning needs analysis of Chinese English majors in a university context? *Asian EFL Journal, 8*(4), 74–79.

Appendix A - The sequence of the analysed lesson *Plant Roots* in practice

Phase	Student activity	Learning form	Learning materials
Engagement	1. Draw a complete plant 2. Answer questions: + *What did you draw?* + *Can you name the parts of the plant you've drawn?* + *Why do you think the plant you've drawn has a root system like that?*	In small groups and in the class as a whole	Group small boards
Experience	3. PREDICTING 3.1. Observe the real mango and the real grass with their root systems fully covered in order to answer the questions: + *What do you think the root system of each of the plants looks like?* + *Why do you think so?* 3.2. Write down answers on the group small boards 3.3. Present the predicting answers to other groups 3.4. Clarify similarities and differences in answers for the predicting questions 4. HANDS-ON 4.1. Open the covers of the root systems of the mango and the grass and observe the root systems 4.2. Working with the learning placemat in order to answer the given questions (5 steps took place in using the adapted learning placemat)	In small groups	- The real mango - The real grass - Group small boards (for Predicting task) - Prepared learning placemats (for Hands-on task)

Exchange	5. Present results of the hands-on activities to other groups 6. Clarify similarities and differences in answers for hands-on questions 7. Clarify similarities and differences in answers for predicting questions compared to those for hands-on questions 8. Answer questions formulated by your peers	In the class as a whole	Completed learning placemats
Follow-up	9. Answer the teacher’s questions: + *Which root type is the mango’s root system?* + *Which root type is the grass’s root system?* + *What are the main functions of the mango’s root system?* + *What are the main functions of the grass’s root system?* + *What is the taproot system?* + *What is the fibrous root system?* + What are the main functions of the taproot system? + *What are the main functions of the fibrous root system?* 11. Provide examples of the taproot and fibrous root systems 10. Identify the types of root systems of real plants given by the teacher and explain why	In the class as a whole	The real radish

Appendix B - The adapted model of the learning placemat used in the lesson *Plant Roots*

Individual ideas Name:	*Individual ideas* Name:	*Individual ideas* Name:	Group:

Hands-on *Open the covers and observe the root systems. Discuss in order to answer the following questions:*

1. What does the root system of the mango look like as you observe it? Explain why the mango has a root system like that.

…………………………………………………………

…………………………………………………………

2. What does the root system of the grass look like as you observe it? Explain why the grass has a root system like that.

…………………………………………………………

…………………………………………………………

3. Do you have any questions to ask or to discuss with the class?

…………………………………………………………

Name: *Individual ideas*	Name: *Individual ideas*	Name: *Individual ideas*

Chapter 1. Introduction and Research Overview

What is the design of curriculum for primary science education that has social constructivist characteristics and is appropriate with Confucian heritage culture?

PROBLEM ANALYSIS

Chapter 2. The implementation of a social constructivist perspective in primary science education in Confucian heritage culture: the case of Vietnam

RQ1. To what extent is a social constructivist perspective implemented in primary science education in Confucian heritage culture?
RQ2. How can this implementation be explained from a Confucian cultural perspective and what are fostering and hindering cultural factors to the implementation?

DESIGN CYCLE 1

Chapter 3. Designing a formal curriculum based on a social constructivist perspective for primary science education in Confucian heritage culture

RQ. What is the design of formal curriculum for primary science education that has social constructivist characteristics and is appropriate with Confucian heritage culture?

Chapter 4. Teacher professional development: The interaction of Confucian heritage teachers with a social constructivism-based curriculum for primary science education

RQ. In what way do Confucian heritage teachers interact with a primary science curriculum, which is based on a social constructivist perspective and made appropriate with Confucian heritage culture, in a program of professional development?

Chapter 5. Scientific argumentation as bottleneck for implementing a social constructivism-based science curriculum in Confucian heritage culture

RQ. To what extent does the unit of the curriculum design for primary science education in Confucian heritage culture meet the social constructivist expectations in the practice of the classroom?

DESIGN CYCLE 2

Chapter 6. Improving scientific argumentation through a social constructivism-based curriculum for primary science education in Confucian heritage culture

RQ1. To what extent does the unit of the adjusted design of social constructivism-based curriculum for primary science education in Confucian heritage culture support students to practice scientific argumentation in a science lesson?
RQ2. To what extent does the unit of the adjusted design of social constructivism-based curriculum for primary science education in Confucian heritage culture support students to attain consensually agreed knowledge on scientific subject-matter?

Chapter 7. Conclusions, Reflection and Recommendations

RQ. What is the design of curriculum for primary science education that has social constructivist characteristics and is appropriate with Confucian heritage culture?

CHAPTER 7 Conclusions, Reflection, and Recommendations

A social constructivist approach is thought to create a learning community, providing students with the strong social and emotional support that enables them to take risks and develop ownership (Beck & Kosnik, 2006). It can thereby help students develop not only knowledge but also critical thinking (Totten, Sills, Digby, & Russ, 1991) and communicative skills (Confrey, 1985).

Many studies show that a social constructivist perspective has come into focus for primary science education in Confucian heritage cultures through recent school reforms. However, there is insufficient in-depth knowledge about the implementation of a social constructivist perspective in primary science education, and about how Confucian heritage culture influences this implementation.

Meanwhile, it is acknowledged that teaching and learning in Confucian heritage culture has been dominated by a teacher-centred, book-centred method with an emphasis on rote memorisation (Liu & Littlewood, 1997). It is usually primarily one-sided: what the teacher says is right and the students are not entitled to ask about sense and purpose, to require reasons, or to question content (Chan, 1999). Culture is acknowledged as a crucial factor that considerably influences teaching and learning (Hofstede, 1986). It has been asserted that teaching a constructivist approach is difficult when the members of a community of students are regarded as passive recipients of knowledge (Neuman & Bekerman, 2000). Therefore, it is important to take cultural resources and contextual realities into consideration before applying educational theories in practice (Neuman & Bekerman, 2000; Nguyen, Elliott, Terlouw, & Pilot, 2009) in order to avoid a cultural mismatch (Örtenblatd, Babur, & Kumari, 2012; Serpell, 2007) and a false universalism (Nguyen et al., 2009).

Despite increasing calls for culturally appropriate curriculum designs, so far there has been little evidence to show that social constructivist curricula have been designed and developed with a concern for the distinct characteristics of Confucian heritage culture. Therefore, this research aims to answer the main research question: *What curriculum design for primary science education has social constructivist characteristics and is appropriate for Confucian heritage culture?* By answering this main research question, this study contributes to a knowledge base about designing and implementing a social constructivism-based curriculum for primary science education in general and particularly in Confucian heritage culture.

To answer the main research question with respect to the design, the study followed a design-based research approach (Bulte, Westbroek, De Jong, & Pilot, 2006), using curriculum representations as described by Van den Akker (2003). The chapters of this study can be considered as separate parts of the larger project that provide answers for the research sub-questions (see figure on page 216). The entire study can be subdivided into three main stages: (initial) problem analysis, cycle 1, and cycle 2. Each of these three main stages is discussed below. The study is situated in Vietnam; a country that has been deeply influenced by Confucianism for a long time (Đạm, 1994). Also, the Vietnamese primary school curriculum, in which primary school science is integrated, has been recently reformed since the year 2000 with the application of innovative educational theories (Hoan, 2002).

Problem Analysis

Chapter 2 presents a problem analysis that focuses on characterising the implementation of a social constructivist perspective in primary science education in Confucian heritage culture, and the influences of that culture. To do that, the social constructivist features synthesised by Beck and Kosnik (2006), as presented in Table 1, and the main features of Confucian heritage culture, including a) the collectivist root, b) the harmony and stability preference as a cultural and human value, c) the virtue focus, d) the support of hierarchical order, e) the family value, and f) the emphasis on theoretical knowledge, were used as the organising elements for data analysis and providing cultural explanations.

Multiple data sources were collected, including classroom observations, questionnaires, interviews, science textbooks, and the curriculum guidelines, as well as diverse cultural literature of Confucian heritage culture, including cultural traditions, folklore, and customary practices experienced by the general population. The study of Chapter 2 showed that the implementation of a social constructivist perspective in primary science education in Confucian heritage culture is unsatisfactory, and the teaching and learning of science is dominated by a teacher-centred and textbook-based approach in which scientific skills and attitudes are not well developed in students. The findings are consistent with the proposition in the conclusion of Central Committee [Vietnam] (2012), in which many weak points of school education are clarified, i.e. the curricula are overloaded with academic knowledge, learning goals are separated from each other, learners' capabilities are not focussed, and so forth. Also, Chapter 2 supports the proposition that basically and comprehensively innovating education and training has been considered an objective and urgent task of the enterprise of fostering industrialisation and modernisation in Vietnam (Centre Committee [Vietnam], 2012). The findings of Chapter 2 align with the cross-cultural studies of Tao, Oliver and Venville (2013), Couchman (1997), Liu and Littlewood (1997), and Chan (1999), which show that lessons in classroom practices in Confucian heritage culture are primarily one-sided in a one-way process: what the teacher announces is right and the students are not entitled to ask about sense and purpose, to require reasons, or to question content.

Table 1. Social constructivist features (see Chapter 2)

Feature	Indicator
1. Learning is social	i. Students work in the whole class, and/or ii. Students work in small groups iii. Students actively share ideas
2. Knowledge is experience-based	i. Students' experiences are provoked ii. Students interpret experiences
3. Knowledge is constructed by learners	i. Students are immersed in realistic learning situations ii. Students elaborate interpretations of their experiences iii. Students test interpretations of their experiences iv. Students construct meaning
4. All aspects of a person are connected	i. Students' attitudes and emotions are revealed in learning ii. Students take part in hands-on activities iii. Students' values are employed and capitalised in learning
5. Learning communities should be inclusive and equitable	i. Types of communities (e.g., families, organisations, institutions, etc.) are involved to support students' learning ii. Interactions of teacher-student and student-student should be equitable rather than hierarchical

Moreover, the study of Chapter 2 explains the considerable influences of Confucian heritage culture on the implementation of a social constructivist perspective. In providing explanations for the implementation, three emergent cultural divergences between Confucian heritage culture and Western educational philosophy were revealed.

(1) Confucian heritage culture emphasises stability and harmony among its human values, whereas Western educational philosophy emphasises the rationality (Totten et al., 1991) that supports argumentation and conflict in discussion and helps students prepare for citizenship (Kolstø, 2001). In the "nature of science" education (Abd-El-Khalick & Lederman, 2000; Dekkers, 2006), conflicts and argumentation are preferred over harmony.

(2) Confucian heritage culture emphasises theoretical knowledge, considering "classical" knowledge and theory as universally correct, whereas Western educational philosophy emphasises empirical knowledge and well-substantiated scientific claims, believing that there is no complete truth and that every aspect of theoretical knowledge is changeable (Abd-El-Khalick & Lederman, 2000; Dekkers, 2006).

(3) Confucian heritage culture emphasises hierarchical order in which the teacher is considered superior and the transmitter of the body of knowledge to students, whereas Western educational philosophy emphasises equitability: the teacher is considered a more advanced learner (Vygotsky, 1978) who facilitates students to learn in order to achieve not only knowledge but also the skills and attitudes used to study science (Bybee, McCrae, & Laurie, 2009; Hofstede, 1986).

In many studies applying cross-cultural approaches to the teaching and learning of science, Confucian heritage culture is acknowledged to have influenced teaching and learning (see, for example, Chan, 1999; Tao et al., 2013; Wong, 2004). However, these studies did not reveal the specific cultural divergences between Confucian heritage culture and Western educational philosophy that clarify the influences of Confucian heritage culture on the implementation of a social constructivist perspective in science education. These specific findings can explain the low implementation of a social constructivist perspective through the influences of Confucian heritage culture. Chapter 2 provides grounds for the need for a culturally appropriate pedagogy (Nguyen et al., 2009) for designing a social constructivism-based curriculum for primary science education in Confucian heritage culture.

Design Cycle 1

Designing the Ideal and Formal Curriculum

Cycle 1 started with designing a formal curriculum for primary science education for Confucian heritage culture based on a social constructivist perspective. Chapter 3 is primarily a theoretical study which focuses on providing arguments to establish the design of the ideal and formal curriculum. The design of the curriculum framework (Table 2) is underpinned by a social constructivist perspective (Beck & Kosnik, 2006) and refers to knowledge about the "nature of science" (Abd-El-Khalick & Lederman, 2000) and to knowledge of Confucian heritage culture. Confucian cultural characteristics and cultural divergences were taken into consideration. The designed curriculum framework was used to design specific curriculum units entitled *Air Pressure*, *Plant Roots*, and *CO_2 Reaction* (Table 3), from which scientific themes were selected based on three criteria: accessibility, relevance, and the use of experimental hands-on activities. The designed curriculum is considered to help Confucian heritage students, who can be "more adequately prepared for their lives as citizens when they are afforded with a fuller understanding of the nature of this thing called science" (McComas, Almazroa, & Clough, 1998, p.528). The curriculum design is the response to a call for interactive teaching strategies for *culture broking* in science education (Jegede & Aikenhead, 1999) that will enable the teaching of Western science in non-Western contexts.

The Perception and Operationalisation of the Designed Curriculum

The designed curriculum was operationalised in the practice of teaching and learning by the involvement of three Vietnamese Confucian heritage teachers who had been applying a traditional approach for science lessons. Chapter 4 describes the interaction of the teachers with the designed curriculum in a programme of teacher professional development. This programme was adapted from a framework for empowering teachers to teach innovative units of context-based education (Stolk, Bulte, De Jong, & Pilot, 2012). The programme was implemented by the application and combination of strategic knowledge about teacher professional development (Agung, 2013; Dolfing, 2013; Stolk, 2013) and curriculum design (Bulte et al., 2006; Meijer, 2011; Prins, 2010). The combined spiral programme of teacher professional development with many iterative activities, as presented in Figure 1, provided the Confucian heritage teachers with opportunities to interact well with the designed curriculum as co-designers, observers, and

Table 2. The designed framework of the social constructivism-based curriculum for primary science education in Confucian heritage culture (see Chapter 3)

PHASE	FUNCTION	LEARNING SETTING: Activity	LEARNING SETTING: Form	EDUCATIONAL EXPECTATIONS
Engagement	A. To provide students with the motivation to learn	1. Doing a small hands-on task with a relevant example related to scientific subject matter 2. Answering *What*, *How*, and *Why* questions about a relevant example related to scientific subject matter	1. In small groups and/or in the class as a whole	a. Students are interested in scientific subject matter
Experience	B. To evoke attitudes toward science C. To acquire procedural knowledge D. To acquire conceptual knowledge E. To acquire argumentative skills	3. Predicting: Observe and discuss in order to answer questions: *What do you observe? What will happen if…? Why do you think so?* 4. Hands-on: Do experiment and discuss in order to answer questions: *What did you observe? How can you explain it? Why do you think so?* 5. Questioning: Formulate questions related to scientific subject matter	2. In small groups	b. Students are curious about representative examples of scientific subject matter c. Students are active in learning about representative examples of scientific subject matter d. Students use their intuitive knowledge to learn about scientific subject matter e. Students argue with each other to attain consensually agreed knowledge on representative examples of scientific subject matter

Exchange	F. To build on attitudes toward science G. To build on procedural knowledge H. To build on conceptual knowledge I. To build on argumentative skills	6. Presenting results to other groups 7. Discussing results with other groups 8. Answering formulated questions related to scientific subject matter	3. In the class as a whole and/or in combined groups	f. Students are interactive in learning scientific subject matter g. Students argue with each other to attain consensually agreed knowledge on scientific subject matter
Follow-up	J. To acquire cognitive flexibility K. To further learning motivation	9. Providing answers and/or solutions for new questions and/or problems related to scientific subject matter	4. In the class as a whole	h. Students can provide appropriate answers and/or solutions on applying attained knowledge i. Students show their desire to learn more about scientific subject matter

Table 3. The designs of exemplary curriculum units (see Chapter 3)

Phase	Unit Air Pressure	Unit Plant Roots	Unit CO_2 Reaction
Engagement	1. Answering: *What will happen if we blow air into the inflated balloon? Why do you think so? What will happen if the inflated balloon is released at once? Why do you think so?*	1. Drawing a complete plant	1. Answering: *What will happen if we blow air through a straw into a water bottle? Why do you think so?*
	2. Blowing air into the inflated balloon and releasing it, and answering: *What happened? How can you explain what was observed?*	2. Answering: *What did you draw? Why did you draw the plant roots like that? How did you know it?*	2. Blowing air through a straw into a water bottle and answering: *What happened? How can you explain what was observed?*
	3. Predicting (Exercise 1): Connect two cylinders with a plastic tube. Discuss with your peers and answer the following questions:	3. Predicting (Exercise 1): Choose a wild plant in the school garden to observe. Discuss in the group the answers to the following questions:	3. Predicting (Exercise 1): Given a Coca Cola bottle and Mentos. Discuss in your group the answers to the following questions:
	a. What will happen if one cylinder is pressed down?	*a. What do you think the plant root looks like? Draw it.*	*a. What will happen if all the Mentos are dropped into the coke bottle?*
	b. Why do you think so?	*b. Why do you think so?*	*b. Why do you think so?*
	4. Hands-on (Exercise 2): Press one of the connected cylinders down. Discuss in the group answers to the following questions:	4. Hands-on (Exercise 2): Pull out the wild plant in the school garden. Discuss in the group the answers to the following questions:	4. Hands-on (Exercise 2): Drop all the Mentos into the coke bottle. Discuss in the group the answers to the following questions:

Experience	*a. What did you observe?*	*a. What does the plant root system look like? Draw it.*	*a. What did you observe?*
	b. How can you explain what was observed?	*b. Why does this plant have a root system like that?* c. What are the functions of the plant root system? Why do you think so?	*b. Why did it happen?*
	5. Questioning (Exercise 3): Write down questions or ideas related to the subject matter that you want to discuss	5. Questioning (Exercise 3): Write down questions or ideas related to the subject matter that you want to discuss.	5. Questioning (Exercise 3): Write down questions or ideas related to the subject matter that you want to discuss
Exchange	6. Presenting results to other groups 7. Discussing results with other groups 8. Answering formulated questions related to subject matter	6. Presenting results to other groups 7. Discussing results with other groups 8. Answering formulated questions related to subject matter	6. Presenting results to other groups 7. Discussing results with other groups 8. Answering formulated questions related to subject matter
Follow-up	9. Answering the questions: *What did you learn from the lesson today? Can you provide some examples related to air pressure and explain why you think what you do about them? How can you relate this knowledge to a natural phenomenon such as the wind?*	9.a. Answering questions: *What did you learn from the lesson today? Can you provide some examples of root types and explain why you think those plants have such root types?* 9.b. Determining type of root for some plants	9. Answering questions: *What did you learn from the lesson today? Can you provide some examples of carbon dioxide reaction and explain why you think what you do about them?*

Table 4. Basic characteristics of a social constructivist (SC) teacher and of a Confucian heritage (CH) teacher (Chapter 4)

Category	Characteristics	
1. Attitude	a. Being open-minded	a. Tending to be closed-minded by teaching for "correct" answers
	b. Being friendly	b. Maintaining a superior role
2. Activity	a. Encouraging students to engage in inquiry	a. Not encouraging students to engage in inquiry
	b. Providing time and space for students to carry out self-regulated learning	b. Imposing knowledge on students
	c. Promoting social interactions among students	c. Adhering to one-way teacher-student interaction
	d. Seeking elaboration of students' initial responses	d. Asking for single answers

active teachers, who reflected on the experimental lessons. In this way, they could accommodate the designed curriculum and change from traditional Confucian heritage (CH) teachers to social constructivist (SC) teachers, as characterised and presented in Table 4.

The study of Chapter 4 reveals that the Confucian heritage teachers considerably changed their attitudes and teaching activities in teaching science lessons. Overall, they became more open-minded and friendly in interacting with the students in the experimental science lessons. In addition, they focussed more on a) encouraging students to engage in inquiry, b) providing time and space for self-regulated learning, c) promoting social interactions among students, and d) seeking elaboration of students' initial responses. The Confucian heritage teachers perceived that the designed curriculum brings more benefits for students than the conventional science curriculum brings. They also acknowledged that the designed curriculum helped to reconceptualise the teaching and learning of science, bringing it closer to a social constructivist perspective and the "nature of science" education.

With the considerable changes observed in the Confucian heritage teachers, Chapter 4 showed that the adapted and combined spiral programme of teacher professional development (Figure 1) established an effective learning community that could facilitate the Confucian heritage teachers' interaction with the designed curriculum, and help them change their attitudes and activities toward a social constructivist perspective of teaching and learning. With these findings, this study can be situated within a larger research programme on developing a framework for professional development with three main stages – preparation for teaching, teaching and observing, and reflection – and, as Stolk et al. (2012) and Dolfing (2013) have recommended, with quite a number of small iterations (nine in this case; Figure 1). The importance of general strategies, such as collaboration, sharing experiences, teaching and observing, and reflecting on the design and lessons are acknowledged by many studies on professional development. The spiral approach in which the three teachers changed sequence so that each teacher was able to teach a first lesson in a unit (Figure 1) balanced the pattern of hierarchy between participants and is consistent with a social constructivist approach, which values equitability (Beck & Kosnik, 2006). This study builds on the knowledge of the establishment of learning communities with a facilitator and the teachers as critical co-designers (see Agung, 2013). With the application and combination of state-of-the-art knowledge about professional development (Dolfing, 2013) and design knowledge on curriculum frameworks and units (Bulte et al., 2006; Meijer, 2011; Prins, 2010), as synthesised in Figure 1, this study reinforces the research results of those former studies.

The experiment and attainment of the designed curriculum

To evaluate the designed curriculum, the best-functioning experimental lesson was selected for the in-depth analysis presented in Chapter 5. The evaluation was implemented through the identification of the extent to which the designed science unit meets social constructivist expectations (Table 2) when taught. These expectations are concrete operationalisations of the social constructivist features presented in Table 1. To evaluate these social constructivist characteristics, multiple data sources were collected and analysed, including the classroom observations, questionnaires, interviews, and learning materials of the sixth lesson, *Plant Roots* (Figure 1 & Table 3). Chapter 5 showed that the curriculum unit can encourage Confucian heritage students to be interested in scientific subject matter (Expectation a, Table 2), curious about learning scientific examples (Expectation b, Table 2), and active in learning science (Expectation c, Table 2). Also, the findings show that the curriculum unit could help the students use intuitive knowledge to learn science (Expectation d, Table 2), be interactive in learning (Expectation f, Table 2), and have a desire to learn science (Expectation i, Table 2). With the majority of the expectations met by the unit,

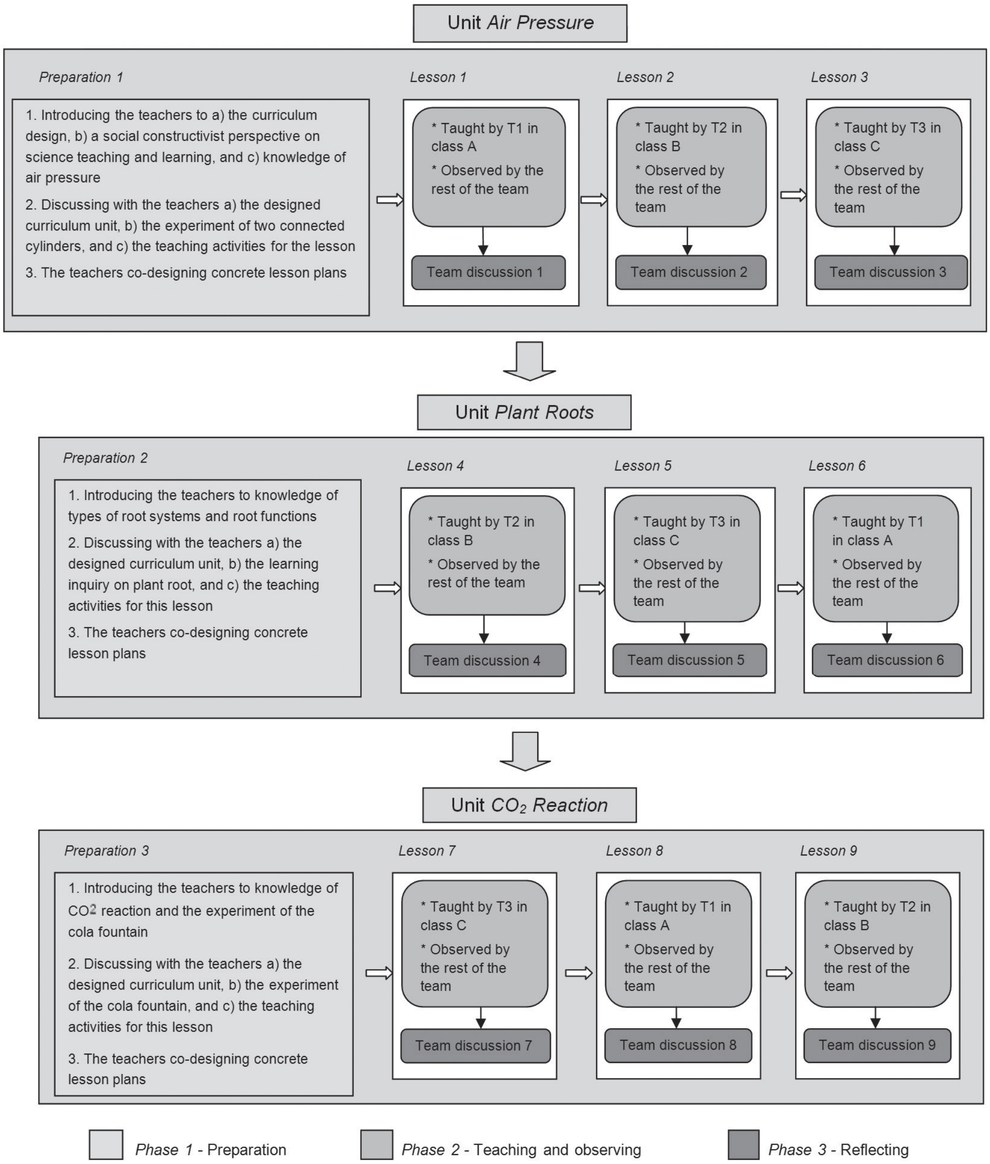


Figure 1. Professional development programme in operating the designed curriculum (see Chapter 4)

the study of Chapter 5 delivered a *proof of principle* (Freudenthal, 1991; Westbroek, Klaassen, Bulte, & Pilot, 2010). Thereby, the study shows that the designed curriculum can be a possibility for applying to primary science education in Confucian heritage culture in order to overcome the problems which were analysed for primary science education. Specifically, the designed curriculum can help Confucian heritage students change from passive learning to a more active and interactive way of learning science that can support them in attaining not only science knowledge but also the skills and attitudes needed to study science effectively. However, a refined problem analysis arose from the detailed analysis of the curriculum unit.

Refined problem of Cycle 1
Scientific argumentation as a bottleneck for implementing a social constructivist science lesson in Confucian heritage culture

Despite the considerable educational achievements, the study showed that the designed curriculum was not effective enough in supporting Confucian heritage students in practicing scientific argumentation in a science lesson. This is evident in the modest attainments of Expectations e, g and h (Table 2) that show a low level of scientific argumentation among the Confucian heritage students in the experimental lesson. This finding is consistent with the rather dramatic challenges teachers encounter when applying inquiry-based approaches and constructivist theories in the practice of science education in Confucian heritage countries such as Taiwan, Korea, Singapore, and China (see Abd-El-Khalick et al., 2004; Kim & Tan, 2011; Lee, Tan, Coh, Chia, & Chin, 2000; Tao et al., 2013).

On the one hand, the low level of scientific argumentation among students and the modest attainment of appropriate answers while applying their knowledge can be attributed to the limitations of a social constructivist perspective, which has been criticised as resulting in relative content knowledge (Benson, 2001). On the other hand, these findings confirm that scientific argumentation is difficult in science education (Driver, Newton, & Osborne, 2000) and can be considered as *the* bottleneck for the implementation of a social constructivist perspective in primary science education in Confucian heritage culture. This refined problem analysis rendered it necessary to address scientific argumentation when applying a social constructivist perspective to primary science education in Confucian heritage culture. Therefore, the next step of the design process involved the designers in searching for appropriate pedagogical solutions that would support scientific argumentation in a manner appropriate with the feature of harmony preference in Confucian heritage culture.

Design Cycle 2

Cycle 2 focussed on a design that supports Confucian heritage students in practicing scientific argumentation in a science lesson (Chapter 6). Three design phases, similar to those of Cycle 1, were carried out, as described below.

Adjusting the framework of the designed curriculum

The designed curriculum was adjusted by the adaptation of the learning placemat (Figure 2) used for argumentative activities in the hands-on task of the Experience phase (Table 2), and the formulation of concrete teaching-learning activities as proposed by the Confucian heritage teachers (Chapter 4). The adjusted design of the curriculum framework is presented in Table 5.

<table>
<tr><td>Individual ideas

Name:</td><td>Individual ideas

Name:</td><td>Individual ideas Group:

Name:</td></tr>
<tr><td colspan="3">Hands-on
1. What do you observe? ....
2. How can you explain your observation?/ Why is it like that? ....
3. Do you have any questions? ....</td></tr>
<tr><td>Name:

Individual ideas</td><td>Name:

Individual ideas</td><td>Name:

Individual ideas</td></tr>
</table>

Figure 2. Adapted model of the learning placemat used in the adjusted design (see Chapter 6)

There are three main differences between the designs of Cycle 1 and Cycle 2. The first design focussed only on student activities and did not provide guidelines for teacher activities. This caused practical difficulties for Confucian heritage teachers in teaching the experimental lessons

(Chapter 4). Secondly, the first design was developed without the use of the model of the learning placemat. The adapted model of the learning placemat (Figure 2) was used in the adjusted design in order to foster argumentative interaction among students to enable them to learn argumentative skills. The third difference is that student activities in the adjusted design were more concrete and better organised due to the articulation with the concrete teaching activities and the use of the adapted model of the learning placemat. In the former design, the activities of presenting and discussing for both the predicting task and the hands-on task took place in the Exchange phase. However, in the adjusted design, the activities of presenting and discussing for the predicting task took place in the Experience phase before the hands-on task began (Table 5). This was done to avoid confusing students and making it difficult for them to catch key ideas of other groups, which was the case when they *predicted* the outcomes of the experiments and presented the *results* of the hands-on tasks at the same time. The confusion in grasping this information simultaneously could make students passive in learning and runs the risk that teaching might return to traditional approaches (Chapter 4).

By separating the activities of predicting the outcomes from presenting the outcomes of the experiments of the hands-on task, the adjusted design can provide students with opportunities to find similarities and differences in group answers within the same tasks and between the different tasks (Student activities 3.4, 7, & 8 in Table 5). This comparison can provide student groups with informative grounds that they can rely on for the next stage of learning. Moreover, it can also help teachers follow the students' learning step by step; hence, they can better master teaching from a social constructivist perspective (Chapter 4). Based on the adjusted framework of the curriculum design, three curriculum units – *Solutions*, *CO_2 Reaction*, and *Plant Roots* – were designed or redesigned.

The Operationalisation of the Adjusted Curriculum

The framework of teacher professional development developed in Cycle 1 (Figure 1) was adapted and utilised in Cycle 2 for the Confucian heritage teachers, who had been intensively involved in Cycle 1. The operationalisation of the adjusted curriculum was implemented one year after the operationalisation of the designed curriculum of Cycle 1. In total, nine experimental lessons were co-designed, observed and taught, and reflected upon by the three Confucian heritage teachers,.

To select the best-functioning experimental lesson, the key criteria based on social constructivist features (Beck & Kosnik, 2006) of Cycle 1 were used again in this Cycle. In addition, one more criterion was added to this list, which focussed on scientific argumentation because this was the focal issue of the second Cycle of the design process. The six experimental lessons of the two units, *Solutions* and *CO_2 Reaction*, were trial lessons and the last experimental lesson of the unit *Plant Roots* was chosen for the in-depth analysis.

The attainment of the adjusted curriculum

The framework about scientific argumentation was set up with a focus on both the personal and social aspects of scientific argumentation through an understanding of the nature of scientific argumentation (Driver et al., 2000; Duschl & Osborne, 2002; Hand, 2011; Ryu et al., 2012; Toulmin, 1958). This framework was used to identify the extent to which the adjusted design supports Confucian heritage students in practicing scientific argumentation in a science lesson, and in attaining consensually agreed knowledge on scientific subject matter. The personal aspect refers to the content of the argument, including elements such as data, evidence, causal structure, and causal coherence. The social aspect refers to argumentative activities, including evaluating, judging, qualifying, justifying, questioning, and rebutting. Two main data sources – classroom observation and learning materials – were collected for the in-depth analysis.

It was found that the Confucian heritage students provided many explanations and arguments, both individually and cooperatively, that were constructed with data, evidence, causal structure, and causal coherence. The students also implemented the social aspect of scientific argumentation by carrying out activities like evaluating, judging, justifying, and questioning when they were arguing with each other. These activities were considered to be effective in helping them provide appropriate answers to questions while applying their knowledge.

Thereby, Chapter 6 delivered *a proof of principle* (Freudenthal, 1991; Westbroek et al., 2010) for the adjusted curriculum. Moreover, Chapter 6 shows that the adapted model of the learning placemat (Figure 2) is a culturally appropriate teaching-learning tool that is useful for facilitating Confucian heritage students to interact with each other and practice scientific argumentation. Despite being specifically designed for Confucian heritage culture, the adapted model of the learning placemat (Figure 2) could be useful for enabling students in other cultures to learn scientific argumentation, because of its ease of use.

Refined problem of Cycle 2

Confucian heritage students and teachers did not pay attention to qualifying and rebutting in scientific argumentation. Cycle 1 showed that scientific argumentation was the bottleneck for implementing a social constructivism-based curriculum in primary science education. This refined problem analysis led to a redesign in Cycle 2 with the adaptation of the learning placemat for argumentative activities for the hands-on task and with the formulation of concrete teaching-learning activities. The implementation of the adjusted design led to a further refined problem analysis: *Confucian heritage students and teachers did not pay attention to qualifying and rebutting in scientific argumentation*. This is considered as a core problem in applying a social constructivist perspective to primary science education in Confucian heritage culture.

<table>
<tr><td>Individual ideas

Name:</td><td>Individual ideas

Name:</td><td>Individual ideas

Name:</td><td>Group:</td></tr>
<tr><td colspan="4">What are your group’s arguments to qualify and/or rebut the given argument?

....

....</td></tr>
<tr><td>Name:

Individual ideas</td><td>Name:

Individual ideas</td><td colspan="2">Name:

Individual ideas</td></tr>
</table>

Figure 3. The adapted model of the learning placemat for supporting qualifying and rebutting

Because both qualifying and rebutting are essential activities of scientific argumentation (Hand, 2011; Toulmin, 1958), further research is recommended to deal with the problem of how to embed these activities in scientific argumentation in a social constructivist science lesson. In thinking of supporting the activities of qualifying and rebutting in science lessons, one recommendation may be to extend the learning placemat with scaffolding questions that specifically focus on qualifying and rebutting, as shown in Figure 3. Furthermore, the analysis of the quality of arguments plays an essential role and may benefit from additional frameworks for analysis. Lakatos' scientific research programmes (Chang & Chiu, 2008) could be chosen and applied as an alternative in supporting the improvement of quality of scientific arguments. The design-based approach and the main findings of this study are presented in Figure 4.

This study provides a curriculum framework with phases and their functions (Table 5), concretised into three units that met three criteria: accessibility, relevance, and experimental activities, so that Confucian heritage students would be motivated and involved in learning science. The in-depth analysis of one of the science lessons showed that most expectations were met. These expectations were based upon social constructivist characteristics. The framework and the concrete science lessons still needed to include the recommendations that followed from Cycle 2. Moreover, the design-based approach not only led to the design of a curriculum framework and its corresponding science unit, but as Figure 4 shows, after each of the cycles a refined problem analysis followed, which led to new arguments for redesigning and fine-tuning. Such a problem analysis is to be included in the answer to the main research question.

The study successively refined the problem of how to implement a social constructivist teaching approach in primary science education in a Confucian Heritage culture: specifically, it dealt with the issues of scientific argumentation as a bottleneck (for Cycle 1) and the students' and teachers' neglecting the activities of qualifying and rebutting (for Cycle 2). With these specific results, this study showed the appropriateness of this design-based research approach, as illustrated in Figure 5.

The design research applied in this study is appropriate because it concerned open or *wicked* problems, as theoretically discussed for design research (Kelly, 2010). Specifically, the study was carried out because a social constructivist perspective was not well implemented in primary science education in Confucian heritage culture. The study of this dissertation provides a design research that is consistent with the one characterised by Kelly (2010), including the activities: identifying the initial stages, identifying the goal states, identifying the operators, and informing the redesign cycle and iterations. Moreover, this study provides the outcomes of problem analysis that Kelly (2010) did not discuss for design research. Therefore, this study, of which the approaches and outcomes of the problem analysis align with those of

Table 5. The adjusted framework of the social constructivism-based curriculum for primary science education in Confucian heritage culture (see Chapter 6)

Phase	Function	Teacher activity	Student activity	Learning form	Expectation
Engagement	A. To provide students with motivation to learn scientific subject matter	i. Using a few key questions to reveal students' prior knowledge and curiosity related to scientific subject matter ii. Staying open to students' responses	1. Doing a small hands-on task with a relevant example related to scientific subject matter 2. Answering What, How, and Why questions about a relevant example related to scientific subject matter	In small groups and/or in class as a whole	a. Students are interested in scientific subject matter
Experience	B. To evoke attitudes toward science C. To acquire procedural knowledge D. To acquire	iii. Delivering the task and being sure that student groups know what to do and how to do the task iv. Establishing time for group discussion v. Observing and supervising groups while they do their group tasks	3. PREDICTING 3.1. Observing and discussing in order to answer questions: What do you observe? What will happen if…? Why do you think so? 3.2. Writing down answers (on the group small boards)	In small groups	b. Students are curious about representative examples of scientific subject matter c. Students are active in learning about representative examples of scientific subject matter

Experience	conceptual knowledge E. To acquire argumentative skills	vi. Encouraging students to present answers, and to compare and assess answers vii. Staying open to students' responses	3.3. Presenting these answers (3.1 & 3.2.) to other groups 3.4. Clarifying similarities and differences in answers for predicting questions among groups 3.5. Discussing the predicting answers with other groups	In small groups	d. Students use their intuitive knowledge to learn about scientific subject matter e. Students argue with each other to attain consensually agreed knowledge on representative examples of scientific subject matter
		viii. Delivering the task and being sure that student groups know what to do and how to do the task ix. Establishing time for group discussion x. Observing and supervising groups while they do their group tasks	4. HANDS-ON 4.1. Doing the experiment and discussing the results in order to answer the questions: What did you observe? How can you explain your observations? Why do you think so?		

			4.2. Writing down answers in the individual ideas area of the adapted learning placemat 4.3. Sharing the written individual ideas in the group	
		xi. Using open-ended elaborative questions to guide students xii. Staying open-minded and friendly to interact with students	4.4. Selecting ideas for the common answers and writing then down in the common ideas area of the adapted learning placemat	
			5. QUESTIONING: Formulating questions related to scientific subject matter	
Exchange	F. To build on attitudes toward science G. To build on procedural knowledge	xiii. Encouraging students to present answers, and to compare and assess answers	6. Presenting results of hands-on activities to other groups 7. Clarifying similarities and differences in answers (6) 8. Clarifying similarities and differences between predicting answers and hands-on answers within groups	f. Students are interactive in learning scientific subject matter

	H. To build on conceptual knowledge I. To build on argumentative skills	xiv. Stimulating groups to interact and argue with each other xv. Using open-ended elaborative questions to guide students to grasp deeper knowledge xvi. Staying open-minded and friendly to interact with students	9. Discussing results of the hands-on activities with other groups	In class as a whole and/or in combined groups	g. Students argue with each other to attain consensually agreed knowledge on scientific subject matter
		xvii. Choosing representative questions formulated by students/groups for students to discuss and answer	10. Answering formulated questions related to scientific subject matter		
Follow-up	J. To acquire cognitive flexibility K. To further learning motivation	xviii. Providing open-ended sub-questions (if necessary) to guide students to answer/ solve new questions/problems xix. Giving compliments to individual students and groups who have achieved successful learning	11. Providing answers/ solutions for new questions/ problems related to scientific subject matter	In class as a whole	h. Students can provide apprpriate answers and/ or solutions on applying attained knowledge i. Students show their desire to learn more about scientific subject matter

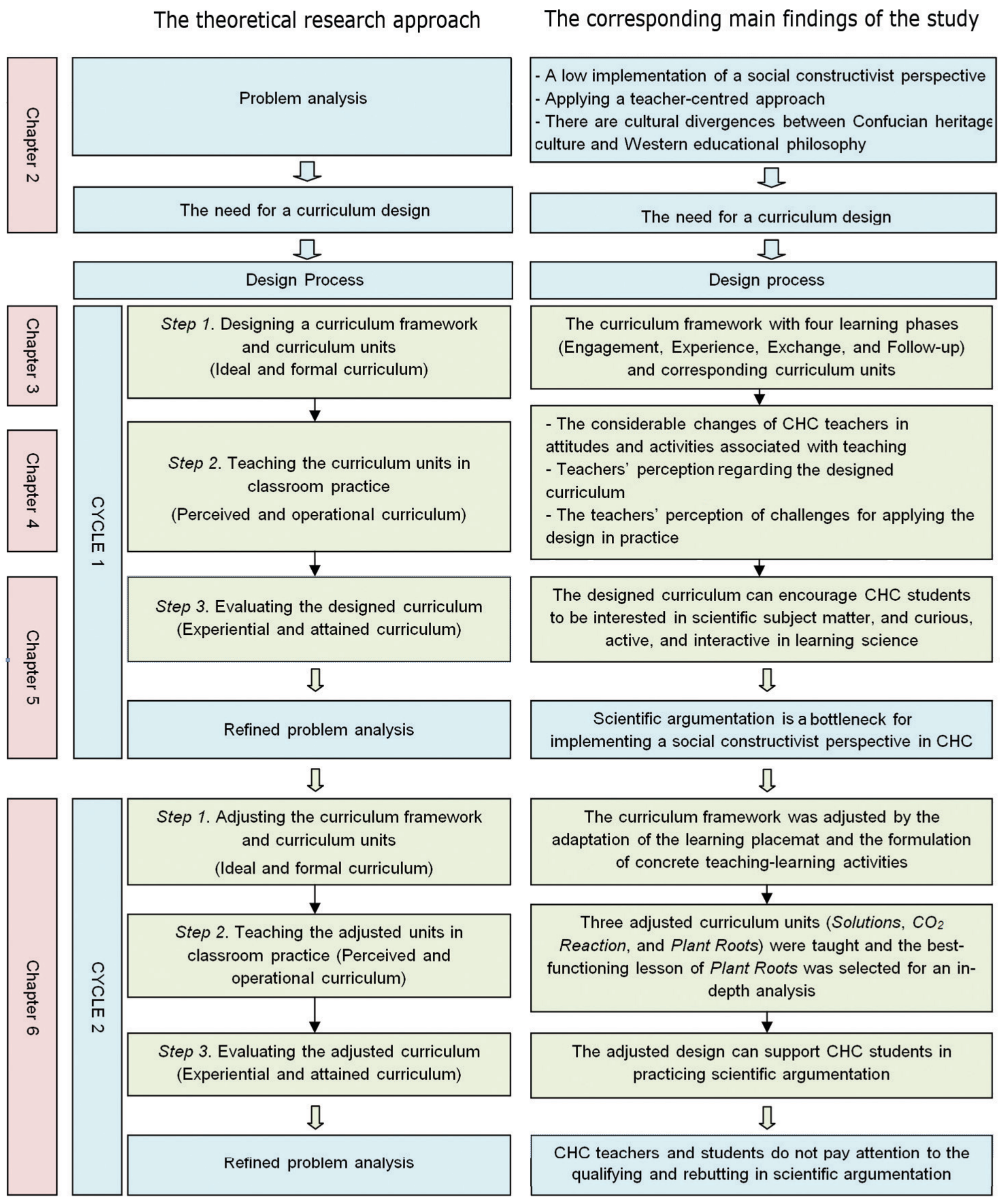


Figure 4. The design-based research approach and the main findings of this study

Bulte et al. (2006) and Meijer, Bulte, and Pilot (2013), contributes to a knowledge base of educational design research that incorporates an awareness of the outcome of problem analysis.

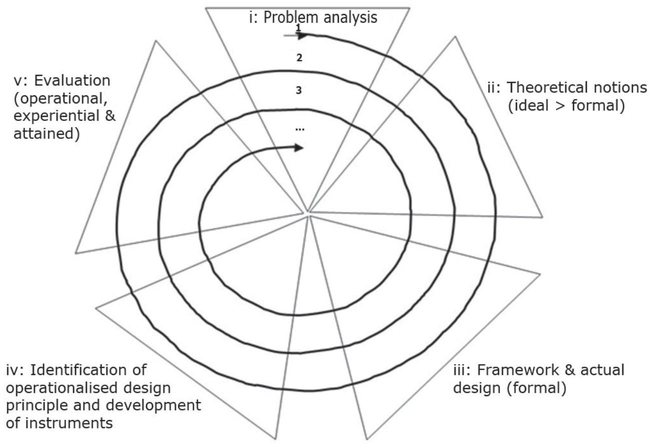


Figure 5. Representation of the spiral character of developmental research (see Bulte et al., 2006)

With the specific design containing concrete teaching-learning activities, this study provides a social constructivism-based curriculum with explicit instructions that is applicable to primary science education in Confucian heritage culture. In achieving this, this study took into consideration and reconciled two educational perspectives that have generated a controversy, supporting neither constructivist approaches nor explicit instructions (see Tobias & Duffy, 2009). In so doing, this study is a positive response to a call for "tighter structuring and scaffolding of students' activities than most social constructivists envision" (Brophy, 2006, p.536). Concrete teaching-learning activities can meaningfully clarify theoretical frameworks, which can then be discussed and compared (Klaassen & Kortland, 2013). This is a contribution of the study, since Klaassen and Kortland (2013) argue that the nature of theory in connection with curriculum design is often unclear. With its concrete teaching-learning activities as an application of a social constructivist perspective, this study aligns with the implications many authors have formulated for a design-based research approach (see Barab & Squire, 2004; Kortland & Klaassen, 2010; Méheut & Psillos, 2004). Moreover, the design with the concrete teaching-learning activities makes a social constructivism-based curriculum easier to use in the practice of primary science education in Confucian heritage culture. It bridges a gap between the ideal and formal curriculum and the experiential and attained curriculum (Van den Akker, 1998, 2003).

With the educational achievements of the adjusted curriculum design, this study shows that Western educational philosophy, specifically a social constructivist perspective and the "nature of science" education, can be appropriately applied in primary science education in Confucian heritage culture. In this way, this study reinforces the propositions that teaching and learning is highly contextual and teachers and learners are highly adaptive (Biggs, 1996; Volet & Renshaw, 1996). For example, it is reported that the longer students study in Australia, the more likely they are to adapt to and adopt an Australian style of teaching and learning (Wong, 2004). In addition, this study shows that when a curriculum is designed in a culturally appropriate way, it can bring changes to primary science education. This study aligns with the "perspectives on Asian learning" approach by adopting "a focus on applying and refining theories developed elsewhere to an Asian context" (Örtenblad et al., 2012, p.132), because this study was conducted primarily to test and refine in Confucian heritage culture a social constructivist approach developed in Western educational philosophy.

Nevertheless, this study also shows that the critiques of a social constructivist approach offered by researchers and educators (see Tobias & Duffy, 2009) still need to be valued. Such critiques are rational and constructive for the development of science curricula and the corresponding design-based research studies that include the identification of a refined problem analysis. Concerning the identification of the refined problems and the potential risks of a social constructivist approach (Benson, 2001; Brophy, 2006; Nuthall, 2002), this study advocates the claim that "teacher input has a major role within a social constructivist framework" (Beck & Kosnik, 2006, p.8). Therefore, teacher professional development and teacher education are considered as essential to the application of a social constructivist framework in primary science education.

In this study, Confucian heritage culture hindered certain aspects of the implementation of a social constructivist perspective in primary science education, in spite of its fostering factors (Chapter 2). Confucianism was taken as an initial base and reinterpreted; its cultural characteristics were addressed in the design and adjustment of the curriculum framework (Chapters 3 & 6). In this way, the design of the social constructivism-based curriculum was made appropriate for a Confucian heritage culture, but it could also be applicable in Non-Confucian heritage cultures – in Western countries, for example. The identification of the hindering factors that Confucian heritage culture contributes to the implementation of a social constructivist perspective in primary science education is not in any way intended to express a negative attitude toward the values of Confucianism. This study showed cultural divergences between Confucian heritage culture and the Western philosophy of science education that were valuable in designing the curriculum and reducing practical difficulties. In this way, the negative influences of Confucianism on science education were revealed. This helped in the attainment of a specific view on the roles of the "nature of science" and the "nature of Confucianism" in primary science education in Confucian heritage culture. In this respect, the researcher considered that the role of the "nature of science" should be emphasised in primary science education in Confucian heritage culture, because it is especially appropriate for science. The nature of Confucianism is about ethics and the ethical values of Confucianism are significant (Drucker, 1981). The researcher agrees that Western-rooted social constructivist views are valuable for primary science education in Confucian heritage culture and Confucianism-rooted ethical views are valuable for Western culture and also for other cultures (Romar, 2004). Confucianism is considered as a universal ethic in which the rules and imperatives of behaviour hold for all individuals (Drucker, 1981).

With all of its concerns about the values of Confucianism and those of the advanced Western philosophy of science education, the design of the curriculum presented in this study has social constructivist characteristics and is appropriate for Confucian heritage culture, as shown in the synthesised curriculum framework presented in Table 5. It provides an answer for the main research question of this study: *What curriculum design for primary science education has social constructivist characteristics and is appropriate for Confucian heritage culture?* The answer is also reflected in the recommendations that followed after the analysis of Cycle 2 of this study.

This situated study was carried out in Vietnam, which is considered a country that has been deeply influenced by Confucianism. However, it might contain differences in its Confucian heritage culture in comparison to other Confucian heritage countries, such as Japan, Korea, Taiwan, Singapore, and China. In this study, differences in the Confucian heritage culture of these countries and epistemic beliefs (Lee, Tsai, &

Chai, 2012) were not taken into account. In addition, the study surveys were carried out in three provinces of Vietnam. All of them were located in the Northern part of Vietnam, while the country is officially divided into three main parts: the North, the Middle, and the South. The northern part of Vietnam is acknowledged to have been influenced by Confucianism more deeply than the other parts of Vietnam. The national level of the cultural influence of Confucianism could be higher and more comprehensive if the surveys were carried out in all of the three parts of Vietnam.

In attempting to provide cultural explanations for the implementation of a social constructivist perspective in primary science education in Vietnam, the study often referred to folklore. Applying the model of uniqueness levels in mental programming (Hofstede, Hofstede, & Minkov, 2010), including a) a universal level – human nature, b) a cultural level – specific to a group/culture, and c) a personal level – specific to the individual, this study utilised folklore that fits well on the cultural level. This means that the values expressed in the folk sayings used in this study may exist elsewhere in other cultures due to human nature, however, they are more important and more emphasised in Confucian heritage culture than in other cultures and have been inherited and learned by Confucian heritage individuals in general.

The operationalisation of the design of this study was carried out with the involvement of three Vietnamese primary teachers, a very small sample from a large population of primary teachers in Vietnam. The effectiveness of the design could only be proved on a larger scale were more primary teachers involved. In this way, experiences would be shared, more experimental lessons would be taught, more extensive reflection on the approach would be provided, and the community of Confucian heritage teachers would therefore learn more about their adaptation to and application of the designed curriculum.

Only four curriculum units, including *Air Pressure* (Cycle 1), *Plant Roots*, *CO_2 Reaction* (both in Cycles 1 & 2), and *Solutions* (Cycle 2), were designed and taught to students aged 10. However, there is a need for a much higher number of science units to provide the entire set of curriculum requirements for science. Furthermore, the entire curriculum needs units for students from the age of 6 to 10 years at the primary education level in Vietnam (Chapter 1). The application of science lessons for younger students may have different foci on argumentation. Therefore, the curriculum design framework is still subject to investigation when applied for younger children.

Implications and Recommendations

Three recommendations are formulated in relation to the conclusions above.

1. Curriculum "growth": The inclusion of more teachers

The study provides a design of a social constructivism-based curriculum that proved to be effective in helping Confucian heritage students be active, interactive, and argumentative in learning science. Therefore, the innovative curriculum with its concrete teaching-learning activities, as briefly presented in Table 5, can be a possibility for application to and improvement of primary science education in Confucian heritage culture. It is therefore recommended that a specific model for the growth of the innovative curriculum for primary science education in Confucian heritage culture be developed and applied.

This study is situated in Vietnam, where about 350,000 primary teachers are employed in primary education. Compared to the three primary teachers involved in this study, there is a huge number of primary teachers to be included in curriculum innovation. However, an effective curriculum innovation cannot be an "invention" of a small group of educators, followed by a national and centralised "implementation." Rather, curriculum innovation is the continuous professional development of teachers, schools, and all participants in the educational process, and there can be no real change unless that change is carried out by the teachers (Bulte & Seller, 2011). A successful curriculum innovation requires a learning process within the whole system (Senge, 1990).

To scale up the innovation with a large population of the primary teachers in Vietnam, the principles of innovation growth elaborated by Bulte and Seller (2011) can offer a possibility. The core idea of this format of curriculum growth is a multiple development programme in which a group of teachers are coached by a professional who sets up a learning community for curriculum innovation. These teachers later take roles as coaches and trainers for other groups of teachers and establish new learning communities dedicated to the innovative curriculum (Figure 7). In this way, new communities are formed from preceding communities and can multiply, transferring the innovative curriculum to teachers in different parts of the country. This format of scaling up innovation with shared learning within and between communities developed for Dutch secondary education (Bulte & Seller, 2011) may provide a useful example for innovating primary science education in Vietnam.

The Confucian heritage teachers (T1, T2, and T3) who took part in the research of this study could take up an essential role, for instance, because they have achieved heuristic knowledge and experiences by being deeply involving in the programme of teacher professional development. These teachers can act as coaches and trainers from whom others can learn about the social constructivism-based curriculum.

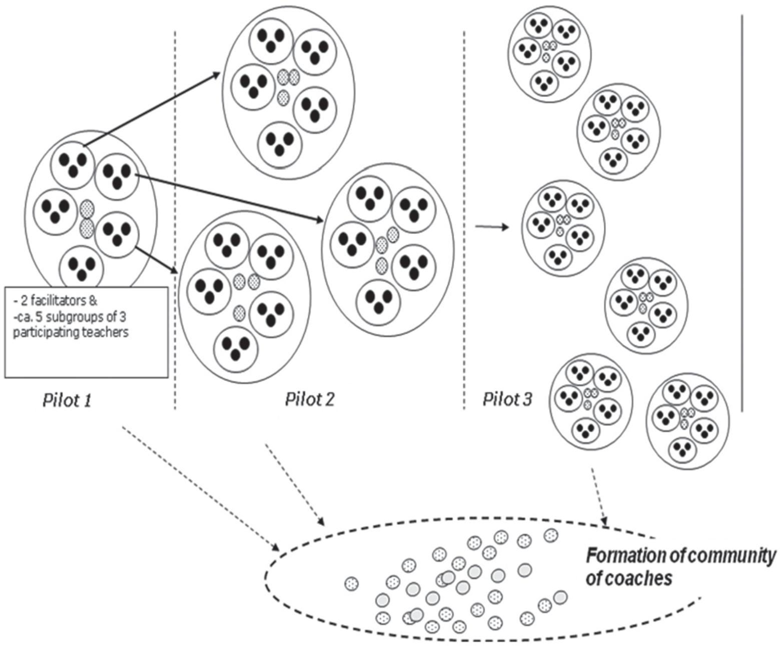


Figure 6. The formation of a new community from preceding communities (see Bulte & Seller, 2011)

2. Curriculum "growth" through teacher professional development on content

The limitations of a social constructivist approach are thought to result in relative content knowledge (Benson, 2001), which can lead lessons to stray from lesson goals and content, and have the potential of exposing the class as a whole to numerous incorrect ideas (Brophy, 2006). These limitations follow from the characteristics of social constructivist teaching and learning, which allows student responses to determine the direction of lessons, shift instructional strategies, and alter content (Watson, 2001). The Confucian heritage teachers who were involved in teaching the experimental lessons acknowledged that there were many challenges for Confucian heritage teachers in applying the innovative curriculum (Chapter 5). They affirmed that Confucian heritage teachers need to have a deep understanding of scientific content knowledge and to be equipped with the knowledge and skills necessary for scientific argumentation (Chapter 5); otherwise, it is difficult for teachers to solve learning problems and questions raised by students or to help students grasp the knowledge and skills associated with the scientific subject matter introduced in the lessons. Although these teachers were introduced to knowledge on the scientific material of the experimental lessons in the programme of teacher professional development, they had to explore more knowledge about air pressure, plant roots, CO_2 reaction, and solutions in order to teach the experimental lessons, and for this they had to search science websites on the internet and contact science teachers at secondary schools.

Teachers' input plays a major role in the social constructivist framework (Beck & Kosnik, 2006; Nuthall, 2002). It is necessary to provide teachers with content knowledge about science and about constructivist teaching in programmes of teacher professional development and in pre-service teacher education,, because teachers are the most influential factors in educational change (Duffee & Aikenhead 1992; Fullan 1991). They are the ones who can make an innovative curriculum work well in the practice of teaching and learning. The programmes of professional development and teacher education should include reflective knowledge of Confucian heritage culture, knowledge about a social constructivist perspective and the characteristics of a social constructivist teacher, knowledge of the "nature of science," and knowledge about the argumentative activities of qualifying and rebutting. In facilitating teacher professional development, the combined spiral programme (Figure 2) in which the learning teachers were involved as co-designers, observers, and active teachers, who systematically reflected on the outcomes, can be a good starting point for designing larger scale professional development. When Confucian heritage teachers are equipped with more advanced professional knowledge on social constructivist science teaching, they can help students practice scientific argumentation and increase the use of qualifying and rebutting in science classes. Also, they can be more effective in guiding students to answer questions and solve problems raised at hand in social constructivist science lessons.

3. Curriculum "growth" through the design of an entire programme for primary science education (students aged 6-10 years)
Along with the two recommendations above, the number of curriculum units should be increased to encompass the entire programme in primary science education. In this study, only four curriculum units on the topics of air pressure, solutions, CO_2 reaction, and plant roots were designed and taught to students in Grade 5 (aged 10 years). However, primary science education in Vietnam includes 140 units for the subject *Nature and Society*, designed for students in Grades 1, 2 and 3 (aged from 6 to 8 years), and 140 more units for the subject *Science,* designed for students in Grades 4 and 5 (aged 9 to 10 years) (see Chapter 1). In calculating and comparing, it becomes clear that there is a need for curriculum units for students from the age of 6 through 10 to cover the entire primary science programme in Vietnam according to a social constructivism-based curriculum.

Scaling up of curriculum units can be integrated with the programme for professional development, gradually involving a larger number of teachers (recommendation 1). Confucian heritage teachers can be expert teachers who are involved as designers and researchers of the innovative curriculum and curriculum units. In this way, Confucian heritage teachers would act as human capital that needs to be built up to make the innovative curriculum grow. Participating teachers should be involved in the respective learning communities as designers and teachers in the same way as the three Confucian heritage teachers (teacher T1, T2, and T3) were involved in this study. These three teachers could act as a core nucleus from which a growing number of new learning communities can be formed. Therefore, they can develop curriculum units based on the innovative curriculum framework and through an immersion in and integrated application of the professional development programme. Curriculum units designed by teachers themselves will no doubt prove to be units that are easier for them to teach. With such integration of curriculum growth and the scaling up of curriculum units, many Confucian heritage teachers can be deeply and variously accommodated within the innovative curriculum. They can develop their own teaching approach using a large number of curriculum units designed in accordance with the ideals of social constructivism adapted and applied to primary science education in Vietnam.

In Retrospect

To conclude this dissertation, the three strategies formulated above are interconnected. It is important to recognise that the innovative science curriculum cannot be forced to grow too fast from the stalk of traditional Confucian heritage education. It should be allowed to grow for many years through programmes that are well structured and organised; otherwise, no real change can take place. The growth of a plant can be used as a metaphor. One cannot make a plant grow faster by pulling it up; the root system of the plant would be separated from the plant. The plant roots are essential: without them, the plant cannot live. A plant can only flourish if it has a healthy root system that can tap deep resources and anchor it firmly to the ground. Curriculum innovation needs to be well rooted and nourished to grow in the same way if it is to bear fruit in the school children of Vietnam.

References

Abd-El-Khalick, F., & Lederman, N. G. (2000). Improving science teachers' conceptions of nature of science: A critical review of the literature. *International Journal of Science Education*, *22*(7), 665–701.

Abd-El-Khalick, F., Boujaoude, S., Duschl, R., Lederman, N. G., Mamlok-Naaman, R., & Hofstein, A. (2004). Inquiry in science education: International perspectives. *Science Education, 88*(3), 397–419.

Agung, S. (2013). *Facilitating professional development of Madrasah chemistry teachers*. Doctoral dissertation. Utrecht University, the Netherlands.

Anderson, R. D. (2007). Inquiry as an organizing theme for science curricula. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 807–830). Oxford, UK: Taylor & Francis.

Barab, S., & Squire, K. (Eds.). (2004). Special issue on design-based research. *The Journal of the Learning Sciences, 13*(1).

Beck, C., & Kosnik, C. (2006). *Innovations in teacher education – A social constructivist approach*. Albany, NY: State University of New York Press.

Benson, G. D. (2001). Science education from a social constructivist position: A worldview. *Studies in Philosophy and Education*, *20*, 443–452.

Berthrong, J. H., & Berthrong, E. N. (2000). *Confucianism: A short introduction*. Oxford, UK: Oneworld.

Biggs, J. (1996). Western misperceptions of the Confucian-heritage learning culture. In D. Watkins & J. Biggs (Eds.), *The Chinese learner: Cultural, psychological and contextual influences* (pp. 45-67). Hong Kong: The University of Hong Kong Comparative Education Research Centre.

Brophy, J. (2006). Graham Nuthall and social constructivist teaching: Research-based cautions and qualifications. *Teaching and Teacher Education*, *22*, 529–537.

Bulte, A. M. W., & Seller, F. (2011). Making an innovation grow: On the shared learning within and between communities. In Lindner, C., Östman, L., Roberts, D. A., Wickman, P.-O., Erickson, G., & MacKinnon, A. (Eds.), *Exploring the landscape of scientific literacy* (pp. 236-254). New York, NY: Taylor & Francis.

Bulte, A. M. W., Westbroek, H. B., De Jong, O., & Pilot, A. (2006). A research approach to designing chemistry education using authentic practices as contexts. *International Journal of Science Education, 28*(9), 1063–1086.

Bybee, R., McCrae, B., & Laurie, R. (2009). PISA 2006: An assessment of scientific literacy. *Journal of Research in Science Teaching*, *46*(8), 865–883.

Chan, S. (1999). The Chinese learning – A question of style. *Education and Training*, *41*(6/7), 294–304.

Central Committee [Vietnam] (2012). The sixth Conference of The eleventh Central Committee dated 29/12/2012 about The proposal "Innovating basically and comprehensively education and training for meeting requirements of industrialization and modernization in conditions of market economy oriented in socialism and international integration". The Conclusion numbered 51-KL/TW. [Hội nghị lần thứ 6 BCHTW khóa XI về ngày 29/10/2012 về Đề án "Đổi mới căn bản và toàn diện giáo dục và đào tạo, đáp ứng yêu cầu công nghiệp hóa, hiện đại hóa trong điều kiện kinh tế thị trường định hướng xã hội chủ nghĩa và hội nhập quốc tế". Kết luận số 51-KL/TW]

Chang, S. N., & Chiu, M. H. (2008). Lakatos› scientific research programmes as a framework for analysing informal argumentation about socioscientific issues. *International Journal of Science Education, 30*(13), 1753-1773.

Chin, C., & Osborne, J. (2010). Supporting argumentation through students' questions: Case studies in science classrooms. *Journal of the Learning Sciences*, *19*(2), 230–284.

Clarke, D., & Hollingsworth, H. (2002). Elaborating a model of teacher professional growth. *Teaching and Teacher Education*, *18*(8), 947–967.

Coenders, F. (2010). *Teachers' professional growth during the development and class enactment of context-based chemistry student learning* *material*. Doctoral dissertation. University of Twente, Enschede, the Netherlands.

Coll, R. K., & Taylor, N. (2012). An international perspective on science curriculum development and implementation. In B. J. Fraser, K. G. Tobin, & C. J. McRobbie (Eds.), *Second international handbook of science education* (Vol. II, pp. 771–782). Dordrecht, Netherlands: Springer.

Confrey, J. (1985). Towards a framework for constructivist instruction. In L. Streefland (Ed.), *Proceedings of the Ninth Conference of the International Group for the Psychology of Mathematics Education* (pp. 477–483). Noordwijkerhout, the Netherlands.

Cotton, D. R. E. (2006). Implementing curriculum guidance on environmental education: The importance of teachers' beliefs. *Journal of Curriculum Studies*, *38*, 67–83

Couchman, J. (1997) Making sense: Cross-cultural variation in the organisation of academic texts by Taiwanese and Australian undergraduate students. In Z. Golebiowski & H. Borland (Eds.), *Academic communication across disciplines and cultures* (pp. 64–76). Melbourne, Australia: Victoria University of Technology.

De Vos, W., Bulte, A. M. W., & Pilot, A. (2002). Chemistry curricula for general education: Analysis and elements of a design. In J. K. Gilberts, O. De Jong, R. Justu, D. F. Treagust, & J. H. Van Driel (Eds.), *Chemical education: Towards research based practice* (pp. 101–124). Dordrecht, the Netherlands: Kluwer Academic Publishers.

Dekkers, P. (2006). Reconstructing the creature – Exploring design criteria for teaching NOS. In E. V. Den Berg, T. Ellermeijer, & O. Stooten (Eds.), *Proceedings of the GIREP Conference Modelling in Physics and Physics Education* (pp. 459–464). Amsterdam, the Netherlands: University of Amsterdam.

Dolfing, R. (2013). *Teacher's professional development in context-based chemistry education: Strategies to support teachers in developing domain-specific expertise.* Doctoral dissertation. Utrecht University, the Netherlands.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education, 84*, 287–312.

Drucker, P. F. (1981, September 14). Ethical Chic. *Forbes*, 160–173.

Duffee, L., & Aikenhead, G. (1992). Curriculum change, student evaluation, and teacher practical knowledge. *Science Education, 76*, 493–506.

Duit, R., & Treagust, D. (1998). Learning in science – From behaviorism towards social constructivism and beyond. In B. L. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (pp. 3–25). Dordrecht, Netherlands: Kluwer Academic Publishers.

Duschl, R. A., & Osborne, J. (2002). Supporting and promoting argumentation discourse in science education. *Studies in Science Education*, *38*, 39–72.

Đạm, Q. (1994). *Nho giáo xưa và nay [Confucianism: before and now].* Hanoi, Vietnam: Culture Publisher.

Fullan, M. G. (1991). *The new meaning of educational change* (2nd ed.). New York, NY: Teachers College Press.

Freudenthal, H. (1991). *Revisiting mathematics education.* Dordrecht, Netherlands: Kluwer Academic Publishers.

Gess-Newsome, J. (1999). Pedagogical content knowledge: An introduction and orientation. In J. Gess-Newsome, & N. G. Lederman (Eds.), *Examining pedagogical content knowledge* (pp. 3–17). Dodrecht, Netherlands: Kluwer Academic Publishers.

Guskey, T. R. (2002). Professional development and teacher change. *Teachers and Teaching: Theory and Practice*, *8*(3/4), 381–391.

Hand, B. (2011). An immersion approach to argument-based inquiry – Does it look the same in different countries? In Y. Kim, J. Park, H. E. Seo, J. A. Lee, & J. Kim (Eds.), *Proceedings of the 2011 EASE International Conference – Lighting the world with science* (pp. 45–54). Chosun University, Gwangju, Korea.

Hoan, Đ. Đ. (2002). *Một số vấn đề cơ bản của chương trình tiểu học mới [Some basic issues of the new primary curricula]*. Hanoi, Vietnam: Education Publisher.

Hofstede, G. (1986). Cultural difference in teaching and learning. *International Journal of Intercultural relations*, *10*, 301–320.

Hofstede, G., Hofstede, G. J., & Minkov, M. (2010). *Cultures and organizations: Software of the mind: Intercultural cooperation and its importance for survival* (3rd ed.). New York, NY: McGraw-Hill.

Jegede, O. J., & Aikenhead, G. S. (1999). Transcending cultural borders: Implications for science teaching. *Journal for Science & Technology Education, 17*(1), 45–66.

Kelly, A. E. (2010). When is design research appropriate? In T. Plomp & N. Nieveen (Eds.), *An introduction to educational design research, Part A: Proceedings of the seminar conducted at the East China Normal University, Shanghai* (PR China), November 23-26, 2007 (pp. 73-88). Enschede, Netherlands: SLO – Netherlands Institute for Curriculum Development. Retrieved from http://international.slo.nl/edr

Kim, M., & Tan, A. L. (2011). Rethinking difficulties of teaching inquiry-based practical work: Stories from elementary pre-service teachers. *International Journal of Science Education*, *33*(4), 465–486.

Klaassen, K., & Kortland, K. 2013. *The role and nature of theory in design research.* Paper presented at the 13th ESERA Conference: Science education research for evidence-based teaching and coherence in learning. Cyprus University, Cyprus.

Kolstø, S. D. (2001). Scientific literacy for citizenship: Tools for dealing with the science dimension of controversial socioscientific issues. *Science Education*, *85*, 291–310.

Kortland, J., & Klaassen, K. (Eds.). (2010). *Designing theory-based teaching-learning sequences for science education*. Utrecht, Netherlands: CDβ Press. Retrieved from http://www.staff.science.uu.nl/~kortl101/book_sympPL.pdf

Lee, K. W., Tan, L. L., Coh, N. K., Chia, L. S., & Chin, C. (2000). Science teachers and problem solving in elementary schools in Singapore. *Research in Science and Technological Education*, *18*(1), 113–126.

Lee, M., Tsai, C., & Chai, C. S. (2012). A comparative study of Taiwan, Singapore, and China preservice teachers' epistemic beliefs. *The Asia-Pacific Education Researcher*, *21*(3), 599–609.

Liu, N. F., & Littlewood, W. (1997). Why do many students appear reluctant to participate in classroom learning discourse? *System*, *25*(3), 371–384.

Loughran, J., Mulhall, P., & Berry, A. (2004). In search of pedagogical content knowledge in science: Developing ways of articulating and documenting professional practice. *Journal of Research in Science Teaching*, *41*(4), 370–391.

McComas, W. F., Almazroa, H., & Clough, M. (1998). The nature of science in science education: An introduction. *Science and Education*, *7*, 511–532.

Méheut, M., & Psillos, D. (Eds.) (2004). Special issue: Teaching-Learning sequences: Aims and tools for science. *International Journal of Science Education, 26*(5).

Meijer, M. (2011). *Macro-meso-micro thinking with structure-property relations for chemistry education: An explorative design-based study*. Doctoral dissertation. Utrecht University, the Netherlands.

Meijer, M., Bulte, A., & Pilot, A. (2013). An approach for design-based research focusing on design principles for science education: A case study on a relevant context for macro-micro thinking. In T. Plomp & N. Nieveen (Eds.), *An introduction to educational design research, Part B: Illustrative cases* (pp. 641–664). SLO – Netherlands Institute for Curriculum Development. Retrieved from http://international.slo.nl/edr

Ministry of Education and Training [Vietnam]. (2006). *Chương trình dạy học - Dành cho bậc tiểu học [Schooling curriculum – For primary education level].* Hanoi, Vietnam: Education Publisher.

Neuman, Y., & Bekerman, Z. (2000). Cultural resources and the gap between educational theory and practice. *Teachers College Record, 103*(3), 471–484.

Nguyen, M., Elliott, J., Terlouw, C., & Pilot, A. (2009). Neocolonialism in education: Cooperative learning, Western pedagogy in an Asian context. *Comparative Education*, *45*(1), 109–130.

Nuthall, G. (2002). Social constructivist teaching and the shaping of students' knowledge and thinking. In J. Brophy (Ed.), *Social constructivist teaching: Affordances and constraints* (pp. 43–79). New York, NY: Elsevier.

Örtenblad, A., Babur, M., & Kumari, R. (2012). Learning in Asia, *Asia Pacific Journal of Education*, *32*(2), 131–136.

Prins, G. (2010). *Teaching and learning of modelling in chemistry education: Authentic practices as contexts for learning*. Doctoral dissertation. Utrecht University, the Netherlands.

Romar, E. J. (2004). Managerial harmony: The Confucian ethics of Peter F. Drucker. *Journal of Business Ethics*, *51*, 199–210.

Ryu, S., & Sandoval, W. A. (2012). Improvements to elementary children's epistemic understanding from sustained argumentation. *Science Education*, *96*(3), 488–526.

Senge, P. M. (1990). *The fifth discipline: The art & practice of the learning organization*. New York, NY: Doubleday.

Serpell, R. (2007). Bridging between orthodox Western higher educational practices and an African sociocultural context. *Comparative Education*, *43*(1), 23–51.

Stolk, M. (2013). *Empowering chemistry teachers for context-based education.* Doctoral dissertation. Utrecht University, the Netherlands.

Stolk, M. J., Bulte, A. M. W., De Jong, O., & Pilot, A. (2012). Evaluating a professional development framework to empower chemistry teachers to design context-based education. *International Journal of Science Education*, 34(10), 1487–1508.

Tao, Y., Oliver, M., & Venville, G. (2013). A comparison of approaches to the teaching and learning of science in Chinese and Australian elementary classrooms: Cultural and socioeconomic complexities. *Journal of Research in Science Teaching*, *50*(1), 33–61.

Tobias, S., & Duffy, T. (2009). *Constructivist instruction: Success or failure.* New York, NY: Routledge.

Tobin, K. G. (1993). *The practice of constructivism in science education*. Washington, DC: American Association for the Advancement of Science.

Totten, S., Sills, T., Digby, A., & Russ, P. (1991). *Cooperative learning: A guide to research*. New York, NY: Garland.

Toulmin, S. (1958). *The uses of argument.* Cambridge, UK: Cambridge University Press.

Van den Akker, J. (1998). The science curriculum: Between ideals and outcomes. In B. Fraser & K. Tobin (Eds.), *International handbook of* *science education* (pp. 421–447). Dordrecht, Netherlands: Kluwer Academic Publishers.

Van den Akker, J. J. H. (2003). Curriculum perspectives: An introduction. In J. J. H. Van den Akker, W. Kuiper, & U. Hameyer (Eds.), *Curriculum landscape and trends* (pp. 1-10). Dordrecht, Netherlands: Kluwer Academic Publishers.

Van Driel, J. H., Verloop, N., & De Vos, W. (1998). Developing science teachers' pedagogical content knowledge. *Journal of Research in Science Teaching*, *35*(6), 673–695.

Volet, S., & Renshaw, P. (1996) Chinese students at an Australian university: Adaptability and continuity. In D. A. Watkins & J. B. Biggs (Eds.), *The Chinese learner: Cultural, psychological and contextual influences* (pp. 205-220). Hong Kong: The Central Printing Press.

Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Watson, J. (2001). Social constructivism in the classroom. *Support for Learning*, *16*(3), 140–147.

Westbroek, H. B., Klaassen, K., Bulte, A., & Pilot, A. (2010). Providing students with a sense of purpose by adapting a professional practice. *International Journal of Science Education*, *32*, 603–627.

Wong, J. K. K. (2004). Are the learning styles of Asian international students culturally or contextually based? *International Education Journal*, *4*(4), 154–166.

Summary

Social constructivist ideas have gained increasing attention from various researchers and educators over the past three decennia. A social constructivist perspective has come into focus for primary science education in Confucian heritage culture through recent school reforms. Nevertheless, there is insufficient in-depth knowledge about how a social constructivist perspective is implemented in primary science education in a Confucian heritage culture. There is also a lack of studies about how Confucian heritage culture influences the implementation of a social constructivist perspective in primary science education. Despite increasing calls for culturally appropriate designs, so far there has been little evidence to show that social constructivist curricula in Confucian heritage culture have been designed and developed with a concern for the distinct characteristics of Confucian heritage culture.

The research of this study aimed to answer the following main research question:

> *What curriculum design for primary science education has social constructivist characteristics and is appropriate for Confucian heritage culture?*

To answer this question, this design-based research project was subdivided into three main stages – problem analysis (Chapter 2), Design Cycle 1 (Chapters 3, 4, & 5), and Design Cycle 2 (Chapter 6) – and involved five studies.

The first study (Chapter 2) determined the extent to which a social constructivist perspective was implemented in primary science education in Confucian heritage culture. It provided explanations for the implementation from a Confucian cultural perspective. The first study aimed to answer two research questions:

> *To what extent is a social constructivist perspective implemented in primary science education in Confucian heritage culture?*
>
> *How can this implementation be explained from a Confucian cultural perspective and what cultural factors are fostering and hindering the implementation?*

The study was carried out in Vietnam, a country which has been deeply influenced by Confucianism and has been working to reform the primary science curriculum since the year 2000. It was found that

a social constructivist perspective has not yet been well implemented in primary science education in Vietnam. Specifically, teaching and learning was still textbook-based and teacher-centred, lessons focussed on factual knowledge, knowledge was transmitted by the teacher and reproduced by the students, hands-on complex tasks were absent, students' personal aspects were discounted, and hierarchical interaction dominated science lessons. In addition, the dominance of whole class grouping and short-term pair grouping for group learning demonstrates the low level of implementation of a social constructivist perspective in primary science education in Vietnam.

The implementation of a social constructivist perspective in primary science education in Vietnam has been considerably influenced by Confucian heritage culture. In providing explanations for the implementation, three emergent cultural divergences between Confucian heritage culture and Western educational philosophy were revealed.

(1) Confucian heritage culture emphasises stability and harmony among its human and cultural values, whereas Western educational philosophy emphasises the rationality that supports argumentation and conflicts in discussion and helps students be prepared for citizenship. In the "nature of science" education, conflicts and argumentation are preferred over harmony.

(2) Confucian heritage culture emphasises theoretical knowledge, considering "classical" knowledge and theory as universally correct, whereas Western educational philosophy emphasises empirical knowledge and the well-substantiated nature of scientific claims, believing that there is no complete truth and that every aspect of theoretical knowledge is changeable.

(3) Confucian heritage culture emphasises hierarchical order in which the teacher is considered superior and the transmitter of the body of knowledge to students, whereas Western educational philosophy emphasises equitability: the teacher is considered a more advanced learner and facilitates students not only to acquire knowledge but also to develop skills and attitudes.

The second study (Chapter 3) was the first part of Cycle 1 and describes the design of a formal curriculum based on a social constructivist perspective for primary science education in Confucian heritage culture. It aimed to answer the following research question:

What formal curriculum design for primary science education has social constructivist characteristics and is appropriate for Confucian heritage culture?

The second study provided a design of a formal curriculum based on a social constructivist perspective for primary science education in Confucian heritage culture. The design integrated knowledge of the "nature of science" education. The design consists of a framework with four phases: Engagement, Experience, Exchange, and Follow-up, along with the corresponding functions for each of these phases. The framework also describes a generalised learning setting with a description of learning activities, learning forms, and learning expectations (see Table 1 for the design of Cycle 2). Three corresponding science units were designed.

The third study (Chapter 4) reports about the perception and operation of the designed curriculum of Cycle 1. It aimed to answer the following question:

In a programme of professional development, how do Confucian heritage teachers interact with a primary science curriculum that is based on a social constructivist perspective and made appropriate for Confucian heritage culture?

The third study provided a programme for professional development in which three teachers interacted with the curriculum design. These Confucian heritage teachers showed considerable changes in the attitudes and activities associated with teaching. They became more open-minded and friendly in interacting with students in the science lessons. In addition, they focussed more on a) encouraging students to engage in inquiry, b) providing time and space for self-regulated learning, c) promoting social interactions among students, and d) seeking elaboration of students' initial responses. The teachers found that the designed curriculum brings more benefits for students compared to the conventional science curriculum. They acknowledged that the designed curriculum helped to reconceptualise the teaching and learning of science, bringing it closer to a social constructivist perspective and the "nature of science" education. In addition, the teachers proposed to formulate teacher activities corresponding with each of the phases of the designed curriculum. The teachers perceived it challenging to apply the designed curriculum in practice in Confucian heritage culture. They also identified the challenges for teachers, as well as the institutional challenges. In terms of the challenges for the teachers, three major challenges were mentioned: a) the influences of habits in traditional teaching methods, b) the need for deep understanding of scientific content knowledge, and c) the difficulty of teaching and learning argumentation in Vietnamese primary education. The institutional challenges were: i) the issue of time for teaching and learning, ii) the measurement of learning results, and iii) the difficulty of a systemic change.

In the fourth study (Chapter 5), the designed curriculum (Cycle 1) was evaluated. It aimed to answer this research question:

> *To what extent does a unit of the curriculum design for primary science education in Confucian heritage culture meet social constructivist expectations in classroom practice?*

It was found that the designed curriculum can support Confucian heritage students in becoming interested, curious, active, and interactive in learning science. In addition, the designed curriculum could help students use intuitive knowledge to learn science and develop a desire to learn science. However, the designed curriculum was not effective enough in supporting scientific argumentation in the practice of science lessons: in the Exchange phase in particular there was a low level of scientific argumentation and the students were less active than they were in the other learning phases. Scientific argumentation was a bottleneck when implementing a social constructivist perspective in primary science education in Confucian heritage culture.

This extensive analysis of Design Cycle 1 led to a redesigned framework, and, consequently, to redesigned science units for Cycle 2. The fifth study (Chapter 6) describes the adjustment of the designed curriculum in order to support Confucian heritage students in practicing scientific argumentation in a social constructivist science lesson. There are three main differences between the designs of Cycle 1 and Cycle 2. The first design focussed only on student activities and did not provide specific teacher activities. Secondly, the first design was developed without the use of the model of the learning placemat. The adapted model of the learning placemat was used in the adjusted design to foster argumentative interaction among students, enabling them to learn argumentation skills. The third difference is that student activities in the adjusted design were more concrete and better organised due to the articulation with the concrete teaching activities and the use of the learning placemat. In the design of Cycle 1, the activities of presenting and discussing both the predicting task and the hands-on task took place in the Exchange phase. However, in the adjusted design of Cycle 2, the activities of presenting and discussing the predicting task took place in the Experience phase before the hands-on task began. This was done to avoid confusing students and making it difficult for them to catch key ideas of other groups, which was the case when they predicted the outcomes of the experiments and presented the results of the hands-on tasks at the same time. Table 1 presents the design in Cycle 2, with the adjustments made to Cycle 1 printed in bold.

The fifth study (Chapter 6) aimed to answer the following questions:

> *To what extent does a unit of the adjusted design of the social constructivism-based curriculum for primary science education in Confucian heritage culture support students in practicing scientific argumentation in a science lesson?*
>
> *To what extent does the unit of the adjusted design of the social constructivism-based curriculum for primary science education in Confucian heritage culture support students in attaining consensually agreed knowledge on scientific subject matter?*

It was found that the adjusted design can support Confucian heritage students in practicing scientific argumentation in a science lesson and in attaining consensually agreed science knowledge. The fifth study also revealed that the activities of qualifying and rebutting were not paid attention to when Confucian heritage students practiced scientific argumentation.

As an answer to the main research question – *What curriculum design for primary science education has social constructivist characteristics and is appropriate for Confucian heritage culture?* – the adjusted design of Cycle 2 was effective in supporting Confucian heritage students in practicing scientific argumentation and in attaining consensually agreed knowledge. It can be considered as *a proof of principle*. The model of the learning placemat is a culturally appropriate teaching-learning tool that is useful for facilitating Confucian heritage students to interact with each other in order to practice scientific argumentation. The curriculum design consists of a curriculum framework with phases and their functions (see Table 1), concretised into three units. The framework and the concrete science lessons still need to include the recommendations that followed from Cycle 2. Moreover, the design-based approach not only led to the design of a curriculum framework

Table 1. The adjusted framework (adjustments in bold) of the social constructivism-based curriculum for primary science education in Confucian heritage culture (Cycle 2)

Phase	Function	**Teacher activity**	Student activity	Learning form	Expectation
Engagement	A. To provide students with motivation to learn scientific subject matter	i. Using a few key questions to reveal students' prior knowledge and curiosity related to scientific subject matter ii. Staying open to students' responses	1. Doing a small hands-on task with a relevant example related to scientific subject matter 2. Answering What, How, and Why questions about a relevant example related to scientific subject matter	In small groups and/or in class as a whole	a. Students are interested in scientific subject matter
Experience	B. To evoke attitudes toward science C. To acquire procedural knowledge D. To acquire	iii. Delivering the task and being sure that student groups know what to do and how to do the task iv. Establishing time for group discussion v. Observing and supervising groups while they do their group tasks	3. PREDICTING 3.1. Observing and discussing in order to answer questions: What do you observe? What will happen if...? Why do you think so? 3.2. Writing down answers (on the group small boards)	In small groups	b. Students are curious about representative examples of scientific subject matter c. Students are active in learning about representative examples of scientific subject matter

Experience	conceptual knowledge E. To acquire argumentative skills	vi. Encouraging students to present answers, and to compare and assess answers vii. Staying open to students' responses	**3.3. Presenting these answers (3.1 & 3.2.) to other groups** **3.4. Clarifying similarities and differences in answers for predicting questions among groups** **3.5. Discussing the predicting answers with other groups**	In small groups	d. Students use their intuitive knowledge to learn about scientific subject matter e. Students argue with each other to attain consensually agreed knowledge on representative examples of scientific subject matter
		viii. Delivering the task and being sure that student groups know what to do and how to do the task ix. Establishing time for group discussion x. Observing and supervising groups while they do their group tasks	4. HANDS-ON 4.1. Doing the experiment and discussing the results in order to answer the questions: What did you observe? How can you explain your observations? Why do you think so?		

			4.2. Writing down answers in the individual ideas area of the **adapted learning placemat** 4.3. Sharing the written individual ideas in the group		
		xi. Using open-ended elaborative questions to guide students			
		xii. Staying open-minded and friendly to interact with students	4.4. Selecting ideas for the common answers and writing then down in the common ideas area of the **adapted learning placemat**		
			5. QUESTIONING: Formulating questions related to scientific subject matter		
		xiii. Encouraging students to present answers, and to compare and assess answers	6. Presenting results of hands-on activities to other groups		
	F. To build on attitudes toward science		**7. Clarifying similarities and differences in answers (6)**		
Exchange	G. To build on procedural knowledge		**8. Clarifying similarities and differences between predicting answers and hands-on answers within groups**	In class as a whole and/or in combined groups	f. Students are interactive in learning scientific subject matter

	H. To build on conceptual knowledge I. To build on argumentative skills	xiv. Stimulating groups to interact and argue with each other xv. Using open-ended elaborative questions to guide students to grasp deeper knowledge xvi. Staying open-minded and friendly to interact with students	9. Discussing results of the hands-on activities with other groups		g. Students argue with each other to attain consensually agreed knowledge on scientific subject matter
		xvii. Choosing representative questions formulated by students/groups for students to discuss and answer	10. Answering formulated questions related to scientific subject matter		
Follow-up	J. To acquire cognitive flexibility K. To further learning motivation	xviii. Providing open-ended sub-questions (if necessary) to guide students to answer/ solve new questions/problems xix. Giving compliments to individual students and groups who have achieved successful learning	11. Providing answers/ solutions for new questions/ problems related to scientific subject matter	In class as a whole	h. Students can provide apprpriate answers and/ or solutions on applying attained knowledge i. Students show their desire to learn more about scientific subject matter

and its corresponding science unit, but after each of the cycles a refined problem analysis followed, which led to new arguments for redesigning and fine-tuning. Such a problem analysis is to be included in the answer to the main research question.

Three recommendations are formulated related to the conclusions above.

1. *Curriculum "growth" through the inclusion of more teachers.*
2. *Curriculum "growth" through teacher professional development on content.*
3. *Curriculum "growth" through the design of an entire programme for primary science education (for students aged 6 to 10 years).*

The approach could be to follow a multiple development programme in which groups of teachers are coached by a curriculum expert and interconnected learning communities are established to design more units for the innovative curriculum. Trained teachers can take the roles of coaches and trainers for other groups of teachers who subsequently set up new learning communities. Thereby, the innovative curriculum can be transmitted to teachers in different parts of the country. Professional development should include knowledge about a social constructivist perspective and the characteristics of a social constructivist teacher, knowledge of the "nature of science" education, and knowledge about the argumentative activities of qualifying and rebutting. The scaling up of curriculum units should be integrated within the programme for professional development. Far more curriculum units are needed than the four designed in this study, and these can be designed by the primary teachers themselves. In this way, the Confucian heritage teachers act as human capital that needs to be built up in order to make the innovative curriculum grow.

Samenvatting

Sociaal constructivistische onderwijsleertheorieën hebben in de afgelopen drie decennia in toenemende mate de aandacht getrokken van onderwijskundigen en docenten. In recente herzieningen van het Vietnamese natuurwetenschappelijk basisonderwijs in de Confuciaanse cultuur is een sociaal constructivistisch perspectief het uitgangspunt geweest. Maar er is onvoldoende diepgaande kennis over de manier waarop een sociaal constructivistisch perspectief ingevoerd kan worden in het natuurwetenschappelijk basisonderwijs in een Confuciaanse cultuur. Ook is nauwelijks onderzocht hoe de Confuciaanse cultuur de invoering van natuurwetenschappelijk onderwijs vanuit een sociaal constructivistisch perspectief beïnvloedt. Ondanks een toenemende vraag naar onderwijsontwerpen die zijn afgestemd op de specifieke kenmerken van de culturele situatie is er tot nu toe weinig evidentie dat sociaal constructivistische curricula in een Confuciaanse cultuur ontworpen en ontwikkeld zijn met voldoende aandacht voor de specifieke kenmerken van de Confuciaanse cultuur.

Dit onderzoek beoogt de volgende onderzoeksvraag te beantwoorden:

> *Welk curriculumontwerp voor natuurwetenschappelijk onderwijs in het primair onderwijs heeft sociaal constructivistische kenmerken en is afgestemd op de Confuciaanse cultuur (Confucian heritage culture, CHC)?*

Om deze onderzoeksvraag te beantwoorden is dit ontwerpgerichte onderzoek onderverdeeld in drie fasen – probleemanalyse (Hoofdstuk 2), Ontwerpcyclus 1 (Hoofdstuk 3, 4 en 5), en Ontwerpcyclus 2 (Hoofdstuk 6) – en omvat het vijf deelstudies.

Het eerste deelonderzoek (Hoofdstuk 2) betrof de mate waarin een sociaal constructivistisch perspectief is ingevoerd in het primair natuurwetenschappelijk onderwijs in de Confuciaanse cultuur. Dit deelonderzoek leverde ook verklaringen op voor de invoering ervan vanuit het perpectief van de Confuciaanse cultuur. Dit eerste deelonderzoek was gericht op twee deelvragen:

> *In welke mate is een sociaal constructivistisch perspectief ingevoerd in primair natuurwetenschappelijk onderwijs in de Confuciaanse cultuur?*

Hoe kan deze mate van invoering worden verklaard vanuit het perspectief van de Confuciaanse cultuur en welke culturele factoren bevorderen en hinderen de invoering?

Dit onderzoek is uitgevoerd in Vietnam, een land dat diepgaand beïnvloed is door het Confucianisme en sinds het jaar 2000 het primair natuurwetenschappelijk onderwijs ingrijpend heeft herzien. Het bleek dat het sociaal constructivistische perspectief nog niet goed was ingevoerd in het primair natuurwetenschappelijk onderwijs in Vietnam. Meer specifiek bleek dat het onderwijs en het leren docentgecentreerd en nog sterk gericht waren op de inhoud van de schoolboeken, dat de lessen gericht waren op feitelijke kennis, dat kennis verbaal werd overgedragen door de docent en werd gereproduceerd door de leerlingen, en dat er geen aandacht werd besteed aan hands-on complexe taken en aan persoonlijke aspecten van leerlingen, terwijl hiërarchische interacties in deze lessen dominant waren. Bovendien toonden de manier waarop de docent het onderwijs in de klas als geheel organiseerde en de geringe mate van groepsleren aan dat het sociaal constructivistische perspectief maar in geringe mate was ingevoerd in het primair natuurwetenschappelijk onderwijs in Vietnam.

De invoering van een sociaal constructivistisch perspectief in het primair natuurwetenschappelijk onderwijs in Vietnam is in hoge mate beïnvloed door de Confuciaanse cultuur. Drie opvallende culturele verschillen tussen de Confuciaanse cultuur en de Westerse onderwijsfiliosofie werden gevonden als verklaring voor de geringe mate van invoering van het sociaal constructivistisch perspectief:

1. De Confuciaanse cultuur legt nadruk op stabiliteit en harmonie tussen menselijke en culturele waarden, terwijl de Westerse onderwijsfilosofie nadruk legt op rationaliteit die argumentatie en conflicten in discussies bevordert en leerlingen helpt zich voor te bereiden op maatschappelijke discussies. In de opzet van het onderwijs volgens het "nature of science" model hebben conflicten en argumentatie de voorkeur boven het streven naar harmonie.
2. De Confuciaanse cultuur legt nadruk op theoretische kennis, en beschouwt 'klassieke' kennis en theorie als universeel correct, terwijl de Westerse onderwijsfilosofie de nadruk legt op empirische kennis en op goed-onderbouwde wetenschappelijke claims, die ervan uit gaan dat er geen volledige waarheid is en dat elk aspect van de theoretische kennis tijdelijk en veranderbaar is.

3. De Confuciaanse cultuur legt nadruk op een hiërarchische orde waarin de docent wordt beschouwd als superieur en als degene die het geheel van kennis overdraagt aan de leerlingen, terwijl de Westerse onderwijsfilosofie meer nadruk legt op intermenselijke gelijkwaardigheid: de docent wordt beschouwd als een meer gevorderde lerende die leerlingen niet alleen behulpzaam is bij het verwerven van kennis maar ook bij het ontwikkelen van vaardigheden en attitudes.

Het tweede deelonderzoek (Hoofdstuk 3) omvat het eerste deel van Cyclus 1 en beschrijft het ontwerp van een formeel curriculum, gebaseerd op een sociaal constructivistisch perspectief voor natuurwetenschappelijk primair onderwijs in een Confuciaanse cultuur. Het doel van dit deelonderzoek was om de volgende deelvraag te beantwoorden:

> *Welk ontwerp voor een formeel curriculum voor natuurwetenschappelijk primair onderwijs heeft sociaal constructivistische kenmerken en is afgestemd op de Confuciaanse cultuur?*

Het tweede deelonderzoek leverde het ontwerp op van een formeel curriculum voor natuurwetenschappelijk primair onderwijs gebaseerd op een sociaal constructivistisch perspectief in Confuciaanse cultuur. In het ontwerp is bovendien kennis over de "nature of science" onderwijsaanpak geïntegreerd. Het ontwerp bestaat uit een raamwerk met vier fasen: Engagement, Ervaringen, Uitwisseling, and Opvolging, samen met overeenkomstige functies voor elk van deze fasen. Het raamwerk beschrijft ook een algemene leersituatie met bijbehorende leeractiviteiten, onderwijsvormen en verwachtingen (zie Tabel 1 voor het ontwerp in Cyclus 2). Op basis van dit raamwerk zijn drie lessen ontworpen.

Het derde deelonderzoek (Hoofdstuk 4) betreft de uitvoering en observaties van het ontworpen curriculum van Cyclus 1. Dit onderzoek was erop gericht de volgende deelvraag te beantwoorden:

> *Hoe gaan Confuciaanse docenten in een programma van professionele ontwikkeling om met een formeel curriculum voor natuurwetenschappelijk primair onderwijs dat is gebaseerd op een sociaal constructivistisch perspectief en is afgestemd op Confuciaanse cultuur?*

Dit derde deelonderzoek leverde een programma op voor professionele ontwikkeling, waarin drie docenten het curriculumontwerp uitwerkten. Uit observaties bleek dat de attitudes en onderwijsactiviteiten van deze Confuciaanse docenten in aanzienlijke mate veranderden. Zij waren meer open en vriendelijk in hun interactie met leerlingen in de natuurwetenschappelijke lessen. Bovendien richtten zij zich meer op a) het aanmoedigen van onderzoeksactiviteiten van leerlingen, b) het geven van tijd en ruimte voor leerling-gestuurde leeractiviteiten, c) het stimuleren van sociale interacties tussen leerlingen, en d) het vragen om verdere uitwerking van initiële antwoorden van leerlingen. De docenten vonden dat het ontworpen curriculum voordelen bood voor leerlingen in vergelijking met het conventionele natuurwetenschappelijke curriculum. Zij waren van mening dat het ontworpen curriculum leerlingen hielp bij het begrijpen van de onderwezen natuurwetenschappelijke vakinhoud, en dat het feitelijke onderwijs meer in overeenstemming was met een sociaal constructivistisch perspectief en de onderwijsaanpak van “nature of science”. Bovendien stelden de docenten voor om docentactiviteiten te formuleren die in overeenstemming waren met elk van de fasen in het ontworpen curriculum. De docenten vonden het een uitdaging om het ontworpen curriculum uit te voeren in de praktijk van de Confuciaanse cultuur. Zij benoemden uitdagingen voor docenten, en uitdagingen voor de onderwijsinstellingen. Als uitdagingen voor docenten noemden zij: a) de invloed van traditionele doceermethoden, b) de behoefte aan diepgaand begrip van de natuurwetenschappelijke vakinhoud, en c) de moeilijkheid om argumenteren te leren en te onderwijzen in het Vietnamese primair onderwijs. De institutionele uitdagingen betroffen: i) de beschikbare tijd voor leren en onderwijzen, ii) het bepalen van leerresultaten, en iii) het probleem van een systeemverandering in het onderwijs.

In het vierde deelonderzoek (Hoofdstuk 5), is het ontworpen curriculum (Cyclus 1) geëvalueerd. Het doel van dit deelonderzoek was het beantwoorden van de volgende deelvraag:

> *In welke mate komt een les van het ontworpen curriculum voor natuurwetenschappelijk onderwijs in de lespraktijk van primair onderwijs in de Confuciaanse cultuur overeen met de sociaal constructivistische verwachtingen?*

Uit de verzamelde gegevens bleek dat het ontworpen curriculum Confuciaanse leerlingen kan helpen geïnteresseerd, nieuwsgierig, actief en interactief te worden in het leren van natuurwetenschappelijke vakinhoud. Bovendien bleek dat het ontworpen curriculum leerlingen kan helpen bij het gebruik van hun intuïtieve kennis bij het leren en bij het ontwikkelen van hun motivatie om meer te leren over natuurwetenschappelijke vakinhoud. Het ontworpen curriculum bleek echter niet effectief genoeg in het ondersteunen van het leren argumenteren in de lespraktijk van deze lessen: vooral in de fase van Uitwisseling was er sprake van een laag niveau van argumenteren en waren de leerlingen minder actief dan in de andere fasen. Argumenteren bleek een knelpunt bij het invoeren van een sociaal constructivistisch perspectief in het natuurwetenschappelijk primair onderwijs in de Confuciaanse cultuur.

Deze analyse van de resultaten van Ontwerp-Cyclus 1 leidde tot een herzien raamwerk en tot herziene ontwerpen van de natuurwetenschappelijke lessen voor Cyclus 2. Het vijfde deelonderzoek (Hoofdstuk 6) geeft een beschrijving van de aanpassingen in het ontworpen curriculum om Confuciaanse leerlingen te ondersteunen bij het oefenen van argumenteren in een sociaal constructivistische les over een natuurwetenschappelijk onderwerp. Er zijn drie belangrijke verschillen tussen de ontwerpen in Cyclus 1 en Cyclus 2. Het eerste ontwerp was alleen gericht op leerlingactiviteiten en omvatte geen specifieke docentactiviteiten. Ten tweede werd in het eerste ontwerp geen gebruikgemaakt van het model van de ‘leerplacemat’. Het aangepaste model van de ‘leerplacemat’ is in het aangepaste ontwerp gebruikt om argumentatieve interactie tussen leerlingen te stimuleren teneinde hen in staat te stellen argumentatieve vaardigheden te verwerven. Het derde verschil is dat leerlingactiviteiten in het aangepaste ontwerp meer concreet en beter georganiseerd zijn door de beschrijving van concrete activiteiten van de docent en het gebruik van de ‘leerplacemat’. In het eerste ontwerp vonden de activiteiten van het presenteren en bespreken van de voorspellende taak en de ‘hands-on-taak’ plaats in de fase van Ervaringen, voordat de ‘hands-on-taak’ begon. Dit was gedaan om verwarring bij de leerlingen te voorkomen, maar het maakte het voor hen moeilijk om de ideeën van de andere groepen leerlingen te begrijpen als ze tegelijkertijd de uitkomsten van de experimenten probeerden te voorspellen en de resultaten presenteerden van de ‘hands-on-taken’. In het aangepaste ontwerp vonden de activiteiten presenteren en bespreken daarom plaats in de fase van Ervaringen, voordat de ‘hands-on-taken’ begonnen. Tabel 1 geeft het ontwerp in Cyclus 2 weer, waarbij de aanpassingen ten opzichte van Cyclus 1 in vet zijn weergegeven.

Tabel 1. Het aangepaste raamwerk (aanpassingen in vet weergegeven) van het sociaal constructivistische curriculum voor natuurwetenschappelijk onderwijs in het basisonderwijs in een Confuciaanse cultuur. (Cyclus 2)

Fase	Functie	**Docentactiviteit**	Leerlingactiviteit	Onderwijsvorm	Verwachting
Engagement	A. Motiveren van leerlingen om natuurweten-schappelijke vakinhoud te leren	i. Gebruik van enkele kernvragen om de voorkennis van leerlingen op te roepen en nieuwsgierigheid op te wekken over het onderwerp van de les ii. Een open houding aannemen voor antwoorden van leerlingen	1. Een kleine hands-on activiteit met een relevant voorbeeld, gerelateerd aan de natuurwetenschappelijke vakinhoud 2. Beantwoorden van Wat, Hoe en Waarom vragen over een relevant voorbeeld, gerelateerd aan de natuurwetenschappelijke vakinhoud	In kleine groepen en/of in de klas als geheel	a. Leerlingen zijn geïnteresseerd n de natuurweten-schappelijke vakinhoud
Ervaringen	B. Oproepen van attitudes over natuur-wetenschappelijke onderwerpen	iii. Uitreiken van de taak en zeker stellen dat de leerling-groepjes weten wat ze moeten doen en hoe ze de taak moeten uitvoeren iv. De tijd voor groepsdiscussie aangeven v. Observeren en begeleiden van groepjes terwijl ze hun groepstaken uitvoeren	3. VOORSPELLEN 3.1. Observeren en bespreken om de vragen te beantwoorden: *Wat neem je waar? Wat zal er gebeuren als …? Waarom denk dat?*		b. Leerlingen zijn nieuwsgierig naar het leren over representatieve voorbeelden van natuurweten-schappelijke onderwerpen

C. Verwerven van procedurele kennis		3.2. Opschrijven van de antwoorden (op de werkbladen van het groepje)	In kleine groepjes	c. Leerlingen zijn actief in het leren over representatieve voorbeelden van natuurwetenschappelijke onderwerpen
D. Verwerven van conceptuele kennis	vi. Leerlingen aanmoedigen om hun antwoorden te presenteren, en de antwoorden te vergelijken en te beoordelen	3.3. Presenteren van deze antwoorden (3.1 & 3.2.) aan de andere groepjes		
E. Verwerven van argumentatieve vaardigheden		3.4. Verhelderen van overeenkomsten en verschillen tussen de antwoorden op de voorspellingsvragen tussen de groepjes		d. Leerlingen gebruiken hun intuïtieve kennis om te leren over natuurwetenschappelijke onderwerpen
	vii. Een open houding aannemen voor antwoorden van leerlingen	3.5. Bespreken van de voorspellingsvragen met andere groepjes		e. Leerlingen argumenteren met elkaar om overeenstemming te verkrijgen over kennis van representatieve voorbeelden van natuurwetenschappelijke onderwerpen
	viii. Uitreiken van de taak en zeker stellen dat de leerling-groepjes weten wat ze moeten doen en hoe ze de taak moeten doen	4. HANDS-ON		

ix. De tijd voor groepsdiscussie vaststellen x. Observeren en begeleiden van groepjes terwijl ze hun groepstaak uitvoeren	4.1.Uitvoeren van een experiment en bespreken van de resultaten om de vragen te beantwoorden: *Wat heb je waargenomen? Hoe kun je je waarnemingen verklaren? Waarom denk je dat?* 4.2.Opschrijven van de antwoorden in de vakken voor individuele antwoorden op de ***aangepaste leerplacemat***
xi. Gebruik van open verwerkingsvragen om leerlingen te leiden xii. Open en vriendelijk blijven in de interactie met leerlingen	4.3. Delen van de opgeschreven individuele ideeën in het groepje 4.4. Selecteren van de ideeën voor gemeenschappelijke antwoorden en opschrijven daarvan in het vak voor gemeenschappelijke antwoorden van ***de aangepaste leerplacemat***
	5. VRAGEN STELLEN: Formuleren van vragen over het natuurwetenschappelijke onderwerp

		xiii. Aanmoedigen van leerlingen om hun antwoorden te presenteren, en die te vergelijken en te beoordelen	6. Presenteren van de resultaten van de hands-on activiteiten aan andere groepjes		
	F. Vergroten van de attitudes ten opzichte van natuurwetenschappelijke onderwerpen		**7. Verhelderen van overeenkomsten en verschillen tussen antwoorden (6)**		f. Leerlingen zijn interactief bij het leren van natuurwetenschappelijke vakinhoud
Uitwisseling	G. Vergroten van procedurele kennis		**8. Verhelderen van overeenkomsten en verschillen tussen antwoorden op voorspellingsvragen en antwoorden op hands-on taken binnen de groepjes**	In de klas als geheel en/of in gecombineerde groepjes	g. Leerlingen argumenteren met elkaar om overeenstemming te verkrijgen over kennis van representatieve voorbeelden van natuurwetenschappelijke onderwerpen
	H. Vergroten van conceptuele kennis	xiv. Stimuleren van groepjes om resultaten uit te wisselen en met elkaar te argumenteren	9. bespreken van de resultaten van de hands-on activiteiten met andere groepjes		
	I. Vergroten van argumentatieve vaardigheden	xv. Gebruik van open verwerkingsvragen om leerlingen te leiden naar meer diepgaande kennis			
		xvi. Open en vriendelijk blijven in de interactie met leerlingen			

		xvii. Kiezen van representatieve vragen, die geformuleerd zijn door individuele leerlingen of groepjes voor discussie en beantwoording	10. beantwoorden van de geformuleerde vragen over gerelateerde natuurwetenschappelijke onderwerpen		
Opvolging	J. Verwerven van cognitieve flexibiliteit	xviii. Geven van open subvragen (indien nodig) om leerlingen te leiden bij het beantwoorden van nieuwe vragen of het oplossen van problemen	11. Presenteren van antwoorden/oplossingen voor vragen/problemen over gerelateerde natuurwetenschappelijke onderwerpen	In de klas als geheel	h. Leerlingen kunnen goede antwoorden geven en/of oplossingen waarbij ze de verworven kennis moeten toepassen
	K. Motiveren tot verder leren	xix. Geven van complimenten aan individuele leerlingen en groepjes die goede leerresultaten behaald hebben			i. Leerlingen laten zien dat ze meer willen leren over natuurweten-schappelijke onderwerpen

Het vijfde deelonderzoek (Hoofdstuk 6) was gericht op de volgende deelvragen:

> *In welke mate ondersteunt de les volgens het aangepaste ontwerp van het sociaal constructivistische curriculum voor primair natuurwetenschappelijk onderwijs in de Confuciaanse cultuur leerlingen bij het oefenen van argumenteren in de lespraktijk?*
>
> *In welke mate ondersteunt de les volgens het aangepaste ontwerp van het sociaal constructivistische curriculum voor primair natuurwetenschappelijk onderwijs in de Confuciaanse cultuur leerlingen bij het bereiken van gemeenschappelijk vastgestelde kennis over natuurwetenschappelijke vakinhoud?*

Uit de gegevens bleek dat het aangepaste ontwerp Confuciaanse leerlingen kan ondersteunen bij het oefenen in argumenteren in natuurwetenschappelijke lessen en in het verkrijgen van gemeenschappelijke kennis over natuurwetenschappelijke vakinhoud. Dit deelonderzoek liet ook zien dat de argumentatieactiviteiten zoals kwalificeren en weerleggen nauwelijks aandacht krijgen als Confuciaanse leerlingen oefenen in het argumenteren.

Het antwoord op de hoofdvraag van dit onderzoek – Welk *curriculumontwerp voor natuurwetenschappelijk onderwijs in primair onderwijs heeft sociaal constructivistische kenmerken en is afgestemd op de Confuciaanse cultuur?* – is dat het aangepaste ontwerp van Cyclus 2 effectief bleek in het ondersteunen van Confuciaanse leerlingen bij het oefenen in het argumenteren in natuurwetenschappelijke lessen en in het verkrijgen van gemeenschappelijke kennis over de natuurwetenschappelijke vakinhoud. Dit kan worden gezien als een '*proof of principle*'. Het model van de leerplacemat is een cultureel afgestemd leermiddel dat bruikbaar is voor het faciliteren van Confuciaanse leerlingen om met elkaar in discussie te gaan om het argumenteren te oefenen. Het curriculumontwerp bestaat uit een curriculumraamwerk met leerfasen en hun functies (zie Tabel 1), dat concreet is uitgewerkt in drie lessen. Het raamwerk en de concrete natuurwetenschappelijke lessen moeten nog aangepast worden aan de aanbevelingen op grond van het onderzoek in Cyclus 2. Bovendien heeft de ontwerpgerichte onderzoeksaanpak niet alleen geleid tot het ontwerp van een curriculumraamwerk en bijbehorende natuurwetenschappelijke lessen, maar ook tot een verfijnde probleemanalyse na elk van de cycli, wat leidde tot nieuwe argumenten voor een herontwerp en detaillering in de afstemming. Deze verfijnde probleemanalyses maken deel uit van het antwoord op de hoofdvraag van dit onderzoek.

Drie aanbevelingen zijn geformuleerd op basis van de bovenstaande conclusies.

1. *Curriculum-"groei" door het betrekken van meer docenten bij deze onderwijsontwikkeling.*
2. *Curriculum-"groei" door professionele ontwikkeling van docenten over de vakinhoud.*
3. *Curriculum-"groei" door het ontwerpen van een volledig programma voor het primair natuurwetenschappelijk onderwijs (voor leerlingen van 6 tot 10 jaar).*

De aanpak hiervan kan bestaan uit een meervoudig ontwikkelingsprogramma waarbij groepen docenten gecoacht worden door een curriculumexpert en waarbij onderling verbonden leergemeenschappen worden gevormd om meer lessen te ontwerpen voor het innovatieve curriculum. Getrainde docenten kunnen de rollen van coaches en trainers op zich nemen voor andere groepen docenten, die vervolgens nieuwe leergemeenschappen vormen. Op deze wijze kan het innovatieve curriculum worden overgedragen aan docenten in andere delen van het land. Professionele ontwikkeling van docenten moet ook kennis betreffen over een sociaal constructivistisch perspectief en de kenmerken van een sociaal constructivistische docent, kennis van de onderwijsaanpak in de "nature of science", en kennis over argumentatieactiviteiten zoals kwalificeren en weerleggen. De opschaling van het aantal lessen in het curriculum moet geïntegreerd worden in het programma voor professionele ontwikkeling van docenten. Er zijn veel meer lessen nodig dan de vier lessen die in dit onderzoek ontwikkeld zijn, en deze kunnen worden ontworpen door de docenten zelf. Op deze manier functioneren de Confuciaanse docenten als het menselijke kapitaal dat verder opgebouwd moet worden om te maken dat deze innovatie kan gaan groeien.

Thiết kế bài dạy khoa học kiến tạo xã hội cho bậc tiểu học trong nền văn hóa kế thừa Nho giáo

Pha học tập	Chức năng	Hoạt động giáo viên	Hoạt động học sinh	Hình thức	Mong đợi
Thu hút	A. Cung cấp cho học sinh động cơ học tập tích cực	i. Sử dụng một vài câu hỏi chìa khóa nhằm khơi gợi ở học sinh kiến thức sẵn có và sự tò mò về vấn đề của bài học	1. Thực hiện một hoạt động thực hành nhỏ với ví dụ gần gũi liên quan đến vấn đề của bài học	Nhóm nhỏ và/hoặc cả lớp	a. Học sinh quan tâm đến vấn đề của bài học
		ii. Duy trì thái độ mở, không đánh giá nhận xét các câu trả lời của học sinh	2. Trả lời các câu hỏi Cái gì, Như thế nào, và Tại sao liên quan đến ví dụ đó		
			3. DỰ ĐOÁN		
		iii. Giao nhiệm vụ và chắc chắn rằng các nhóm biết được cần phải làm gì và làm như thế nào đối với nhiệm vụ học tập được giao iv. Ấn định thời gian thảo luận nhóm v. Quan sát và theo dõi các nhóm thực hiện nhiệm vụ			
	B. Gợi lên ở học sinh những thái độ học tập tích cực đối với môn khoa học	vi. Khuyến khích học sinh trả lời câu hỏi, đối chiếu so sánh và đánh giá các câu trả lời	3.1. Quan sát và thảo luận để đưa ra các câu trả lời cho các câu hỏi: Em quan sát thấy gì? Điều gì sẽ xảy ra nếu...? Tại sao em nghĩ vậy? 3.2. Viết câu trả lời vào bảng nhóm 3.3. Trình bày câu trả lời (3.1 & 3.2.)		b. Học sinh tò mò về vấn đề (ví dụ) đại diện cho nội dung khoa học của bài học

Trải nghiệm	C. Giúp học sinh hình thành kiến thức về quy trình, hoạt động khoa học D. Giúp học sinh hình thành kiến thức về khái niệm khoa học E. Giúp học sinh hình thành các kĩ năng tranh luận, lý giải	vii. Duy trì thái độ mở, không đánh giá nhận xét các câu trả lời của học sinh	3.4. Chỉ rõ sự giống và khác trong các câu trả lời 3.5. Thảo luận trao đổi về các câu trả lời	Nhóm nhỏ	c. Học sinh tích cực trong học tập d. Học sinh vận dụng kiến thức trực quan cảm tính trong khi học e. Học sinh tranh luận với nhau để đạt được sự thống nhất về vấn đề khoa học
		viii. Giao nhiệm vụ và chắc chắn rằng các nhóm biết được cần phải làm gì và làm như thế nào đối với nhiệm vụ học tập được giao ix. Ấn định thời gian thảo luận nhóm x. Quan sát và theo dõi các nhóm thực hiện nhiệm vụ	4. THỰC HÀNH - THÍ NGHIỆM 4.1. Thực hành thí nghiệm và thảo luận để đưa ra các câu trả lời cho các câu hỏi: Em đã quan sát thấy gì? Giải thích như thế nào cho điều đó? Tại sao em lại nghĩ vậy? 4.2. Viết các câu trả lời vào phần ý kiến cá nhân của phiếu tương tác 4.3. Chia sẻ các câu trả lời cá nhân với các thành viên khác trong nhóm		

		xi. Sử dụng các câu hỏi dẫn dắt gợi mở để hướng dẫn học sinh xii. Cởi mở và thân thiện khi tương tác với học sinh	4.4. Lựa chọn những ý kiến phù hợp để đưa ra câu trả lời của cả nhóm và sau đó viết vào phần ý kiến chung của phiếu tương tác		
			5. ĐẶT CÂU HỎI: Đặt các câu hỏi liên quan đến vấn đề của bài học		
Trao đổi	F. Phát triển ở học sinh những thái độ học tập tích cực đối với môn khoa học G. Giúp học sinh phát triển kiến thức về quy trình, hoạt động khoa học H. Giúp học sinh phát triển kiến thức về khái niệm khoa học I. Giúp học sinh phát triển các kĩ năng tranh luận, lý giải	xiii. Khuyến khích học sinh trả lời câu hỏi, đối chiếu so sánh và đánh giá các câu trả lời xiv. Khuyến khích các nhóm tương tác và tranh luận với nhau xv. Sử dụng các câu hỏi dẫn dắt gợi mở để hướng dẫn học sinh đạt được kiến thức sâu hơn xvi. Cởi mở và thân thiện khi tương tác với học sinh xvii. Lựa chọn những câu hỏi tiêu biểu được đặt bởi học sinh để học sinh thảo luận và trả lời	6. Trình bày kết quả của hoạt động thực hành thí nghiệm (4.1) với các nhóm khác 7. Chỉ rõ sự giống và khác trong các câu trả lời (6) 8. Chỉ rõ sự giống và khác giữa các câu trả lời dự đoán (3.3) và câu trả lời thực hành (6) của các nhóm 9. Thảo luận trao đổi về các câu trả lời thực hành thí nghiệm 10. Trả lời các câu hỏi (5)	Cả lớp và/ hoặc nhóm trộn	f. Học sinh tương tác với nhau trong quá trình trao đổi vấn đề khoa học g. Học sinh tranh luận với nhau để đạt được sự thống nhất về vấn đề khoa học

Tiếp nối	J.Giúp học sinh vận dụng kiến thức linh hoạt K. Nuôi dưỡng động cơ học tập khoa học cho học sinh	xviii. Đưa ra những câu hỏi mở (nếu cần) để hướng dẫn học sinh trả lời/giải quyết những câu hỏi/vấn đề mới liên quan đến nội dung của bài học xix. Khen ngợi những cá nhân và nhóm học sinh đã tích cực tham gia và học tập tốt	11. Đưa ra các câu trả lời/cách giải quyết cho các câu hỏi/vấn đề liên quan đến nội dung bài học	Cả lớp	h. Học sinh có thể đưa ra các câu trả lời/cách giải quyết phù hợp cho các câu hỏi/vấn đề vận dụng kiến thức i. Học sinh bộc lộ sự mong muốn, khát khao học tập

Acknowledgements

One tree cannot make a forest but many trees can [Một cây làm chẳng nên non/Ba cây chụm lại nên hòn núi cao]. I use this old Vietnamese saying to illustrate the way in which this doctoral dissertation has been carried out and completed. I could never have made the "forest" without the help, support, guidance, and effort of many other people.

I would like to express my deep gratitude to my promoters, Albert and Astrid, who have supported and encouraged me throughout my research. Their wholeheartedness, open-mindedness, and dedication to my study and my stay in the Netherlands have motivated me. They gave me good opportunities to explore scientific issues with my own eyes and to gain more knowledge of and skills for science education research. There is no doubt that the interesting and fruitful discussions I had with Albert, or Astrid, or both of them have been and will continue to be valuable experiences for me as a researcher and an educator.

I would also like to express my gratitude to Marijn, the supervisor of my first year of study as a PhD student at the Freudenthal Institute. His patience, kindness and dedication to my study have been meaningful for me while carrying out this research, not just in the first year but throughout the four years of my work in the Netherlands.

My profound thanks go to Hans, my host and landlord whom I call my Dutch culture supervisor. I am very fortunate to have been treated as a close member of his big family. They have always been willing to introduce me to the distinct beauties of the Netherlands and the ways of most easily adapting to Dutch culture. The warmness of this family has made my stay in the Netherlands a most enjoyable experience, and has also made me feel less homesick so that I could concentrate better on my research.

This doctoral dissertation would not have been a possibility if I had not been provided with a scholarship for four years of doctoral research in the Netherlands by NUFFIC, the Dutch organisation for international cooperation in higher education. Therefore, I would like to express my sincere gratitude to NUFFIC. NUFFIC gave me a wonderful opportunity for this in-depth study of science for primary education, the area that I have been attracted to and passionate about for a long time. Thanks to NUFFIC, I know much more about the Netherlands and have had some fine years with some unforgettably sweet memories in this country. NUFFIC is indeed a bridge that has provided a path for me to join the country of flowers, the Freudenthal Institute, and the talented colleagues I discovered there. The interesting chats and discussions I have shared with Gjalt, Ria, Salamah, Martin, Nienke, Caty, Suzanne, Koos, Dirk-Jan, Kees, Arend-Jan, and many other colleagues have been helpful and supportive for both me and my study. Therefore, I would also like to express my thankfulness to the institute and those colleagues.

The completion of this doctoral dissertation would not have been possible if I had not been provided with good conditions to do this doctoral research by Hanoi National University of Education and my faculty of primary education. Despite the distance between Vietnam and the Netherlands, I was always facilitated and encouraged from a distance by my colleagues in Vietnam. From the bottom of my heart, I would like to express my warmest thanks to my home university and my home faculty.

I am also very grateful to the primary teachers of Đông Ngàn primary school in Vietnam, especially the three participating teachers Đỗ Thị Thanh Vân, Nguyễn Thu Hương, and Nguyễn Thị Ánh, all of whom participated enthusiastically in my research.

I am sure that I could not have attempted and completed this doctoral dissertation without the wholehearted support and countless sacrifices of my family in Vietnam. I would like to express my immeasurable gratitude to my parents, my husband, my little daughter, my brothers and my sisters for all the support they have given me to do my research in the Netherlands.

Curriculum vitae

Ngô Vũ Thu Hằng was born on September 10, 1981 in Bacninh, Vietnam. She got her high school diploma in 1999 from the public high school Lý Thái Tổ in Bacninh. She got her bachelor degree on primary education at Hanoi National University of Education in 2003. After that, in the same year, she was accepted at the Faculty of Primary Education of this university to work as a teacher trainer. In 2004, she entered her master's program at the same university faculty and got her Master's degree two years later. During her time working at Faculty of Primary Education, she took part in several educational training courses that were organized in Malaysia and Japan. In early 2010, she was awarded a scholarship from NUFFIC, the Dutch organization for international cooperation in higher education to pursue her doctoral study at Utrecht University. At Utrecht University, she joined the Freudenthal Institute for Science and Mathematics Education (Flsme) under the supervision of Prof. Dr. Albert Pilot and Dr. Ir. Astrid Bulte.

Publications

Nguyễn Trại (Ed.) Ngô Vũ Thu Hằng, Nguyễn Thị Cẩm Hường (2003). *Thiết kế bài giảng tự nhiên và xã hội 2* [Plans of Nature and Science lessons – Grade 2]. Nhà xuất bản Hà Nội [Publishing House of Hà Nội]

Ngô Vũ Thu Hằng (2005). Vận dụng trò chơi Đôminô nhằm tích cực hoá quá trình dạy học các nội dung khoa học [Using domino game to foster the teaching and learning of science]. *Tạp chí Giáo dục* - Số 113 [Journal of Education – No.113]

Ngô Vũ Thu Hằng (2005). Kỹ thuật dạy học bằng các hoạt động phóng tác [Teaching technique by adaptation activities]. *Tạp chí Giáo dục* - Số 122 [Journal of Education – No.122]

Ngô Vũ Thu Hằng (2008). Nâng cao chất lượng dạy học tiểu học thông qua một số kĩ năng cơ bản [Improving the quality of primary education through some fundamental skills of teaching and learning]. *Tạp chí Giáo dục* - Số 199 [Journal of Education – No.199]

Dương Giáng Thiên Hương (Ed.), Vũ Thị Lan Anh, Ngô Vũ Thu Hằng, Quản Hà Hưng, Nguyễn Thị Phương (2009). *Giáo trình rèn luyện nghiệp vụ sư phạm tiểu học : Dùng cho hệ cử nhân giáo dục tiểu học* [Textbook of pedagogical profession training of primary education – For Bachelor Level of Primary Education]. Nhà xuất bản Đại học Sư phạm Hà Nội [Publishing House of Hà Nội National University of Education]

Conferences

International biennial conference "Light of Science" of East-Asian Association for Science Education (EASE) Gwangju, Korea 2011

The 10th Conference of the European Science Education Research Association (ESERA) "Science Education Research for Evidence-based Teaching and Coherence in Learning" Nicosia, Cyprus 2013

FIsme Scientific Library

(formerly published as CD-b Scientific Library)

81.	Sun, L. (2014). *From rhetoric to practice: enhancing environmental literacy of pupils in China.*
80.	Mazereeuw, M. (2013). *The functionality of biological knowledge in the workplace. Integrating school and workplace learning about reproduction.*
79.	Dierdorp, A. (2013). *Learning correlation and regression within authentic contexts.*
78.	Dolfing, R. (2013). *Teachers' Professional Development in Context-based Chemistry Education. Strategies to Support Teachers in Developing Domain-specific Expertise.*
77.	Mil, M.H.W. van (2013). *Learning and teaching the molecular basis of life.*
76.	Antwi, V. (2013). *Interactive teaching of mechanics in a Ghanaian university context.*
75.	Smit, J. (2013). *Scaffolding language in multilingual mathematics classrooms.*
74.	Stolk, M. J. (2013). *Empowering chemistry teachers for context-based education. Towards a framework for design and evaluation of a teacher professional development programme in curriculum innovations.*
73.	Agung, S. (2013). *Facilitating professional development of Madrasah chemistry teachers. Analysis of its establishment in the decentralized educational system of Indonesia.*
72.	Wierdsma, M. (2012). *Recontextualising cellular respiration.*
71.	Peltenburg, M. (2012). *Mathematical potential of special education students.*
70.	Moolenbroek, A. van (2012). *Be aware of behaviour. Learning and teaching behavioural biology in secondary education.*
69.	Prins, G. T., Vos, M. A. J., & Pilot, A. (2011). *Leerlingpercepties van onderzoek & ontwerpen in het technasium.*
68.	Bokhove, Chr. (2011). *Use of ICT for acquiring, practicing and assessing algebraic expertise.*
67.	Boerwinkel, D. J. & Waarlo, A. J. (2011). *Genomics education for decision-making. Proceedings of the second invitational workshop on genomics education, 2-3 December 2010.*
66.	Kolovou, A. (2011). *Mathematical problem solving in primary school*.
65.	Meijer, M. R. (2011). *Macro-meso-micro thinking with structure-property relations for chemistry. An explorative design-based study*.
64.	Kortland, J., & Klaassen, C. J. W. M. (2010). *Designing theory-based teaching-learning sequences for science. Proceedings of the symposium in honour of Piet Lijnse at the time of his retirement as professor of Physics Didactics at Utrecht University*.

63.	Prins, G. T. (2010).*Teaching and learning of modelling in chemistry education. Authentic practices as contexts for learning*.
62.	Boerwinkel, D. J., & Waarlo, A. J. (2010). *Rethinking science curricula in the genomics era. Proceedings of an invitational workshop*.
61.	Ormel, B. J. B. (2010). *Het natuurwetenschappelijk modelleren van dynamische systemen. Naar een didactiek voor het voortgezet onderwijs*.
60.	Hammann, M., Waarlo, A. J., & Boersma, K. Th. (Eds.) (2010). *The nature of research in biological education: Old and new perspectives on theoretical and methodological issues – A selection of papers presented at the VIIth Conference of European Researchers in Didactics of Biology*.
59.	Van Nes, F. (2009). *Young children's spatial structuring ability and emerging number sense*.
58.	Engelbarts, M. (2009*). Op weg naar een didactiek voor natuurkunde-experimenten op afstand. Ontwerp en evaluatie van een via internet uitvoerbaar experiment voor leerlingen uit het voortgezet onderwijs*.
57.	Buijs, K. (2008). *Leren vermenigvuldigen met meercijferige getallen*.
56.	Westra, R. H. V. (2008). *Learning and teaching ecosystem behaviour in secondary education: Systems thinking and modelling in authentic practices*.
55.	Hovinga, D. (2007). *Ont-dekken en toe-dekken: Leren over de veelvormige relatie van mensen met natuur in NME-leertrajecten duurzame ontwikkeling*.
54.	Westra, A. S. (2006). *A new approach to teaching and learning mechanics*.
53.	Van Berkel, B. (2005). *The structure of school chemistry: A quest for conditions for escape*.
52.	Westbroek, H. B. (2005). *Characteristics of meaningful chemistry education: The case of water quality*.
51.	Doorman, L. M. (2005). *Modelling motion: from trace graphs to instantaneous change*.
50.	Bakker, A. (2004). *Design research in statistics education: on symbolizing and computer tools*.
49.	Verhoeff, R. P. (2003). *Towards systems thinking in cell biology education*.
48.	Drijvers, P. (2003). *Learning algebra in a computer algebra environment. Design research on the understanding of the concept of parameter*.
47.	Van den Boer, C. (2003). *Een zoektocht naar verklaringen voor achterblijvende prestaties van allochtone leerlingen in het wiskundeonderwijs*.
46.	Boerwinkel, D. J. (2003). *Het vormfunctieperspectief als leerdoel van natuuronderwijs. Leren kijken door de ontwerpersbril.*
45.	Keijzer, R. (2003). *Teaching formal mathematics in primary education. Fraction learning as mathematising process*.

44.	Smits, Th. J. M. (2003). *Werken aan kwaliteitsverbetering van leerlingonderzoek: Een studie naar de ontwikkeling en het resultaat van een scholing voor docenten*.
43.	Knippels, M. C. P. J. (2002). *Coping with the abstract and complex nature of genetics in biology education – The yo-yo learning and teaching strategy*.
42.	Dressler, M. (2002). *Education in Israel on collaborative management of shared water resources.*
41.	Van Amerom, B.A. (2002). *Reinvention of early algebra: Developmental research on the transition from arithmetic to algebra*.
40.	Van Groenestijn, M. (2002). *A gateway to numeracy. A study of numeracy in adult basic education.*
39.	Menne, J. J. M. (2001). *Met sprongen vooruit: een productief oefenprogramma voor zwakke rekenaars in het getallengebied tot 100 – een onderwijsexperiment*.
38.	De Jong, O., Savelsbergh, E.R., & Alblas, A. (2001). *Teaching for scientific literacy: context, competency, and curriculum.*
37.	Kortland, J. (2001). *A problem-posing approach to teaching decision making about the waste issue.*
36.	Lijmbach, S., Broens, M., & Hovinga, D. (2000). *Duurzaamheid als leergebied; conceptuele analyse en educatieve uitwerking*.
35.	Margadant-van Arcken, M., & Van den Berg, C. (2000). *Natuur in pluralistisch perspectief – Theoretisch kader en voorbeeldlesmateriaal voor het omgaan met een veelheid aan natuurbeelden*.
34.	Janssen, F. J. J. M. (1999). *Ontwerpend leren in het biologieonderwijs. Uitgewerkt en beproefd voor immunologie in het voortgezet onderwijs*.
33.	De Moor, E. W. A. (1999). *Van vormleer naar realistische meetkunde – Een historisch-didactisch onderzoek van het meetkundeonderwijs aan kinderen van vier tot veertien jaar in Nederland gedurende de negentiende en twintigste eeuw*.
32.	Van den Heuvel-Panhuizen, M., & Vermeer, H. J. (1999). *Verschillen tussen meisjes en jongens bij het vak rekenen-wiskunde op de basisschool – Eindrapport MOOJ-onderzoek*.
31.	Beeftink, C. (2000). *Met het oog op integratie – Een studie over integratie van leerstof uit de natuurwetenschappelijke vakken in de tweede fase van het voortgezet onderwijs*.
30.	Vollebregt, M. J. (1998). *A problem posing approach to teaching an initial particle model*.
29.	Klein, A. S. (1998). *Flexibilization of mental arithmeticsstrategies on a different knowledge base – The empty number line in a realistic versus gradual program design*.

28.	Genseberger, R. (1997). *Interessegeoriënteerd natuur- en scheikundeonderwijs – Een studie naar onderwijsontwikkeling op de Open Schoolgemeenschap Bijlmer*.
27.	Kaper, W. H. (1997). *Thermodynamica leren onderwijzen*.
26.	Gravemeijer, K. (1997). *The role of context and models in the development of mathematical strategies and procedures*.
25.	Acampo, J. J. C. (1997). *Teaching electrochemical cells – A study on teachers' conceptions and teaching problems in secondary education*.
24.	Reygel, P. C. F. (1997). *Het thema 'reproductie' in het schoolvak biologie*.
23.	Roebertsen, H. (1996). *Integratie en toepassing van biologische kennis – Ontwikkeling en onderzoek van een curriculum rond het thema 'Lichaamsprocessen en Vergift'*.
22.	Lijnse, P. L., & Wubbels, T. (1996). *Over natuurkundedidactiek, curriculumontwikkeling en lerarenopleiding*.
21.	Buddingh', J. (1997). *Regulatie en homeostase als onderwijsthema: een biologie-didactisch onderzoek*.
20.	Van Hoeve-Brouwer G. M. (1996). *Teaching structures in chemistry – An educational structure for chemical bonding*.
19.	Van den Heuvel-Panhuizen, M. (1996). *Assessment and realistic mathematics education*.
18.	Klaassen, C. W. J. M. (1995). *A problem-posing approach to teaching the topic of radioactivity*.
17.	De Jong, O., Van Roon, P. H., & De Vos, W. (1995). *Perspectives on research in chemical education.*
16.	Van Keulen, H. (1995). *Making sense – Simulation-of-research in organic chemistry education*.
15.	Doorman, L. M., Drijvers, P. & Kindt, M. (1994). *De grafische rekenmachine in het wiskundeonderwijs*.
14.	Gravemeijer, K. (1994). *Realistic mathematics education*.
13.	Lijnse, P. L. (Ed.) (1993). *European research in science education*.
12.	Zuidema, J., & Van der Gaag, L. (1993). *De volgende opgave van de computer*.
11.	Gravemeijer, K., Van den Heuvel-Panhuizen, M., Van Donselaar, G., Ruesink, N., Streefland, L., Vermeulen, W., Te Woerd, E., & Van der Ploeg, D. (1993). *Methoden in het reken-wiskundeonderwijs, een rijke context voor vergelijkend onderzoek*.
10.	Van der Valk, A. E. (1992). *Ontwikkeling in Energieonderwijs*.
9.	Streefland, L. (Ed.) (1991). *Realistic mathematics education in primary schools*.
8.	Van Galen, F., Dolk, M., Feijs, E., & Jonker, V. (1991). *Interactieve video in de nascholing reken-wiskunde.*
7.	Elzenga, H. E. (1991). *Kwaliteit van kwantiteit*.

6.	Lijnse, P. L., Licht, P., De Vos, W., & Waarlo, A. J. (Eds.) (1990). *Relating macroscopic phenomena to microscopic particles: a central problem in secondary science education*.
5.	Van Driel, J. H. (1990). *Betrokken bij evenwicht*.
4.	Vogelezang, M. J. (1990). *Een onverdeelbare eenheid*.
3.	Wierstra, R. F. A. (1990). *Natuurkunde-onderwijs tussen leefwereld en vakstructuur*.
2.	Eijkelhof, H. M. C. (1990). *Radiation and risk in physics education*.
1.	Lijnse, P. L., & De Vos, W. (Eds.) (1990). *Didactiek in perspectief*.