Representations of Selected Aspects of Chemistry in Secondary School Chemistry Textbooks from Different Chinese Communities

DISSERTATION

submitted for the fulfillment of the degree of doctor of natural science

(Dr. rer. nat.)

By

Xiaoge Chen

Faculty of Biology and Chemistry

University of Bremen

Examination Committee

Chairperson:

Prof. Dr. Doris Elster

Co-examiners:

Prof. Dr. Ingo Eilks

Prof. Dr. Verena Pietzner

PD Dr. Christoph Kulgemeyer

02. July 2019

Bremen

ACKNOWLEDGEMENTS

First and foremost, I am profoundly grateful to my mentor Professor Dr. Ingo Eilks for offering me the opportunity to conduct my Ph.D. research. I have seen kind personalities from him, such as equality, creativity, cooperation and many alike. I will bring them along with me for the rest of my career. My research would have been impossible without the generous support and fruitful suggestion of him.

I would like to thank Professor Dr. Verena Pietzner for accepting the invitation to be the external examiner of my thesis and defense. My sincere thanks to Professor Dr. Doris Elster for acting as the chairman of the doctoral committee. I am also grateful to PD Dr. Christoph Kulgemeyer for being the internal examiner.

I would like to acknowledge the China Scholarship Council (CSC) and the University of Bremen for funding my study.

Special thanks to Professor Dr. David F. Treagust, Professor Dr. Mei-Hung Chiu for cooperating with us. Generous supports from Professor Dr. Mageswary Karpudewan, Professor Dr. Robin Millar, Dr. Chua Kah Heng and Hongseok Jeong are warmly acknowledged.

I am also grateful to all the co-workers in Prof. Eilks's academic group, including present co-workers Safwatun Nida, Robby Zidny, Nina Hamidah, Johanna Dittmar, Christian Zowada, Dr. Nadja Frerichs, Dr. Antje Siol as well as former co-workers Dr. Rouba Khaddoor, Dr. Yannik Tolsdorf, Dr. Fiona Affeldt, Dr. Luciane Fernandes de Goes, Professor Dr. Silvija Markic. Many thanks to our former secretary Rita Fofana and present secretary Susanne Carraro as well as our technician Heike Steljes for their warm help during my studies. I am deeply grateful to Dr. Nadja Frerichs, Christian Zowada, Safwatun Nida and Robby Zidny for their feedback to improve my thesis. Special thanks to my office mates Nina Hamidah and Christian Zowada for bringing many great moments and offering hot water every day.

Without my parents' encouragement and understanding, I would not be strong and firm enough to work on my dreams. I am deeply grateful for everything they have done for me. Big thanks to my sister and brother for accompanying our beloved parents while I am abroad. Many thanks to my boyfriend Weichao Xue for sharing concerns and strength throughout the years.

The three years of abroad life gave me many wonderful memories. Lots of people inspired me. Thanks for your encouragement.

OVERVIEW

This thesis is composed of four studies. It focuses on representations of selected aspects of chemistry in secondary school chemistry textbooks from different Chinese Communities, namely from the People's Republic of China, Taiwan, and the Chinese minority in Malaysia.

The first study looks at the representation of the intended curriculum in grade 10 chemistry textbooks, identifying similarities and differences concerning the curriculum orientation of the seven sets of textbooks (more detail in Chapter 3, Section 3.1).

The first study finds different characteristics of the intended curriculum in different Chinese communities, even though the sample shares similar ethnics, language and cultural background. This outcome, in turn, inspires us to conduct another two parallel studies (Chapter 3, Section 3.2 & 3.3), such as redox reactions and practical work.

Chapter 3, Section 3.2 introduces a study on the analysis of the visual representation of redox reactions in upper secondary chemistry textbooks from PR China, Taiwan and Malaysia. The study aims at displaying how chemistry textbooks deal with visual representations of redox reactions, and further exploring if the visualizations provide any indications of the intended curriculum orientation.

Chapter 3, Section 3.3 is a brief look on how practical work is presented in grade 10 chemistry textbooks and corresponding experimental textbooks from PR China, Taiwan and the Chinese minority in Malaysia. Specific instruments are adapted to analyze the type of learning, intended learning outcomes, inquiry level, and students' involvement, to give a basic overview of features of practical work in transferring the intended curriculum. This study explores how practical work links two domains of knowledge from observables to ideas, and makes a contribution to the body of research of practical work in secondary school chemistry education through a Chinese perspective.

During the conduction on the aforementioned study, new Upper Secondary School Chemistry Curriculum Standard was released in 2017 (USSCCS) in PR China. Because the official curriculum standard serves as the guideline for textbook design, the release of the new curriculum standard inspired us to explore the differences between the new Upper Secondary School Chemistry Curriculum Standard (2017 USSCCS) and the prior Upper Secondary School Chemistry Curriculum Standard (2003 USSCCS), which are both officially released by the Ministry of Education (see Chapter 3, Section 3.4).

Generally, these results show that intended curricula delivered by Taiwanese textbooks take a high degree of contextualization, while textbooks from Malaysia use a rather traditional approach. Textbooks from the People's Republic of China lie somewhere between the textbooks from Taiwan and Malaysia. Chapter 3 gives more details about the general information (Section 3.1) and richer details related to redox reactions (Section 3.2) and practical work (Section 3.3) in corresponding textbooks.

ZUSAMMENFASSUNG

Diese Arbeit besteht aus vier Teilstudien, welche den Schwerpunkt auf den intendierten Lehrplan der Chemieschulbücher der Sekundarstufe II verschiedener chinesischer Gemeinschaften (Volksrepublik China, Taiwan und die chinesische Minderheit in Malaysia) legen.

Die erste Teilstudie befasst sich mit der Darstellung des intendierten Lehrplans der Chemieschulbücher der Klasse 10 und zeigt Ähnlichkeiten und Unterschiede in Bezug auf die Lehrplanausrichtung der sieben gewählten Chemieschulbuchsätze auf (weitere Einzelheiten in Kapitel 3, Abschnitt 3.1).

In der ersten Studie wurden unterschiedliche Merkmale des intendierten Lehrplans in verschiedenen chinesischen Gemeinschaften festgestellt, obwohl die Stichprobe einen ähnlichen ethnischen, sprachlichen und kulturellen Hintergrund aufweist. Dieses Ergebnis führte zu zwei weiteren Studien (Kapitel 3, Abschnitt 3.2 und 3.3) zu den Themen Redoxreaktionen und praktisches Arbeiten.

In Kapitel 3, Abschnitt 3.2, wird eine Studie zur Analyse der visuellen Darstellung von Redoxreaktionen in Chemieschulbüchern der Sekundarstufe II aus der VR China, Taiwan und Malaysia vorgestellt. Die Studie zeigt auf, wie Chemieschulbücher mit visuellen Darstellungen von Redoxreaktionen umgehen, und untersucht folgend, ob die Visualisierungen Hinweise auf die intendierte Lehrplanorientierung liefern.

Kapitel 3, Abschnitt 3.3, gibt einen Überblick darüber, wie das praktische Arbeiten in Chemieschulbüchern der 10. Klasse und zugehörigen Experimentierhandbüchern aus der VR China, Taiwan und der chinesischen Minderheit in Malaysia dargestellt ist. Zur Analyse der praktischen Arbeit wurden verschiedene Untersuchungsinstrumente angepasst, um den Lerntyp, die intendierten Lernergebnisse, das Level of Inquiry und die Beteiligung der Schüler zu analysieren sowie einen grundlegenden Überblick über die Merkmale der praktischen Arbeit bei der Übertragung des intendierten Lehrplans zu geben. Diese Teilstudie untersucht, wie die praktische Arbeit zwei Wissensbereiche verbindet, nämlich das Beobachtbare und Ideen, und leistet damit einen Beitrag zur Erforschung der praktischen Arbeit im Bereich der Chemie in der Sekundarstufe II aus chinesischer Sicht.

Während der Durchführung der oben genannten Teilstudie wurden 2017 in der VR China neue Standards für den Chemielehrplan der Sekundarstufe II (USSCCS) veröffentlicht. Da die offiziellen Curriculum-Standards als Richtlinie für die Gestaltung von Schulbüchern dienen, wurden wir durch die Veröffentlichung der neuen Curriculum-Standards dazu inspiriert, die Unterschiede zwischen dem neuen USSCCS-Standard für Chemie der Sekundarstufe II (2017) und den früheren

Chemiestandards für die Sekundarstufe II (2003) zu untersuchen, die beide vom Bildungsministerium offiziell herausgegeben wurden (siehe Kapitel 3, Abschnitt 3.4).

Abschließend zeigen diese Ergebnisse, dass der intendierte Lehrplan in taiwanesischen Schulbüchern mit einem hohen Grad an Kontextualisierung umgesetzt wird, während Schulbücher aus Malaysia einen eher traditionellen Ansatz verfolgen. Schulbücher aus der VR China bewegen sich zwischen diesen Trends. Kapitel 3 enthält Weiterführendes (Abschnitt 3.1) und ausführlichere Informationen zu Redoxreaktionen (Abschnitt 3.2) sowie zu dem praktischen Arbeiten (Abschnitt 3.3) in entsprechenden Schulbüchern.

Table of content

1 FRAMEWORK OF THE STUDIES

Science is about gathering evidence, and doing science is about gathering evidence from nature (Watson, Swain & McRobbie, 2004). Since the 1980s, new standards of secondary chemistry education emerged. In Western countries, the new standards imply the innovation of chemistry curricula from pure learning of facts, concepts, laws and theories towards learning based on everyday life and societal issues (Eilks, Rauch, Ralle & Hofstein, 2013). A corresponding shift towards science learning with a starting point from everyday life and societal contexts has also been introduced in Asian regions such as the People's Republic of China (Wang, Zhu, Jiang, Wei, Zhou, Guo, Wei, Yang & Liu, 2016), Taiwan (Guo & Chiu, 2016), Malaysia (Halim & Meerah, 2016) and Korea (Choi & Choi, 2016).

The embedding of challenging issues from the local to the global level raises the perception of relevance of school science learning, and helps to promote a fundamental understanding of chemistry to deal with life in society (Stuckey, Hofstein, Mamlok-Naaman & Eilks, 2013). Chemistry education should integrate conceptual learning via a context-based approach (Apotheker, 2014) that includes the human element of science (Sjöström & Talanquer, 2014). It is also suggested that chemistry teachers should take efforts to assign the learning of chemistry to everyday life perspectives and societal contexts (Eilks et al., 2013), or in some cases, to apply teaching in science with the aid of traditional or unconventional media (Belova & Eilks, 2015). Research reports that an advanced philosophy of the science curriculum sees science education in general and chemistry education in particular with a strong connection to society, technology and everyday life (Eilks et al., 2013).

1.1 A BRIEF LOOK ON CURRICULUM THEORY

There is a strong movement towards promoting science-related issues for lifelong participation in society (Roth & Lee, 2004). Secondary school education is also considered to be a transitional and prerequisite stage for some of the students to attain higher educational levels and jobs in scientific and technological domains.

Roberts (1982) briefly mentioned two physics textbooks used in secondary school and found that these two textbooks differ from one to another, because the subject matter is used based on different curricula intentions. The themes of the different viewpoints of the science subject matter are depicted as curriculum emphases by Roberts (1982), which he describes as follows:

> *"A curriculum emphasis in science education is a coherent set of messages to the student about science (rather than within science). Such messages constitute*

> *objectives which go beyond learning the facts, principles, laws, and theories of the subject matter itself-objectives which provide answers to the student question: 'Why am I learning this?'"* (p. 245)

Seven curriculum emphases are inductively listed by Roberts (1982), which are Everyday Coping; Structure of Science; Science, Technology, and Decisions; Scientific Skill Development; Correct Explanations; Self as Explainer; Solid Foundation. These curriculum emphases reflect explicit and implicit messages about curriculum diversity. Furthermore, Roberts (1982) stated that curriculum emphases could change. That was later elaborated and condensed into three curriculum emphases by Van Berkel (2005): Fundamental Chemistry (FC); Knowledge Development in Chemistry (KDC); Chemistry, Technology and Society (CTS). These three general curriculum emphases were later explained by Van Driel, Bulte and Verloop (2007). Briefly, they are:

- Fundamental Chemistry (FC) puts the learning of theoretical concepts and facts at the fore. The curriculum is based on the view that facts and concepts need to be learned first for later application and provide the best ground for understanding the natural world.
- Knowledge Development in Chemistry (KDC) is based on the idea that students should learn how chemistry knowledge emerged as well as changed over time. It also attempts to show how it was influenced by the corresponding socio-historical context, thus making chemistry a culturally-determined system.
- Chemistry, Technology and Society (CTS) puts the interrelationship between science, technology and society at the center of the curriculum. Students should learn how to make decisions on societal issues that are connected to chemistry and technology and to learn how to effectively communicate about them.

In 2006, De Jong pointed out four basic domains related to context-based teaching and learning, namely, the personal domain, the social and society domain, the professional practice domain as well as the scientific and technological domain. He suggested that context-based education should bear this in mind to make chemistry teaching and learning meaningful and successful.

Later in 2013, Eilks and his co-workers came up with six curriculum orientations based on De Jong's (2006) ideas. These six curriculum orientations provide an approach from which chemistry lessons are suggested to begin and from which curricula are suggested to be designed. Briefly summarized by Chen, Chiu and Eilks (2019a), the curriculum orientations are:

- Structure of the discipline orientation: The chemistry curriculum mirrors the inner structure of academic chemistry. The curriculum is designed for structured learning of scientific facts and theories. A corresponding school curriculum might look like a ‘lighter’ version of an academic general chemistry textbook.
- History of chemistry orientation: The chemistry curriculum is structured along episodes from the history of chemistry. The curriculum is designed to learn about the nature of chemistry and how chemistry knowledge emerged over time illustrated by references to the life of real chemists.
- Everyday life orientation: The chemistry curriculum is structured using everyday life topics and issues to provide meaningful contexts for learning chemistry concepts.
- Environmental orientation: The chemistry curriculum is structured by environmental issues and problems, including questions of environmental protection.
- Technology and industry orientation: The chemistry curriculum is structured by developments from chemical technology and industry. This might include the interplay of science and technology within society.
- Socio-scientific issues (SSI) orientation: The chemistry curriculum is structured by using controversial socio-scientific issues. It is suggested that students develop general skills to allow them to act as responsible citizens in society.

As reported by Chen et al. (2019a), the ideas of curriculum emphases (Van Berkel, 2005) and curriculum orientations (Eilks et al., 2013) have similar foci at a certain point. Structure of discipline orientation can be considered closely related to Fundamental Chemistry. The history of chemistry orientation has an emphasis on Knowledge Development in Chemistry. If the focus of technology and industry refers to the development of certain technologies in the past, it may intend Knowledge Development in Chemistry. The Chemistry, Technology and Society emphasis is considered as being mostly prominent in curriculum orientation in terms of everyday life, the environment and socio-scientific issues.

The above mentioned research highlighted the essential role of curriculum of science education in general and chemistry education in particular. In this context, our focus lies on two important topics in secondary chemistry teaching and learning. The first one is redox reactions, and the second one is practical work in secondary chemistry education. In terms of redox reactions, it is believed that they offer a wide variety of daily applications and provide a basis for advanced chemistry learning, such as electrochemistry, organic chemistry or cross-curricular links. They are regarded as a central concept (Basheer, Hugerat, Kortam & Hofstein, 2017) that implies difficulties for secondary education and beyond (De Jong & Treagust, 2002; Finley, Stewart & Yarroch,1982; Obomanu & Onuoha, 2012; Paik, Kim & Kim, 2017; Schmidt

& Volke, 2003). Speaking about practical work it is undisputable that it plays a central and unique role in chemistry teaching and learning. Most educational standards in science education claim the importance of practical work for science education (Hofstein, 2017).

1.2 THE TEXTBOOK AS A BRIDGE BETWEEN THE SUBJECT AND THE LEARNER

In terms of the development of chemistry education, especially in the school context, three areas are quite relevant, including curriculum policy related to school education, instructional materials conducted by teachers, and curriculum operation practiced by students. As instructional materials, textbooks transmit curriculum orientation (Chen et al., 2019a; Chen, Goes, Treagust, Eilks, 2019b) and promote different perspectives of chemistry education.

At the same time, there is a body of research supporting the importance of textbooks in teaching and learning. As such, textbooks:

- indicate the intended curriculum (Khaddoor, Amoush & Eilks., 2017)
- are highly used (Wang et al., 2015) under a centralized education system in China (Zhang & Gao, 2013)
- provide indicators of common classroom practice (Devetak & Vogrinc, 2013)
- give cultural ideological values of a nation/group (Souza & Porto., 2012)
- stand as the medium linking chemistry with the learner (Lee, 2010), and represent a type of ideal and formal curriculum (Van Den Akker, 1998) for teachers to rely on (Stern & Roseman, 2004), and for students to depend on (Gkitzia, Salta & Tzougraki, 2011)
- are potential catalysts for improving science teaching and learning (Roseman, Stern & Koppal, 2010)
- reflect both publisher and authors' choices on explaining nature of science (Chiappetta & Fillman, 2007)

1.3 THE STATE OF TEXTBOOK ANALYSIS STUDIES

Textbooks are the bridge between official standards and the implemented curriculum (Cheng & Wong, 2014). If textbooks pass the official review of the according national Ministry of Education, the corresponding content and pedagogical instructions carried by textbooks represent the intended curriculum (Martínez-Gracia, Gil-Quýlez & Osada, 2003). This is especially true when teachers have a high usage of curricula-related instructional materials

(Wang, Tang, Zhang, Hu, Zhi & Wei, 2015) under the centralized education system in Mainland China (Zhang & Gao, 2013).

Devetak et al.'s study plays an important role in the scientific community when it comes to analyzing educational material resources. Devetak & Vogrinc (2013) summarized that educational material, i.e., textbooks, presents different concepts with the aid of text and visual (pictorial) components, which have an impact both on students' understanding of concepts and teachers' designing of lesson plans. They claimed that textbooks are one of the initial teaching aids from where students obtain knowledge. Both textual and visual (pictorial) materials are important teaching resources in the textbooks, and the content analysis of textbooks and other educational materials are suggested to be placed on three levels:

- general structure, e.g., number of pages, chapters, the length of the chapters, etc.
- textual material, e.g., instructions for practical work, explanations, summary of concepts, etc.
- pictorial material, e.g., photograph, drawing, graph, maps molecular structure, macroscopic, submicroscopic images, etc.

With regard to these three levels, Devetak and Vogrinc (2013) developed criteria and specific sub-criteria for science textbooks and other learning materials to evaluate the quality of these materials. Besides, they suggested that teachers could take it as references to evaluate practical teaching materials before they choose one. Beyond, they also stated that authors and publishers of textbooks should take these three levels into consideration when they develop learning materials. Next, they called for a partnership of the cooperation between researchers and curriculum developers in the pursue of high-quality textbooks (Devetak, Vogrinc & Glažar, 2010; Devetak & Vogrinc, 2013).

1.4 INFLUENCE AND DEVELOPMENT OF THE JOHNSTONE TRIANGLE: A SPECIAL VIEW ON REDOX REACTIONS

Another source of difficulties for chemistry teaching and learning was suggested by Johnstone (1991) who describes chemical understanding between three representational levels: the macroscopic, submicroscopic, and symbolic level (Figure 1). Later in 1993, Johnstone referred to the components of his so-called triangle as levels of thoughts.

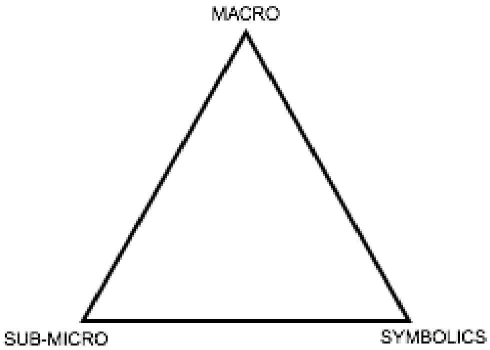


Figure 1. Jonestone's triangle (Jonestone, 1991, p. 78)

In Johnstone's 1993 work, he structured the mental model of reasoning about chemical phenomena with three components:

> *"[…] the macrochemistry of the tangible, edible, visible; the submicrochemistry of molecular, atomic and kinetic and the representational chemistry of symbols, stoichiometry, and mathematics"* (Johnstone, 1993, p. 702).

Furthermore, his 2006 study (Johnstone, 2006) pointed out that an overlapping between the three levels exists. Johnstone also claimed that the improper use of the three levels might be a reason for learning difficulties and suggested that "*concepts must be built from the macroscopic and gradually be enriched with submicroscopic and representational aspects*" (Johnstone, 2010, p. 28).

The idea of Johnstone's (1991) triangle of different levels of chemical representations shed light on chemistry education, and his idea was built upon over time, guiding the work of chemistry teachers, curricula and textbook writers (Talanquer, 2010). Specifically, Johnstone's (1991) model is widely used in chemistry education by researchers (Eilks et al., 2007).

The understanding of Johnstone's triangle aids the understanding of redox reactions. Students often have problems in understanding redox reactions at different representational levels (Osman & Lee, 2014) as well as linking the different levels of representation with each other (Eilks, Moellering & Valanides, 2007; Ramnarain & Joseph, 2012).

To address these issues, visual representations can help students create connections between different representational levels (Gilbert, 2006), especially to link the macroscopic with the submicroscopic and symbolic levels; proper visual representations are important factors to avoid further misunderstanding (Eilks, Witteck & Pietzner, 2012). It is suggested to use different levels of visual representations in secondary chemistry teaching and learning (Upahi & Ramnarain, 2019).

1.5 PRACTICAL WORK IN CHEMISTRY EDUCATION: LINKING TWO DOMAINS

As stated by Millar et al. (1999), practical work helps communicating information and ideas about the natural world to students. Stated by Abrahams and Millar (2008), science involves an interplay between ideas and observation. In 2011, motivated by Millar et al.'s work (1999), Abrahams demonstrated that practical work serves as a link of two domains of knowledge, namely the domain of objects and observables and the domain of ideas.

In a review of literature on practical work, it was described that practical work enables the achievement of effective science education by:

- linking learning science with doing science, providing collaboration, deliberation and communication with peers (Katchevich, Hofstein & Mamlok-Naaman, 2013)
- bringing science processes as well as fundamental knowledge to students which they are expected to understand (Abrahams & Reiss, 2012)
- assisting concept learning, which is positively viewed by students (Jones, Gott & Jarman, 2000)
- communicating information and ideas about the natural world (Millar, Le Maréchal & Tiberghien, 1999)

1.6 BRIDGING THE GAP: THE CHINESE CONTEXT

The difficulties in learning chemistry range from the nature of chemistry itself to human factors (Upahi & Ramnarain, 2019). As claimed by Devetak et al. (2010), a vast area of research indicates that the misconceptions of students' learning science concepts are caused by students' inaccurate reading of textbooks and the poor design of textbooks. Overall, there is growing support on the importance of textbooks in defining school subjects (Devetak & Vogrinc, 2013), presenting a curriculum outline (Aldahmash, Mansour, Alshamrani & Almohi, 2016), and aiding teaching and learning (Abd-El-Khalick, Waters & Le, 2008; Stern & Roseman, 2004). The vital position of textbooks in science education cannot be over-emphasized, which is in line with the research of Rusek and Vojíř (2019).

Abrahams and Millar (2008) described that teachers put more emphasis on the interpretation of scientific content, instead of student inquiry, and practical tasks were seen to be deficient in helping students to make these links. Hofstein (2017) recently asked for a deeper reflection of practical work because the implementation of practical work seemed not to have changed so much over the past years.

Aldahmash et al. (2016) analyzed textbooks from Saudi Arabia, where these textbooks are unanimously used by all teachers and students in school. Their data showed that a more teacher-centered approach exists in corresponding textbooks; however, more specific characteristics were not defined by them. Khaddoor et al.'s (2017) study about chemistry textbooks from seven Arab countries indicated that the influence of tradition and educational policy may be the main factor that contributes to the differences between Arabic textbooks, although they all have a similar cultural and economic background.

Under the centralized Chinese education system (Zhang & Gao, 2013), textbooks are widely used. Generally, teachers rely on them to transmit curriculum into instructional materials (Wang et al., 2015). Previous studies on Chinese chemistry textbooks mainly focus on the content (Wang & He, 2012) and less on the presentation from an intended curriculum perspective. In terms of general characteristics of the textbooks, to date, there is no transnational science textbook comparison of Chinese communities with a special focus towards curriculum orientation. Concerning content analysis, there is little research regarding redox reactions or practical work instructions as initial learning resources, and corresponding research with regard to Chinese context is even less present. Therefore, we anticipated to bridge this gap. Our studies aim at exploring how textbooks present the intended curriculum, with a special focus refer to redox reactions and practical work. However, we did not look at the operated curriculum. Results of our studies provide a general overview of the differences of intended curriculum identities within different Chinese communities.

2 RESEARCH BACKGROUND: A CHINESE PERSPECTIVE

2.1 BACKGROUND OF PR CHINA WITH A SPECIAL VIEW ON HONGKONG AND SHANGHAI

Chinese people account for one of the largest ethnics, and there are Chinese communities in many countries worldwide. Educational systems in Mainland China and Hong Kong take grade 10 as the first year of upper secondary education.

In China, curricula are centralized by nationally unified instructional materials. Over the past two decades, two rounds of upper secondary school chemistry curriculum standards have been released by the Ministry of Education. One was in 2003 (Wang, 2010), which led to an increasing number of studies on learning of science, e.g., science teaching (Hu & Wang, 2005) and scientific inquiry (Ding, 2010); the other upper secondary school chemistry curriculum standard was released in 2017 (Ministry of Education, 2017), and the corresponding textbooks were suggested to conduct trials in several provinces and will be fully applied nationally in the fall semester of 2022 (Ministry of Education, 2018).

In our study, a special focus refers to Hongkong, because it is a special administrative region of China influenced by the United Kingdom during the colonial time; the other focus is Shanghai because Shanghai is one of the most developed and industrialized cities in China, and it is one of the trial provinces/municipalities for curriculum reform.

2.2 BACKGROUND OF TAIWAN

The retrospect of curriculum study in Taiwan dates back to 1949, when foreign curriculum studies migrated and re-conceptualized into Taiwan (Hwang & Chang, 2003). Ever after that, basic education in Taiwan developed and evolved from transformation to innovation (Liu, 2010). Also, science education started to gain more attention (Guo & Chiu, 2016). Hence, more emphases are placed on science education by the government. Compulsory education in Taiwan consists of 3 levels, e.g., grade 1-6 forming the elementary level, grade 7-9 forming the lower secondary level, and grade 10-12 forming the upper secondary level (Chiu, 2016). Taiwan has been following the development of science curricula since the 1970s (Chen et al, 2019a), and science educators actively contribute to the international science education community since then (Chiu, 2016). With the openness of Taiwan, foreign languages are becoming more prominent, and dialects are developing to represent the localization. However, Chinese is still the official language mainly taught by teachers (Chou & Ching, 2012) in public schools.

2.3 BACKGROUND OF MALAYSIA

Malaysia is a multi-ethnic based community, with 69.1% Malay, 23.0% Chinese, 6.9% Indians, and 1.0% others by official data released by Department of Statistics Malaysia (2018). In early 19^{th} century, when Chinese that mainly came from the southern areas of China (e.g., Hainan province, Fujian province, Hunan province etc.) immigrated to Malaya (Vivien, 2018), Chinese schools were founded (Raman & Sua, 2015). To date, Malaysia has a comprehensive Chinese education (Xia, Yang & Lee, 2018) from primary school to college (Xu & Xu, 2016). To maintain Chinese education in Malaysia, an associated community named Dong Jiao Zong which is made up of the United Chinese School Committees' Association (UCSCA or Dong Zong) and the United Chinese School Teachers' Association (UCSTA or Jiao Zong) (Dong Zong, 2018) plays an important role (Raman & Sua, 2015). The Chinese sector in Malaysia operates its own educational system and schools, teaching students mainly in Chinese (Karpudewan & Chua, 2016). Independent Chinese Secondary Schools (ICSSs) were segregated by using Chinese as the main instructional medium (Vivien, 2018). Rules and regulations in ICSSs are different from those in the governmental schools. Students who attend ICSSs have an additional academic year of upper secondary school, similar to the education system in China. The Malaysian upper secondary chemistry textbook (Upper Secondary School Chemistry) is edited according to the chemistry syllabus for secondary schools which is hosted by the Malaysia Independent Chinese Secondary School Working Committee (MICSS).

3 SHORT DESCRIPTION OF THE STUDIES

3.1 THE ANALYSIS OF CURRICULUM ORIENTATION AND EMPHASIS IN SELECTED TEXTBOOKS (PAPER 1)

This section introduces the paper entitled "An Analysis of the Orientation and Emphasis of Intended Grade-10 Chemistry Curricula as Represented in Textbooks from Different Chinese Communities".

3.1.1 Sample

The sample in this study consists of seven sets of grade 10 chemistry textbooks (details in Table 1), including four sets from PR China (CN1, CN2, CN3, and CN4); two sets from Taiwan (TW1, TW2); one from Malaysia (MY).

3.1.2 Method

The textbooks were qualitatively analyzed in a cyclical approach. An inductive analyzing approach was used, which is inspired by Khaddoor et al. (2017). A memo-approach was used to capture links, look for relationships, ask questions about the collective data, and identify the main characteristics for each of the sample. Criteria are briefly listed below (description of sub-criteria is left out in this section).

a. criteria for the first-round analysis were adapted from Devetak & Vogrinc (2013), including: general structure; textual material; numbers of visual representations.
b. criteria for developing the final categories were inspired by Khaddoor et al. (2017), including: content representation; visual representation; practical work and activities; tasks and assessment; modern issues in chemistry; curriculum emphasis; curriculum orientation.
c. coding grid for analyzing each category:
   0: corresponding feature is absent or almost completely absent in the book
   1: corresponding feature is present in the book, but only in certain places and plays a minor role in the appearance and character of the book
   2: The corresponding feature is present throughout the book, but it does not play a central role in the appearance and character of the book
   3: corresponding feature is present throughout the book and plays a central role in the appearance and character of the book

Table 1. Overview of the textbooks

Community	Chief Editor	Title	Publisher	Version	Publication Date	Edition
People's Republic of China	Xinqi Song	Chemistry 1	PEP	Renjiao Edition	March 2007	3rd
	Xinqi Song	Chemistry 2	PEP	Renjiao Edition	March 2007	3rd
	Zuhao Wang	Chemistry 1	JEP	Sujiao Edition	June 2014	6th
	Zuhao Wang	Chemistry 2	JEP	Sujiao Edition	June 2015	6th
	Lei Wang	Chemistry 1	SSTP1	Luke Edition	July 2007	3rd
	Lei Wang	Chemistry 2	SSTP1	Luke Edition	July 2007	3rd
	Zipeng Yao	Chemistry	SSTP2	Shangke Edition	July 2007	1st
	Zipeng Yao	Chemistry	SSTP2	Shangke Edition	January 2007	1st
Taiwan	Ded-Shih Huang	Basic Chemistry 1	LTC	Lungteng Edition	March 2010	1st
	Ming-Chang P. Yeh	Basic Chemsitry 1	Nan I	Nan I Edition	April 2010	1st
Malaysia	MICSS	Upper Secondary School Chemistry	Dong Zong	Malaysia	November 1996	1st

3.1.3 Main results

Data (see Table 2 and Table 3) indicates a wide range of different curriculum emphases and orientations in the seven selected textbooks. Intended curricula which are driven by application of chemistry, relevant issues and processes (Holman, 1987) can be found in textbooks from Taiwan and to a certain extent in some of the textbooks from PR China, but they are deficient in the case of Malaysia. Malaysian textbooks seem to convey a traditional curriculum and take fundamental chemistry as the prominent role. Comparing to Malaysian textbooks, indications show that the textbooks from the PR China align the learning of chemistry more with everyday life contexts and societal views on the applications of chemistry.

Table 2. Rating of certain characteristics of the textbooks

Textbook	Meaningful textual contextualization of content	Meaningful and rich use of visual representations	Suggestion for practical work	Use of tasks and assessment	Appearance of modern issues
CN1	medium	medium	high	medium	medium
CN2	medium	medium	high	medium	medium
CN3	medium	medium	medium	medium	medium
CN4	medium	medium	medium	medium	low
TW1	high	high	low	high	high
TW2	high	high	medium	high	medium
MY	low	low	low	medium	low

3.1.4 Discussion and conclusion

Larger differences exist between the textbooks from different Chinese communities than within them. This likely reason is that the textbooks in this study are written under the corresponding guideline of different official curriculum standards released by corresponding Ministry of Education. This is especially the case for the Taiwanese books, both Taiwanese textbooks (TW1 and TW2) share approximately the same amount of pages as well as similar topics.

Table 3. Prevalent curriculum emphasis and curriculum orientations

Textbook	Main curriculum emphasis	Use of orientations of the curriculum operated in the book
CN1	FC	● structure of the discipline (medium) ● everyday life (medium) ● history of chemistry (low) ● SSI (low) ● industry and technology (low) ● environmental (low)
CN2	FC	● everyday life (high) ● structure of the discipline (medium) ● industry and technology (medium) ● history of chemistry (low) ● SSI (low) ● environmental (low)
CN3	FC	● SSI (high) ● structure of the discipline (medium) ● everyday life (medium) ● industry and technology (medium) ● history of chemistry (low) ● environmental (low)
CN4	FC	● structure of the discipline (high) ● history of chemistry (high) ● everyday life (low) ● industry and technology (low) ● environmental (low)
TW1	CTS	● everyday life (high) ● history of chemistry (high) ● SSI (high) ● industry and technology (medium) ● structure of the discipline (low) ● environmental (low)
TW2	CTS	● everyday life (high)

		• history of chemistry (high) • SSI (high) • environmental (medium) • industry and technology (low) • structure of the discipline (low)
MY	FC	• structure of the discipline (high) • history of chemistry (low) • everyday life (low) • environmental (low)

Textbooks from Taiwan seem to fit what modern research prescribes for chemistry curricula: learning embedded in meaningful contexts (Eilks et al., 2013) with rich illustrations (Devetak & Vogrinc, 2013). The textbooks from the People's Republic of China show indications of a beginning use of context-based as well as societal-oriented chemistry education. The same could not be indicated by the Chinese minority textbooks from Malaysia yet.

As we mentioned above, Taiwan actively participates and contributes to the international science education community (Chiu, 2016) since the 1970s. Taiwan has been closely following the development of science curriculum in Western countries, which might have influenced the Taiwanese curriculum later. People's Republic of China started this process later. But in the last few decades, science education researchers from the People's Republic of China have also made great efforts in the internationalization of science education research (Liu, Liang & Liu, 2012). The integration of a more modern science curriculum into the chemistry curriculum might inspire Chinese chemistry education in Malaysia to shift to a more context-based and societal-oriented way.

3.2 The analysis of visual representation of redox reactions in selected textbooks (Paper 2)

This section presents key ideas of the paper entitled "An Analysis of the Visual Representation of Redox Reactions in Secondary Chemistry Textbooks from Different Chinese Communities".

3.2.1 Sample

The sample in this study consists of seven sets of upper secondary chemistry textbooks (details in Table 4):

a. five sets from PR China: CN1, CN2, CN3, CN4 from Mainland China, with a special view on Hongkong textbook: HK
b. one set from Taiwan: TW
c. one set from Malaysia: MY

Table 4. Information of the textbooks which include redox reactions content

	Reference
CN1	Song, X. Q. (Ed.). (2007). Chemistry 1 (3rd ed.). Beijing: People Education Press.
	Song, X. Q. (Ed.). (2007). Chemical reaction mechanism (3rd ed.). Beijing: People Education Press.
CN2	Wang, L. (Ed.). (2007a). Chemistry 1 (3rd ed.). Shandong: Shandong Science and Technology Press.
	Wang, L. (Ed.). (2011). Chemical reaction mechanisms (4th ed.). Shandong: Shandong Science and Technology Press.
CN3	Wang, Z. H. (2014). Chemistry 1 (6th ed.). Nanjing: Jiangsu Education Press.
	Wang, Z. H. (2014). Chemical reaction mechanisms (5th ed.). Nanjing: Jiangsu Education Press.
CN4	Yao, Z. P. (Ed.). (2007). Chemistry (Volume 1) (1st ed.). Shanghai: Shanghai Scientific and Technical Publishers.
	Yao, Z. P. (Ed.). (2008). Chemistry (Volume 3) (1st ed.). Shanghai: Shanghai Scientific and Technical Publishers.
HK	Zhong, H. M. (2009). New 21st Century Chemistry 2B (1st ed.). Hong Kong: Jing Kung Educational Press.
TW	Huang, D. S. (Ed.). (2010). Basic Chemistry 1 (1st ed.). Taiwan: LungTeng Culture.
	Huang, D. S. (Ed.). (2011). Basic Chemistry 2 (1st ed.). Taiwan: LungTeng Culture.
	Huang, D. S. (Ed.). (2012). Selective Chemistry 1 (1st ed.). Taiwan: LungTeng Culture.
MY	MICSS (1996). Upper secondary school chemistry (volume 1) (1st ed.). Malaysia: United Chinese School Committees' Association of Malaysia.
	MICSS (1997). Upper secondary school chemistry (volume 2) (1st ed.). Malaysia: United Chinese School Committees' Association of Malaysia.

3.2.2 Method

This study focused on visual representations of redox reactions in the mentioned Chinese textbooks. Specific criteria were employed as our instrument and revised accordingly after several rounds of analysis. Criteria for each stage are listed below (description of sub-criteria are left out in this section).

To explore the representational levels of the redox reactions, a category from Gkitzia et al. (2011) was adapted and further applied in this study. The criteria looked at all levels of visual representations:

a. levels of representation
b. degree of correlation between representations
c. relation to text

To figure out the function of the images in relation to the text, a category was modified based on Carney and Levin's (2002) study from the following aspects:

a. decorative
b. organizational
c. interpretational

To explore the orientation of the intended curriculum of the textbooks, a category was adapted from Eilks et al. (2013):

a. structure of the discipline orientation
b. history of science orientation
c. everyday life orientation
d. environmental orientation
e. industry and technology orientation
f. socio-scientific issues orientation

3.2.3 Main results

A total of 346 visual representations related to redox reactions were identified in the textbooks from PR China, Taiwan, and Malaysia. Data shows that the differences in the textbooks between different Chinese communities are larger than the differences within the communities (details in Figure 2). Figure 2 shows that representations on the macroscopic (maximum 68%), symbolic (maximum 45%), and macro-symbolic (maximum 50%) levels are more prominent than the other levels of representation. The analysis indicates that all textbooks show a high usage of macro representations, except the Shanghai and Malaysian textbooks (Figure 2).

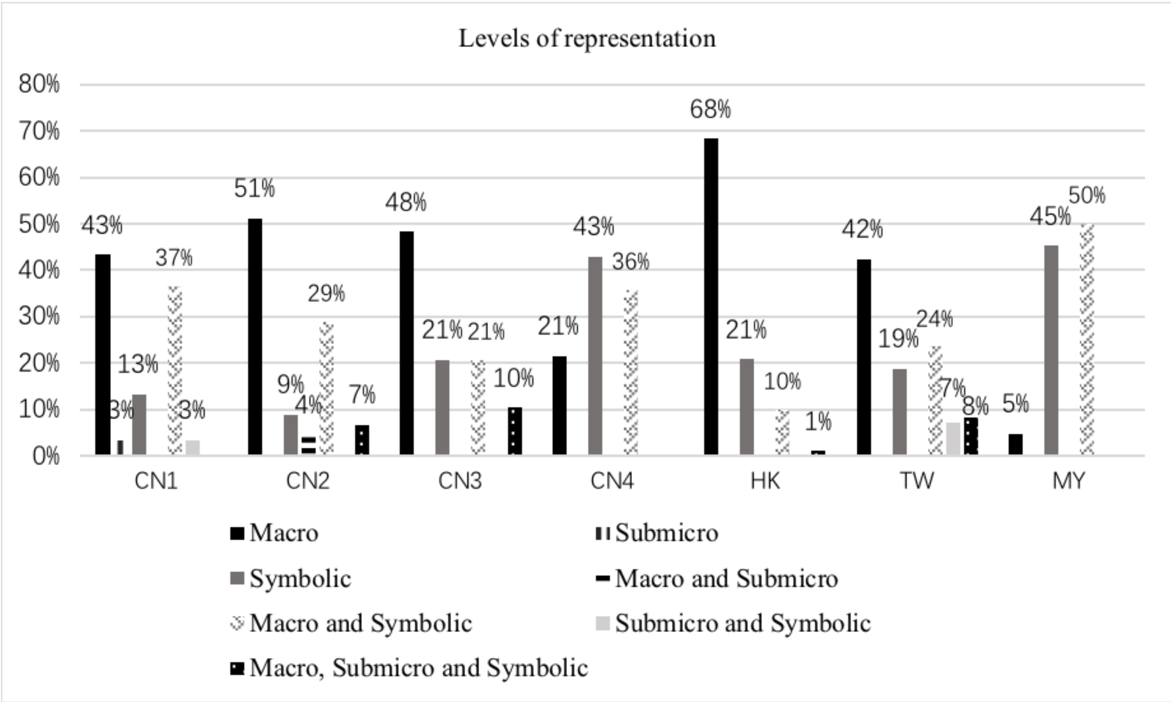


Figure 2. Distribution of different levels of visual representations in the textbooks. (Note: due to the numerical value limit, the sum value of CN1 is 99%).

Degree of Correlation between Representations

Data shows that textbooks from Hongkong, Taiwan and one from the PR of China (CN2) contain visual representations which are insufficiently linked, but these numbers are small (average 10%) (Figure 3).

Relation to Text

In terms of the relation between pictures and text, most of the textbooks show a high relation to the text (Figure 4), with concrete references in the text and captions connecting the pictures with the text.

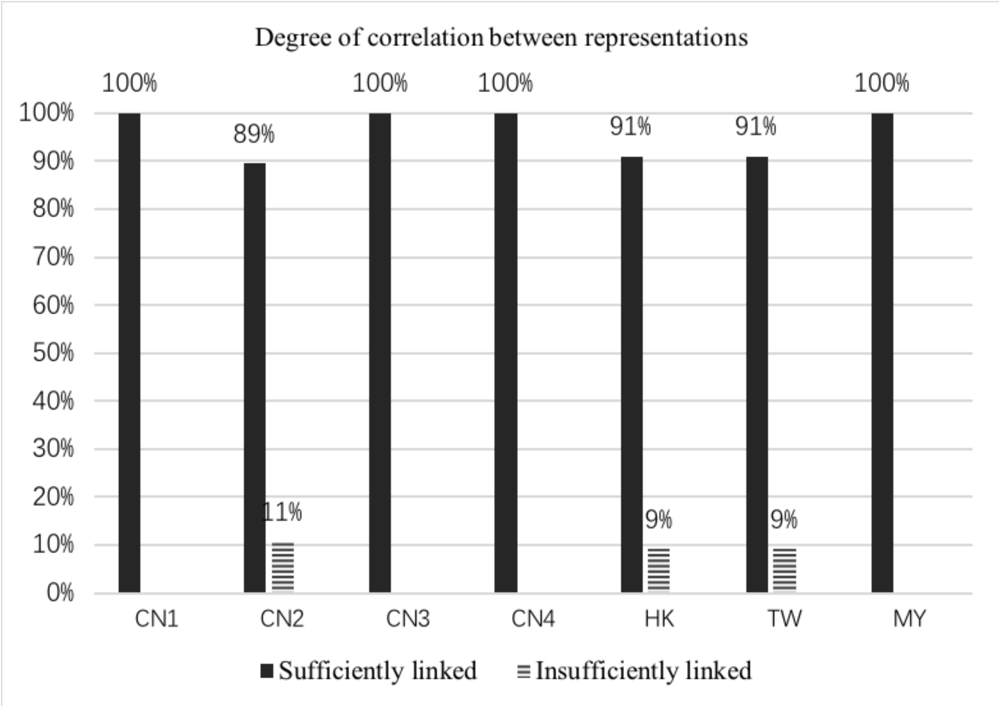


Figure 3. Degree of correlation between multiple representations in the textbooks

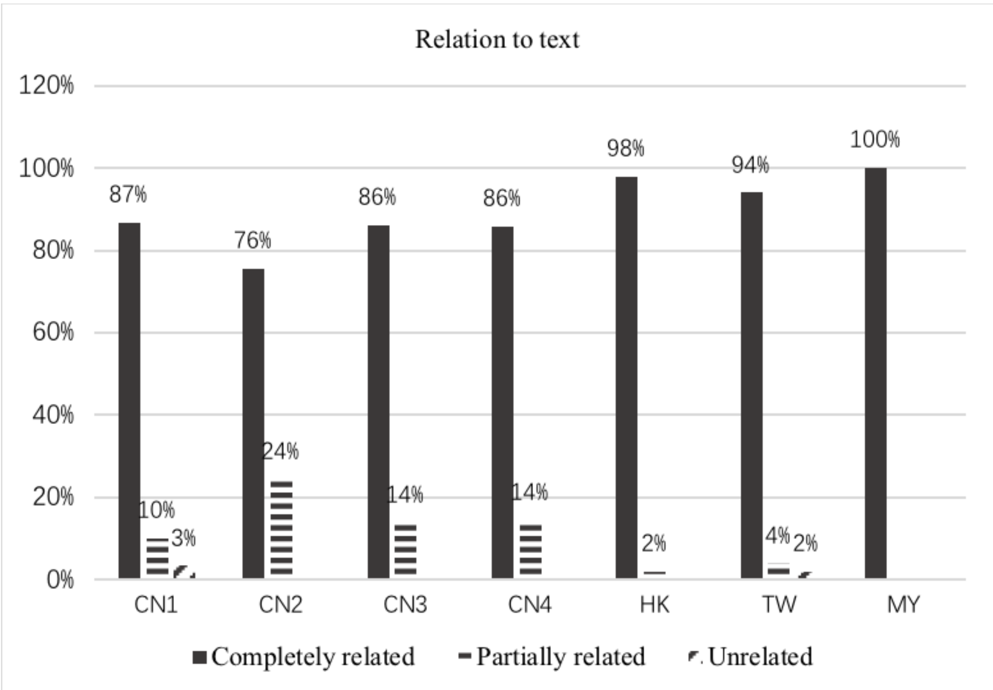


Figure 4. Degree of relation to text in the textbooks

Function of Images

In terms of the function of images, decorative, organizational, and interpretational images appear in all the textbooks (Figure 5). It is notable that the Shanghai textbook (CN4) has the highest use of organizational images. The Malaysian textbook has the highest rate of interpretational images and the textbook from Hongkong as well as one of the textbooks from the PR of China (CN2) have the highest proportion of decorative images.

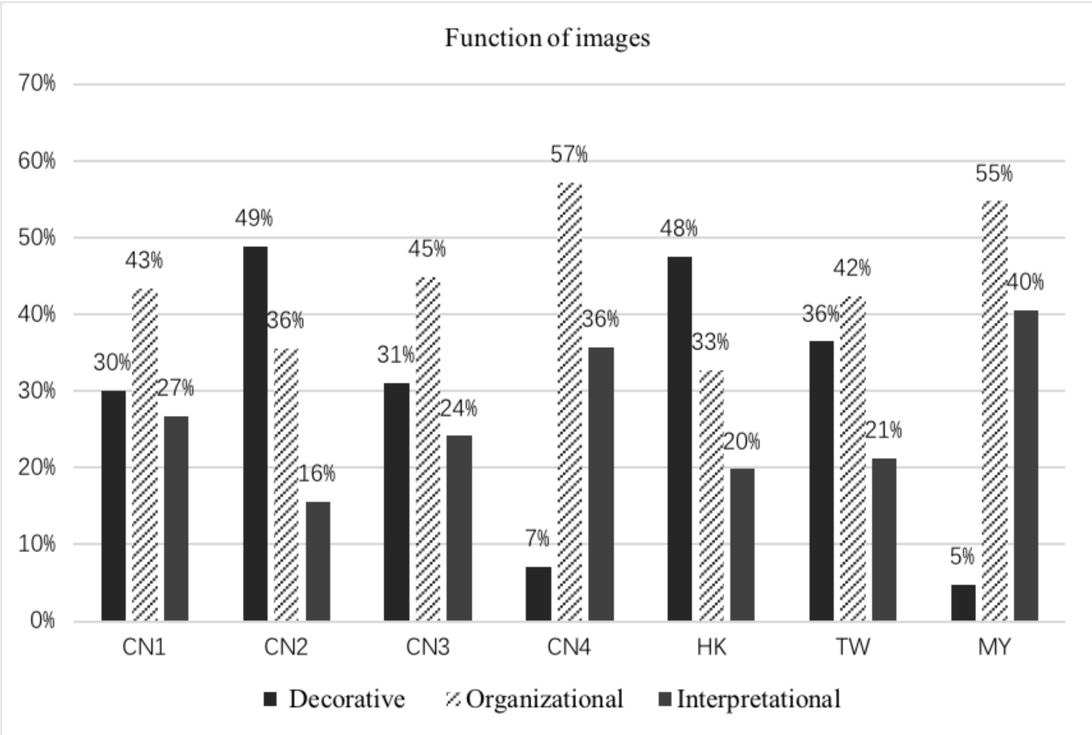


Figure 5. Degree of the function of images in the textbooks. (Note: due to the numerical value limit, the sum value of HK and CN2 are both 101% and the sum value of TW is 99%).

Curriculum Orientation

The results indicate that structure of the discipline orientation is prominent in all the mentioned textbooks (Figure 6), especially in the Shanghai (CN4) and Malaysia sample (MY).

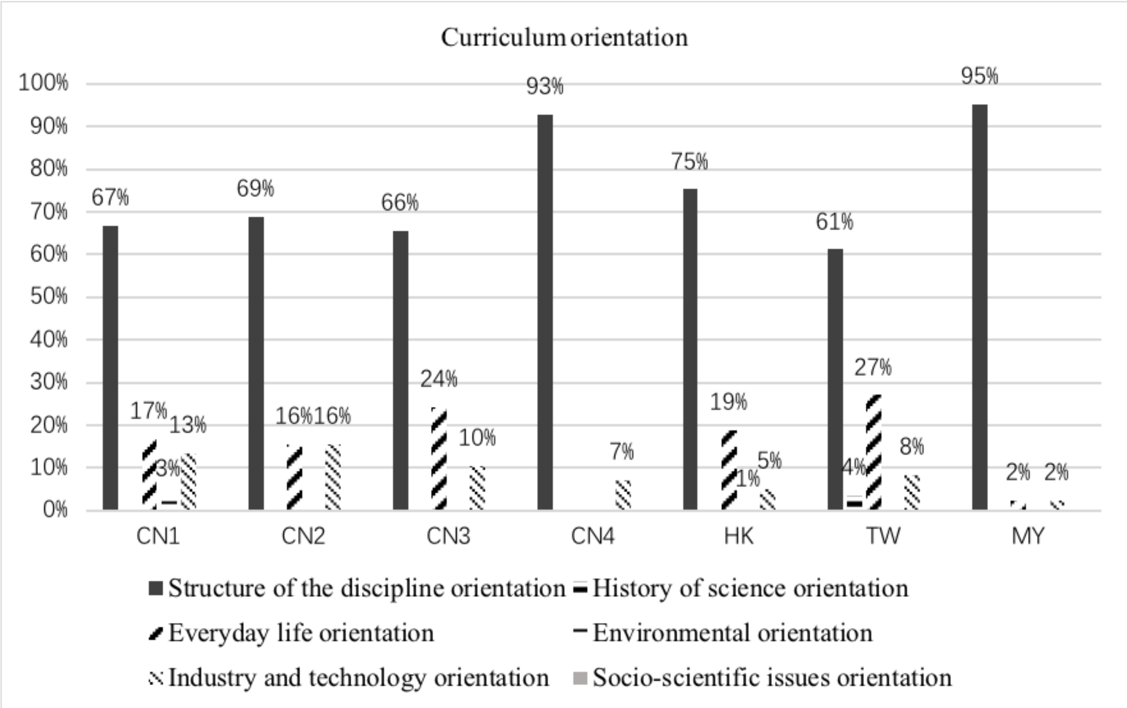


Figure 6. Degree of curriculum orientation in the textbooks. (Note: due to the numerical value limit, the sum value of CN2 is 101% and the sum value of MY is 99%).

3.2.4 Discussion and conclusion

All the textbooks lay a stronger emphasis on the structure of the discipline. Considering the frequencies and levels of visual representations, this study shows that textbooks from the People's Republic of China mostly focus on the macro and macro-symbolic levels and some aspects of everyday life as well as industry and technology. Textbooks from Taiwan use multiple macroscopic-submicroscopic-symbolic representations to illustrate redox reactions. The textbook from Hongkong shows a strong structure of discipline orientation with mostly macro level representations. The textbook from Malaysia follows a strong structure of discipline orientation with limited visual support.

The purpose of the current study is to describe how chemistry textbooks from different Chinese communities present redox reactions. Concerning the distribution of the levels of representation, macroscopic representation is more dominant than other visual representations. This finding is very different from recently reported findings on chemistry textbooks from Africa. For instance, Upahi and Ramnarain (2019) reported a dominance of symbolic representations for the textbooks in Nigeria. Treagust et al. (2003) stated that macroscopic representation lays the foundation of chemistry learning, but macroscopic understanding depends on the explanation of the submicroscopic level. In this case, combined representations could contribute to learner's understanding. Combined visual representations are, however, limited in the sample of textbooks in this study. But the degree of correlation between the representational levels is high (above 89%). Russell et al. (1997) claimed that the use of simultaneous macroscopic, submicroscopic and symbolic representations can help to reduce alternative conceptions in learning chemistry.

3.3 THE ANALYSIS OF REPRESENTATION OF PRACTICAL WORK IN SELECTED TEXTBOOKS (PAPER 3)

This section presents key ideas of the paper entitled "An Analysis of the Representation of Practical Work in Secondary Chemistry Textbooks from Different Chinese Communities".

3.3.1 Sample

The study investigates the intended curriculum with respect to practical work of grade 10 chemistry textbooks and associated experimental workbooks from different Chinese communities: People's Republic of China, Taiwan and Malaysia (details in Table 5). The sample includes:

a. four sets from PR of China: CN1, CN2, CN3 and CN4
b. two sets from Taiwan: TW1 and TW2
c. one set from Malaysia: MY

Table 5. Overview of the textbooks in this study

Textbook	Reference
CN1	Song, X. Q. (ed.). (2007). Chemistry 1 (3rd ed.). Beijing: People Education Press.
	Song, X. Q. (ed.). (2007). Chemistry 2 (3rd ed.). Beijing: People Education Press.
	Song, X. Q. (ed.). (2007). Chemistry Experiment (4rd ed.). Beijing: People Education Press.
CN2	Wang, L. (ed.). (2007). Chemistry 1 (3rd ed.). Shandong: Shandong Science and Technology Press.
	Wang, L. (ed.). (2007). Chemistry 2 (3rd ed.). Shandong: Shandong Science and Technology Press.

	Wang, L. (ed.). (2007). Chemistry Experiment (2nd ed.). Shandong: Shandong Science and Technology Press.
CN3	Wang, Z. H. (2014). Chemistry 1 (6th ed.). Nanjing: Jiangsu Education Press. Wang, Z. H. (2015). Chemistry 2 (6th ed.). Nanjing: Jiangsu Education Press. Wang, Z. H. (2009). Chemistry Experiment (2nd ed.). Nanjing: Jiangsu Education Press.
CN4	Yao, Z. P. (ed.). (2007). Chemistry (Volume 1) (1st ed.). Shanghai: Shanghai Scientific and Technical Publishers. Yao, Z. P. (ed.). (2007). Chemistry (Volume 2) (1st ed.). Shanghai: Shanghai Scientific and Technical Publishers. Yao, Z. P. (ed.). (2007). Chemistry Workbook (Volume 1) (1st ed.). Shanghai: Shanghai Scientific and Technical Publishers. Yao, Z. P. (ed.). (2007). Chemistry Workbook (Volume 2) (1st ed.). Shanghai: Shanghai Scientific and Technical Publishers.
TW1	Huang, D. S. (ed.). (2010). Basic Chemistry 1 (1st ed.). Taiwan: LungTeng Culture. Huang, D. S. (ed.). (2010). Basic Chemistry 1-Experimental Manuscript (1st ed.). Taiwan: LungTeng Culture.
TW2	Yeh, M.C. P. (ed.). (2010). Basic Chemistry 1 (1st ed.). Taiwan: Nan I Book Enterprise. Yeh, M.C. P. (ed.). (2011). Basic Chemistry 1- Experimental Manuscript (1st ed.). Taiwan: Nan I Book Enterprise.
MY	Wang, C. K. (2017). Upper secondary school chemistry (Volume 1) (1st ed.). Malaysia: United Chinese School Committees' Association of Malaysia. Wang, C. K., Lin, Y. (2018). Chemistry Experiment Manuscript (Volume 1) (1st ed.). Malaysia: United Chinese School Committees' Association of Malaysia.

3.3.2 Method

To explore the general characteristics of the mentioned textbooks, all textbooks were checked page by page. The representation of practical work was collected. The collection includes suggestions for practical work, descriptions of laboratory process, and sketches/pictures showing examples of practical work. Pilot trial analysis was performed until the final categories (Table 6) sufficiently matched the data.

Table 6. Basic overview of features of practical work (adapted from Millar et al., 1999)

	Practical Work Concerns
C1	Type of learning
	C1.1 Operating a given experiment
	C1.2 Picture/sketch for illustrations
	C1.3 Picture/sketch for illustration of a laboratory technique
	C1.4 Scientific investigation with an open approach
C2	Intended learning outcomes
	C2.1 Identify objects and phenomena and become familiar with them
	C2.2 Learn fact (s)
	C2.3 Learn concept
	C2.4 Learn a relationship
	C2.5 Learn a theory/model with reference to the sub-microscopic level
C3	Inquiry level of practical works
	C3.1 Confirmatory learning without hypothesis
	C3.2 Confirmatory inquiry learning
	C3.3 Structured inquiry learning
	C3.4 Guided inquiry learning
	C3.5 Open inquiry learning
C4	Students’ engagement
	C4.1 Context
	C4.2 Performance
	C4.3 Application

3.3.3 Main results

A total number of 508 practical activities appears in the mentioned textbooks, 98 from CN1 textbook, 75 from CN2 textbook, 70 from CN3 textbook, 61 from CN4 textbook, 43 from TW1 textbook, 45 from TW2 textbook and 116 from MY textbook. Data were collected and analyzed based on the categories mentioned in Table 6 (details can be found in the full paper attached in Appendix).

We find similarities and differences in the mentioned textbooks from different Chinese communities. One significant feature is that the larger differences in textbooks exist between different Chinese regions than within them, which is also found in our former study related to redox reactions (Chen et al., 2019b).

C1: Type of learning

In terms of type of learning presented by textbooks, a big variety exists (Figure 7). Most of the textbooks do not give clear instructions of the operation of practical work, whether they are designed to be operated by students or by teachers. Figure 7 shows that most of the textbooks look at operating a given experiment except the Taiwanese textbooks; the Taiwanese textbooks have more picture/sketch illustration. Scientific investigation with an open approach appears in textbooks from China and Malaysia, ranking from 5 (CN4) to 23 (CN1).

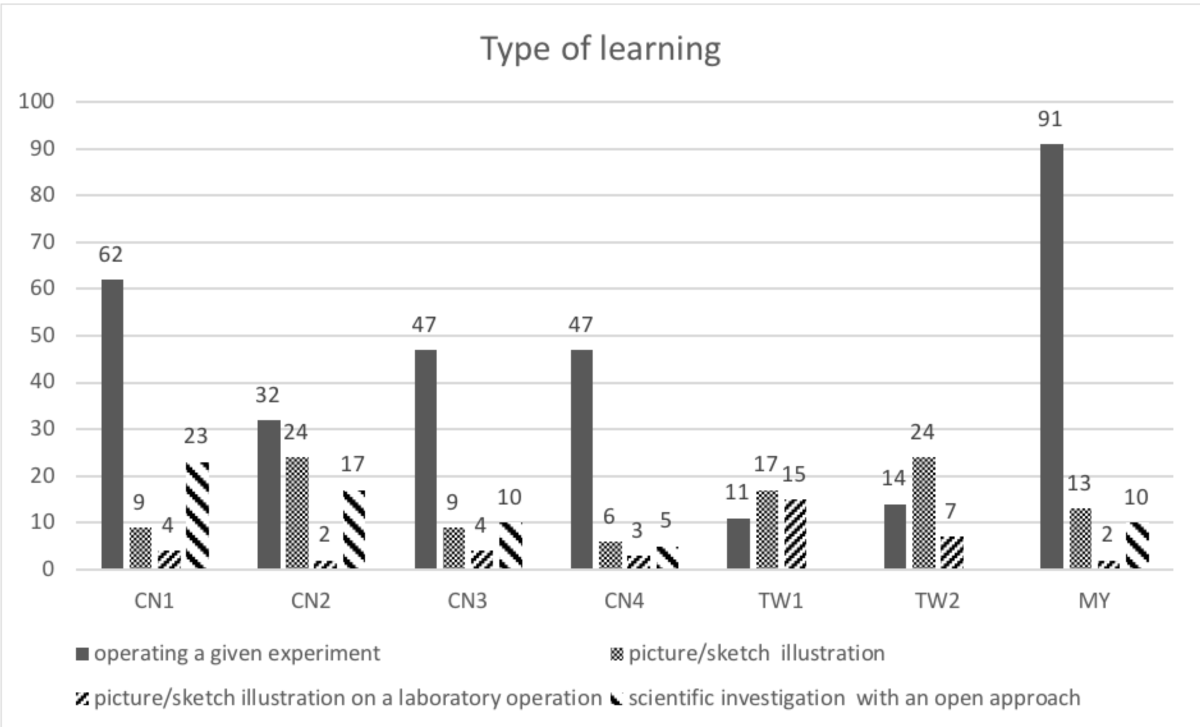


Figure 7. Type of learning of the textbooks (actual numbers of codings have been counted)

C2: Intended learning outcomes

In the category of intended learning outcomes of practical work, we can see that a trend of learning fact(s) (Figure 8) is quite dominant in textbooks from China and Malaysia (CN1, CN2, CN3, CN4 & MY). Next, data shows that Taiwanese textbooks contain lower numbers of figures overall, and the identification of chemical objects and learning laboratory techniques are higher than learn fact(s). The proportion of learn concept in all textbooks ranks from roughly 20% to 30%. The learning of a theory/model mainly focuses on the sub-microscopic level, and this kind of practical work appears in 7 out of 508 codes in the whole sample.

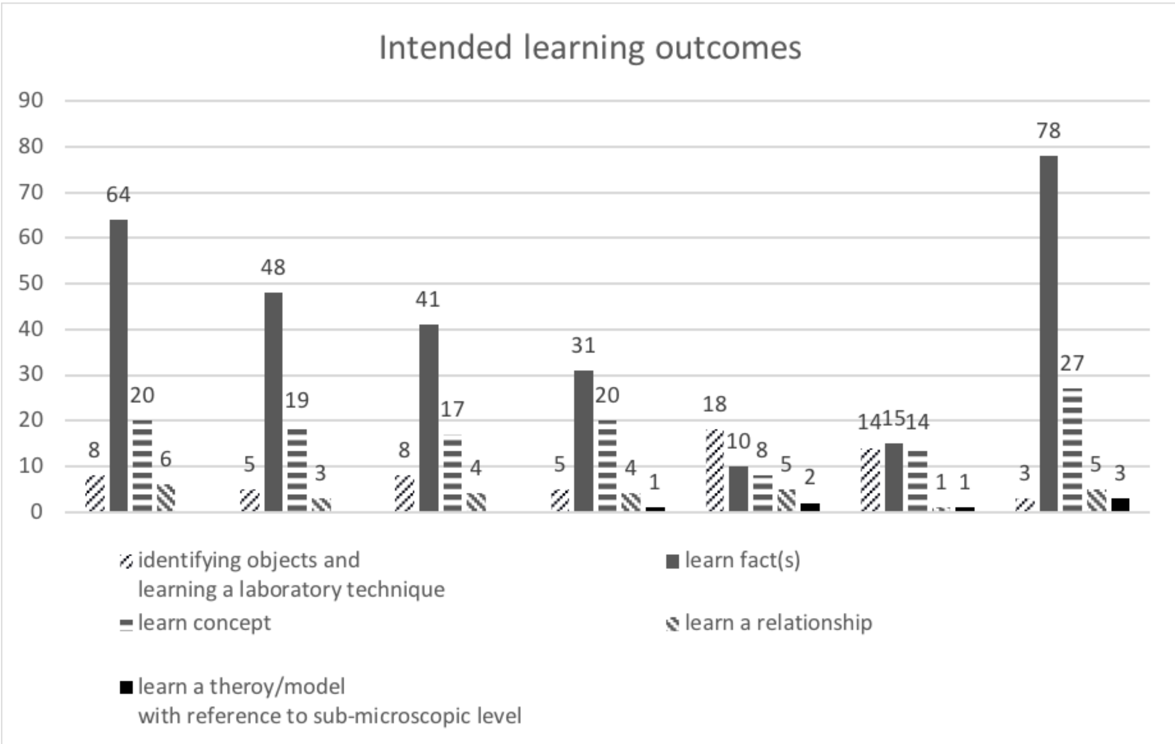


Figure 8. Intended learning outcomes of the textbooks (actual numbers of codings have been counted).

C3: Inquiry level of practical work

Looking at the data in terms of inquiry level of practical work, we find that textbooks from Mainland China and Malaysia suggest more structured learning and a certain proportion of guided inquiry learning (Figure 9). In terms of Taiwan, these textbooks refer more to practical work by pictures and sketches for illustration at the observation level. Confirmatory learning without hypotheses mainly refers to illustrating the proper use of the apparatus and essential operation processes such as filtration, distillation and so on. Open learning appears in only one of the textbooks from China (CN1) and is presented in an optional module in the experimental workbook.

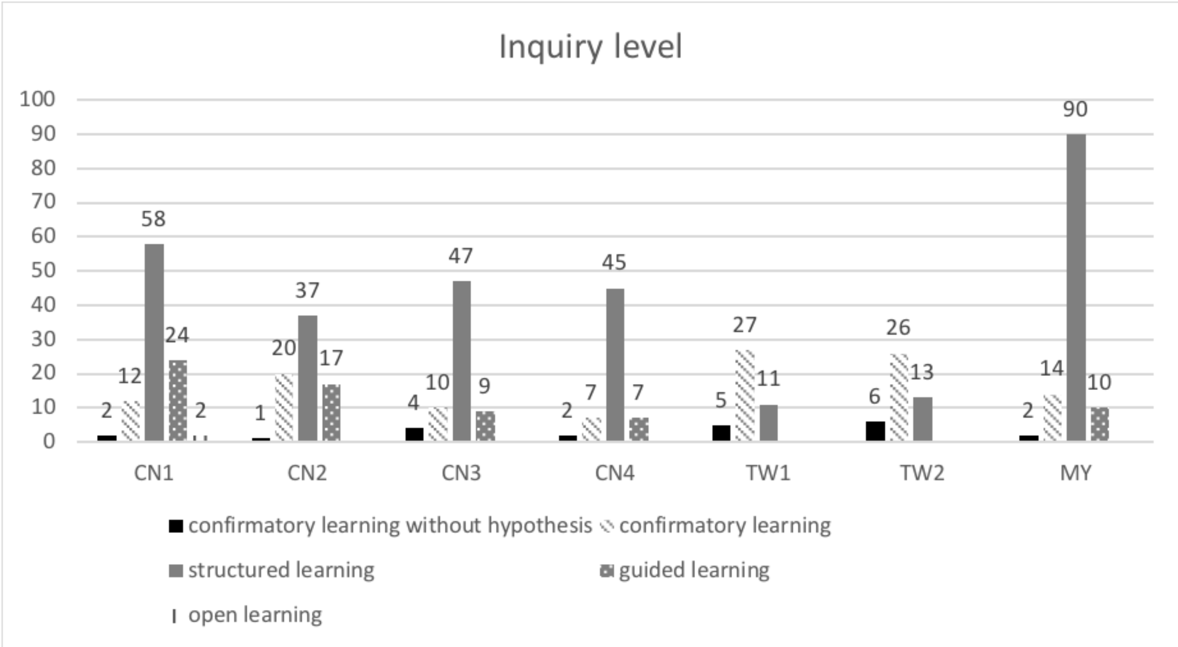


Figure 9. Inquiry level of the textbooks (actual numbers of codings have been counted)

C4: Students' engagement with practical work

Concerning students' engagement with practical work, the textbooks from Mainland China and Malaysia contain practical work with a detailed instruction and use pictures or sketches to support learning (Figure 10). The highest number of detailed operation processes can be found in the textbook from Malaysia, and the Malaysian textbook asks students' action on chemical equation writing quite often. In Taiwan, there are much less detailed operation processes, while practical work with pictures and sketches are dominate. All other categories play a minor role.

It is also notable that hands-on activities are more often explicitly suggested in the textbooks from Mainland China and Malaysia than in the textbooks from Taiwan (Figure 11). Figure 12 shows that all practical activities in the mentioned textbooks are assigned with corresponding extra tasks asking students to practice on a similar learning-into-application context. For example, after students learn about the zinc-copper galvanic cell, they are given extra tasks and asked to build a fruit battery.

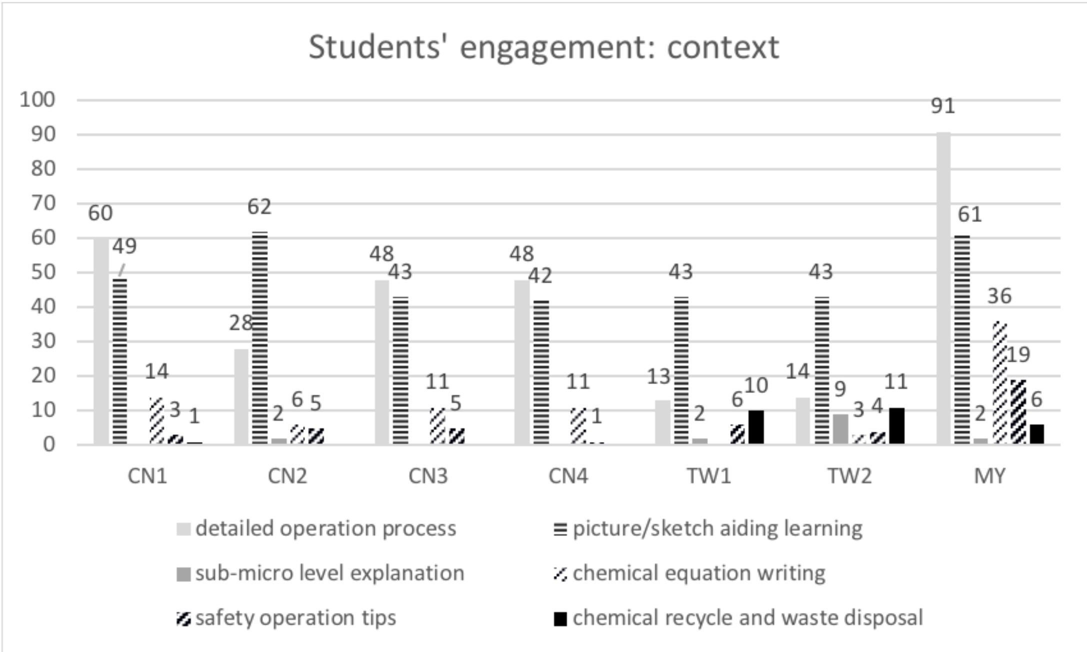


Figure 10. Students' engagement: context presentation by different textbooks (actual numbers of codings have been counted)

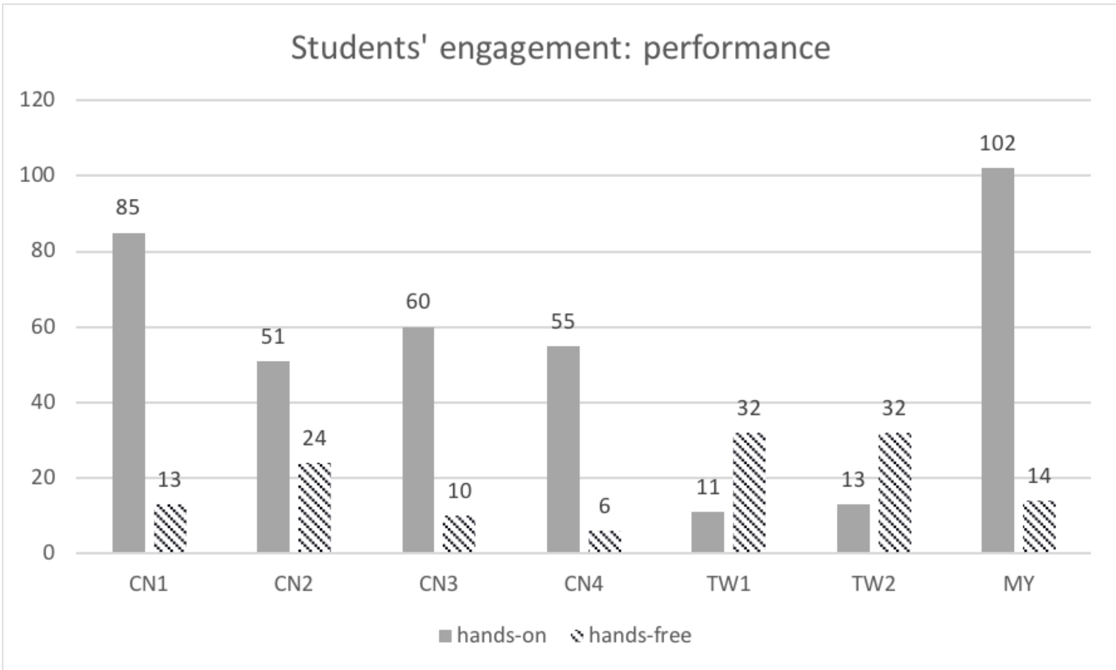


Figure 11. Students' engagement: performance presentation by different textbooks (actual numbers of codings have been counted)

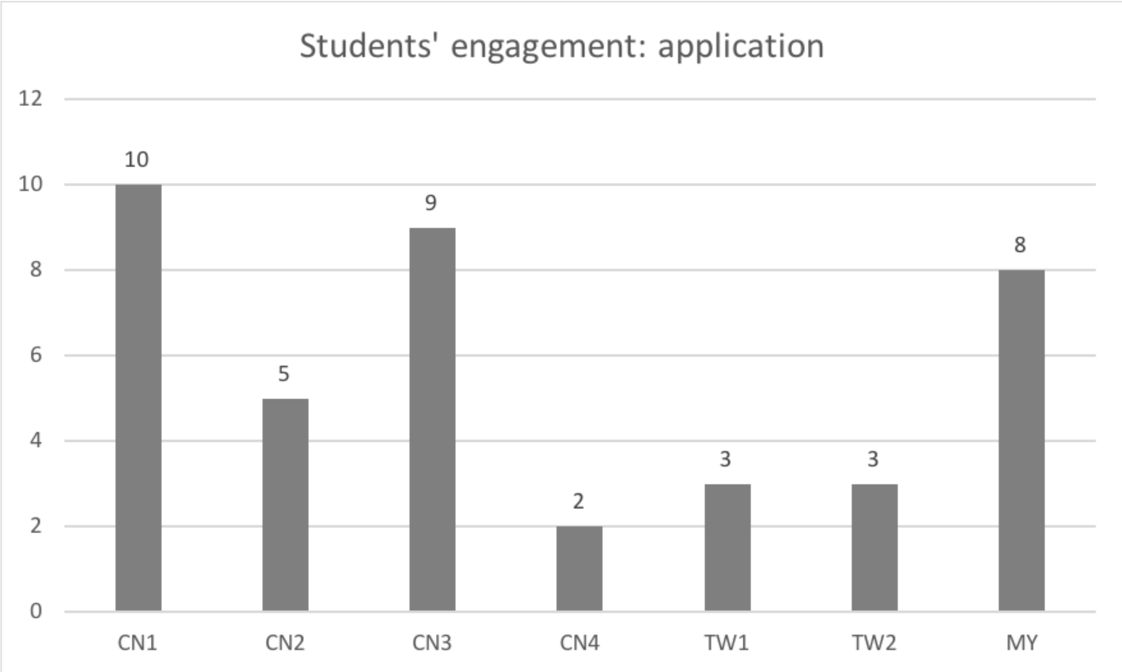


Figure 12. Students' engagement: application presentation by different textbooks (actual numbers of codings have been counted)

3.3.4 Discussion and conclusion

The purpose of this study is to examine the representation of practical work in grade 10 chemistry textbooks and associated experimental workbooks, in light of the four domains (type of learning; intended learning outcomes; inquiry level; students' engagement) to explore the way how practical work is linking observable variables to ideas.

In terms of the first category, type of learning, results indicate that a general trend of the operation of a given experiments takes up a higher proportion than other tasks. The intended learning outcomes mostly focus on learning fact(s), with Malaysian textbooks taking the highest proportion of learning fact(s). Identifying processes and learning concepts are also assigned with a rather high proportion than learn a relationship or learn theory/model. Most textbooks take a structured learning based approach, which leave results open for students to explore by themselves; open learning is quite limited.

It is widely believed that textbooks reflect the nature of science (Chiappetta & Fillman, 2007), and if laboratory activities in textbooks are properly developed, they have the potential to develop students' meaningful learning and conceptual understanding. The curriculum in Mainland China is centralized and reviewed by central authorities (Zhang & Gao, 2013) and in most cases teachers tend to follow the national curriculum step by step (Wang, Lavonen & Tirri, 2018). However, we are not sure how teachers will use the textbooks in classroom.

3.4 THE ANALYSIS OF THE TRANSFORMATION OF CURRICULUM STANDARDS (PAPER 4)

This section describes key ideas of the paper entitled "Transformation of chemistry education in the People's Republic of China–A view on the chemistry education standards"

3.4.1 Sample

The sample consists of the upper secondary school chemistry curriculum standards (USSCCs) released by the Ministry of Education in the People's Republic of China in 2003 (Ministry of Education, 2003) and 2017 (Ministry of Education, 2017).

3.4.2 Method

This study aimed at analyzing the content of the two USSCCs, especially focusing on exploring the innovative themes and contents. Stuckey et al.'s (2013) relevance model was used as the analyzing instrument (Figure 13), to explore how new chemistry curriculum in People's Republic of China is suggested to embrace innovative themes and contents related to the three dimensions, namely, individual, societal and vocational relevance of science education.

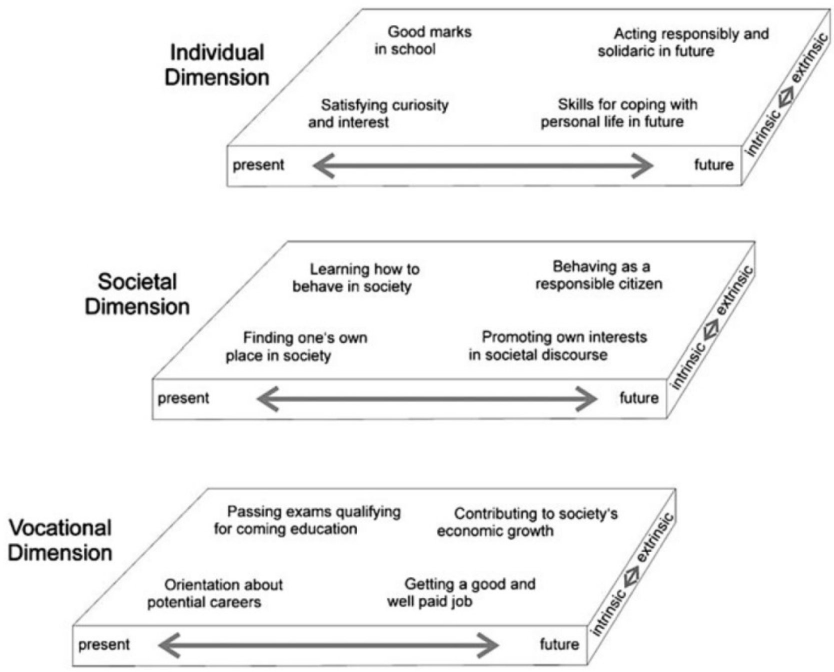


Figure 13. The model of the three dimensions of relevance by Stuckey et al. (2013, p. 19)

3.4.3 Main results

The two USSCCs released in 2003 and 2017 both suggest to start chemistry education with a view on its individual relevance as a base. Furthermore, they align chemistry learning with its societal and vocational relevance. Concerning the three dimensions of relevance in science education (Stuckey et al., 2013). These USSCCs conceptualize them in a different way. Table 7 gives more details about the differences between the two versions of USSCCs in terms of the three relevance dimensions.

Table 7 General characteristics of the two USSCCs

	2003 USSCC	2017 USSCC
Individual relevance	Fundamental knowledge Scientific inquiry Skills for life application	Fundamental knowledge Scientific inquiry Skills for life application Modeling cognition Critical thinking Evidence deducting
Societal relevance	Citizen responsibility STS	Citizen responsibility STSE Balance cognition
Vocational relevance	Interdisciplinary application Contributing to society	Interdisciplinary application Contributing to society Orientation about potential careers
Degree of suggested relevance dimension coverage	Individual relevance - high Societal relevance - medium Vocational relevance - low	Individual relevance - high Societal relevance - high Vocational relevance - medium

3.4.4 Discussion and conclusion

Both curriculum standards place more emphases on the individual dimension of relevance in science education, they focus more on knowledge and skills of fundamental chemistry and less on the societal or vocational dimension. One reason could be that PR China is still one of many Asian countries where paper and pencil examinations dominate the narrow way for Chinese youth to aspire higher college/university education (Davey, Lian & Higgins, 2007).

The two USSCCs can be considered as the development of the intended curriculum towards relevant chemistry education. The 2017 USSCC includes more aspects of relevant science education. The vocational dimension is highlighted with interdisciplinary applications and potential career applications in the 2017 USSCC.

4 SUMMARY

To date, research about Chinese chemistry textbooks of different regions is still unprecedented. These studies aim at minimizing the gap and showing the diversity of intended curricula by analyzing textbooks. The purpose of these studies is neither to recommend one "best" textbook, nor to investigate mistakes or uncertainties.

Similarities and differences are conveyed by secondary chemistry textbooks from different Chinese communities. In general, these studies (Section 3.1 to Section 3.3) report that larger differences exist between the textbooks from different Chinese communities than within them. This is especially the case with respect to the Taiwanese textbooks (Chen et al., 2019a; 2019b).

In terms of general curriculum orientation, the Taiwanese textbooks have a high degree of contextualization and socio-scientific issues orientation, with rich and colorful illustrations as well as the integration of macro- and submicroscopic aspects of chemistry concepts. They fit what modern research prescribes for chemistry curriculum, namely learning embedded in meaningful contexts (Eilks et al.,2013) with rich and helpful illustrations (Devetak & Vogrinc, 2013). This is in accordance with Holman's (1987) claim that curricula can be driven by applications of chemistry, relevant issues, and processes. When we look into specific topics in Taiwanese textbooks, i.e., redox reactions and practical work respectively, the findings show that these textbooks from Taiwan provide the richest demonstrations with multiple macroscopic, submicroscopic, and symbolic representations to illustrate redox reactions. Practical work in Taiwanese textbooks contains the highest proportion of picture/sketch resources but less detailed laboratory operation processes. Research already showed that technology-aided learning in science education has become a popular trend in Taiwan (Lin & Tsai, 2016) and was also introduced in secondary chemistry education (Chen, 2018). If the textbooks from Taiwan would be combined with other learning resources, it will result a low representation of hands-on practical work and instructional guidance on practical work.

The analysis of the representation of the intended curriculum in People's Republic of China shows some indications of student-oriented learning and a certain degree of daily life aspects as well as societal issues, albeit discipline oriented (Section 3.1). The structure of the different versions of Chinese textbooks (CN1-CN4) is quite similar since they were edited under the same curriculum standards released by the Ministry of Education officially. In terms of redox reactions (Section 3.2), results show that representations in CN1-CN4 textbooks mostly focus on the macro and macro-symbolic levels with some aspects of everyday life as well as industry and technology orientation. The textbook from Hongkong has a strong orientation on pure chemistry learning, with dominant representations at macro level. The representation of practical work (Section 3.3) indicates close instructional guidance along with the textbook. The intended learning outcomes of practical work mostly focus on learn fact(s) via a structured inquiry learning approach. One of the likely reasons is that the educational system is a combination of nation policy, school principle, local education authority, class size, class resources, learners' background and so on (Watson et al., 2004). Another possibility is that a centralized national college entrance exam in China focuses more on knowledge than inquiry skills (Davey et al., 2007). Nevertheless, the comparison of curriculum standards (Section 3.4) indicates that the societal dimension and the vocational dimension are emerging in a higher proportion compared to the individual dimension. Further research is needed to identify the implementation of curriculum reform.

In the case of Malaysia, our studies show that Malaysian textbooks follow a structure-of-the-discipline orientation with less contextualization and fewer illustrations (Section 3.1). Visual representations related to redox reactions are quite limited (Section 3.2). Practical work representations in Malaysian textbooks engage the highly structured learning approach along with detailed operation process, and practical work mostly focuses on learning fact(s). Research shows that in Malaysian secondary schools, students highly rely on teachers for all information and instructions, and they get used to listening passively to teachers with occasionally limited questions (Peen & Arshad, 2014). The localized education background may lead to a teacher-centered pedagogy with decontextualized textbooks in Malaysia Independent Chinese Secondary Schools (ICSSs).

As mentioned before, the difficulties of learning chemistry vary from the intrinsic nature of chemistry itself to extrinsic human factors (Upahi et al., 2019). Textbooks play as a medium in linking chemistry and the learner (Lee, 2010), and they represent an ideal and formal type of curriculum (Van Den Akker, 1998). Consequently, teachers relied on them to guide their teaching efforts (Stern & Roseman, 2004), and students used them to guide their studies (Gkitzia et al., 2011). Shehab et al. (2017) claimed that the proper design of primary learning materials (textbooks for example) does not guarantee that students will attain high representational competence naturally and imply visualization into their own reasoning about chemical phenomenon automatically. Nevertheless, the appropriate presentation of textbooks is the base to help students to gain knowledge. Curricula are constricted by local educational systems as well as culture, and the representations in the corresponding textbooks are affected by that. That explains why the differences between the Chinese communities are larger than differences within them.

Most Asian countries are simultaneously making efforts to improve science education (Lavonen, 2016). Specifically, Taiwanese science education has been developing substantially due to its economic boom. Since that, Taiwan has built active collaborations concerning the development of science education within East Asia (Yore, Shymansky & Treagust, 2016) and western countries (De Jong, 2016). This may be why the Taiwanese textbooks provide the richest representation of content.

People's Republic of China started this process later. It is believed that high educational qualifications result in high incomes and good opportunities in the labor market, which leads to an exam-oriented education and further contributes to the obstacles to the curriculum reform application (Chai & Cheng, 2011). Nevertheless, over the last decades, science education researchers have also made efforts in the internationalization of science education research (e.g. Liu et al., 2012). From the development of the curriculum standards, we have already seen that chemistry education at the intended curriculum level is moving forward.

However, we do not know how teachers will imply the intended curriculum in practice, which can be a focus of the further research. Our studies focus on the intended curriculum level, exploring how textbooks deliver scientific knowledge to students. We can see that differences exist in textbooks even though the mentioned Chinese communities have a similar cultural background. To promote further development of textbooks as well as other educational resources, there probably should be reflections on the evaluation system.

5 References

Abd-El-Khalick, F., Waters, M., & Le, A. P. (2008). Representations of nature of science in high school chemistry textbooks over the past four decades. *Journal of Research in Science Teaching*, *45*(7), 835–855.

Abrahams, I. (2011). *Practical work in secondary science: a minds-on approach*. London: Continuum.

Abrahams, I., & Millar, R. (2008). Does practical work really work? A study of the effectiveness of practical work as a teaching and learning method in school science. *International Journal of Science Education*, *30*(14), 1945–1969.

Abrahams, I., & Reiss, M. J. (2012). Practical work: Its effectiveness in primary and secondary schools in England. *Journal of Research in Science Teaching*, *49*(8), 1035–1055.

Aldahmash, A. H., Mansour, N. S., Alshamrani, S. M., & Almohi, S. (2016). An analysis of activities in Saudi Arabian middle school science textbooks and workbooks for the inclusion of essential features of inquiry. *Research in Science Education*, *46*(6), 879–900.

Apotheker, J. (2014). The development of a new chemistry curriculum in the Netherlands: introducing concept-context based education. *African Journal of Chemistry Education*, *4*(2), 44–63.

Basheer, A., Hugerat, M., Kortam, N., & Hofstein, A. (2017). The effectiveness of teachers' use of demonstrations for enhancing students' understanding of and attitudes to learning the oxidation reduction concept. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(3), 555–570.

Belova, N., & Eilks, I. (2015). Research and innovation on learning with and about advertising in science education. In N. I. Yates (Ed.), *New developments in science education research* (pp. 29–50). Hauppauge: Nova.

Carney, R. N., & Levin, J. R., (2002). Pictorial illustrations still improve students' learning from text. *Educational Psychology Review*, *14*(1), 5–26.

Chai, C., & Cheng, G. (2011). Policies on China's basic education over the last thirty years. In X. Zhang (Ed.), *China's education development and policy, 1978-2008* (pp. 111-163). Leiden: Brill.

Chen, X. G, Chiu, M.-H., & Eilks, I. (2019a). An analysis of the orientation and emphasis of intended grade-10 chemistry curricula as represented in textbooks from different Chinese communities. *Eurasia Journal of Mathematics, Science and Technology Education, 15*(2), em1663.

Chen, X. G, Goes, L. F., Treagust, D. F., & Eilks, I. (2019b). An analysis of the visual representation of redox reactions in secondary chemistry textbooks from different Chinese communities. *Education Sciences*, *9*(1), 42.

Chen, Z. S. (2018). Application of software and platform in primary and secondary chemistry teaching-promote the acid-base conceptual learning by creating an educational platform. *Chemistry Education in Taiwan, 2018* (24), 1–7. (in Chinese).

Cheng, K. L, & Wong, S. L. (2014). Nature of science as portrayed in the physics official curricula and textbooks in Hong Kong and on the Mainland of the People's Republic of China. In C. Bruguière, A. Tiberghien & P. Clément (Eds.), *Topics and trends in current science education* (pp. 519–534). Dordrecht: Springer.

Chiappetta, E. L., & Fillman, D. A. (2007). Analysis of five high school biology textbooks used in the United States for inclusion of the nature of science. *International Journal of Science Education, 29*(15), 1847–1868.

Chiu, M.-H. (2016). Introduction: science education research and practice in Taiwan: A little giant! In M.-H. Chiu (Ed.), *Science education research and practices in Taiwan: challenges and opportunities* (pp. 1–8). Singapore: Springer.

Choi, B.-S., & Choi, A. (2016). Overview of science education research and practice in Korea. In M.-H. Chiu (Ed.), *Science education research and practice in Asia* (pp. 245-273). Singapore: Springer.

Chou, C., & Ching, G. (2012). Course, curriculum, and textbooks. In C. Chou & G. Ching (Eds.), *Taiwan education at the crossroad: when globalization meets localization* (pp. 89-98). New York: Palgrave Macmillan.

Davey, G., Lian, C. D., & Higgins, L. (2007). The university entrance examination system in China. *Journal of Further and Higher Education, 31*(4), 385–396.

De Jong, O. (2006). Making chemistry meaningful: conditions for successful context-based teaching. *Educación Químic*a, *17*(2), 215–226.

De Jong, O. (2016). Thoughts on science curriculum reform and teacher learning in western countries and Taiwan. In M.-H. Chiu (Ed.), *Science education research and practices in Taiwan* (pp. 387–394). Singapore: Springer.

De Jong, O., & Treagust, D. F. (2002). The teaching and learning of electrochemistry. In J. K. Gilbert, O. De Jong, R. Justi, D. F. Treagust & J. H. Van Driel (Eds.), *Chemical education: towards research-based practice* (pp. 317–337). Dordrecht: Springer.

Department of Statistics Malaysia, 2018. Available at: https://www.dosm.gov.my/v1/index.php?r=column/cthemeByCat&cat=155&bul_id=c1pqTnFjb29HSnNYNUpiTmNWZHArdz09&menu_id=L0pheU43NWJwRWVSZklWdzQ4TlhUUT09 (accessed on 08 February 2019).

Devetak, I., & Vogrinc, J. (2013). The criteria for evaluating the quality of the science textbooks. In M.S. Khine (Ed.), *Critical analysis of science textbooks: evaluating instructional effectiveness* (pp. 3–15). Dordrecht: Springer.

Devetak, I., Vogrinc, J. & Glažar, S. A. (2010). States of matter explanations in Slovenian textbooks for students aged 6 to 14. *International Journal of Environmental & Science Education*, *5*(2), 217-235.

Ding, B. P. (2010). On the typologies and essential characteristics of inquiry-oriented science teaching. *Educational Research*, *2010*(10), 81–85. (in Chinese).

Dong Zong (2018). The background of Dong Zong's establishment. Available at: http://www.dongzong.my/eindex.php (accessed on 5 January 2018).

Eilks, I., Moellering, J., & Valanides, N. (2007). Seventh-grade students' understanding of chemical reactions: reflections from an action research interview study. *Eurasia Journal of Mathematics, Science and Technology Education*, *3*(4), 271–286.

Eilks, I., Rauch, F. Ralle, B., & Hofstein, A. (2013). How to allocate the chemistry curriculum between science and society. In I. Eilks & A. Hofstein (Eds.), *Teaching chemistry—a studybook* (pp. 1–36). Rotterdam: Sense.

Eilks, I., Witteck, T., & Pietzner, V. (2012). The role and potential dangers of visualisation when learning about sub-microscopic explanations in chemistry education. *Center for Educational Policy Studies Journal*, *2*(1), 125–145.

Finley, F. N., Stewart, J., & Yarroch, W. L. (1982). Teachers' perceptions of important and difficult science content. *Science Education*, *66*(4), 531–538.

Gilbert, J. K. (2006). On the nature of "context" in chemical education. *International Journal of Science Edcuation*, *28*(9), 957–976.

Gkitzia, V., Salta, K., & Tzougraki, C. (2011). Development and application of suitable criteria for the evaluation of chemical representations in school textbooks. *Chemistry Education Research and Practice*, *12*(1), 5–14.

Guo, C.-J., & Chiu, M.-H. (2016). Opportunities and challenges for science education in Asia: Perspectives based on the Taiwan experience. In M.-H. Chiu (Ed.), *Science education research and practice in Asia* (pp. 175-196). Dordrecht: Springer.

Halim, L., & Meerah, T. S. M. (2016). Science education research and practice in Malaysia. In M.-H. Chiu (Ed.), *Science education research and practice in Asia* (pp. 71–93). Dordrecht: Springer.

Hofstein, A. (2017). The role of laboratory in science teaching and learning. In K.S. Taber & B. Akpan (Eds.), *Science education-an international course companion* (pp. 357–368). Rotterdam: Sense.

Holman, J. (1987). Resources or courses? Contrasting approaches to the introduction of industry and technology to the secondary curriculum. *School Science Review, 68*(244), 432–438.

Hu, J. H., & Wang, L. (2005). Scientific teaching exploration: an inquiry-based constructive teaching. *Education Science Research*, *2005*(4), 35–37. (in Chinese).

Hwang, J.-J., & Chang, C.-Y. (2003). Curriculum study in Taiwan: retrospect and prospect. In W. F. Pinar (Ed.), *International handbook of curriculum research* (pp. 595-605). New Jersey: Lawrence Erlbaum.

Johnstone, A. H. (1991). Why is science difficult to learn? Things are seldom what they seem. *Journal of Computer Assisted Learning*, *7*(2), 75–83.

Johnstone, A. H. (1993). The development of chemistry teaching: A changing response to changing domain. *Journal of Chemical Education*, *70*(9), 701–705.

Johnstone, A. H. (2010). You can't get there from Here. *Journal of Chemical Education*, *87*(1), 22–29.

Johnstone, A. H., (2006). Chemical education research in glasgow in perspective. *Chemistry Education Research and Practice*, *7*(2), 49–63.

Jones, M. E., Gott, R., & Jarman, R. (2000). Investigations as part of the key stage 4 science curriculum in Northern Ireland. *Evaluation & Research in Education*, *14*(1), 23–37.

Karpudewan, M., & Chua, K. E. (2016). Cultural background and the science laboratory learning environment: the Malaysian lower secondary students' perspective. In I. Eilks, S. Markic & B. Ralle (Eds.), *Science education research and practical work* (pp. 93-104). Aachen: Shaker.

Katchevich, D., Hofstein, A., & Mamlok-Naaman, R. (2013). Argumentation in the chemistry laboratory: Inquiry and confirmatory experiments. *Research in Science Education*, *43*(1), 317–345.

Khaddoor, R., Al-Amoush, S., & Eilks, I. (2017). A comparative analysis of the intended curriculum and its presentation in 10th grade chemistry textbooks from seven Arabic countries. *Chemistry Education Research and Practice*, *18*(2), 375–385.

Lavonen, J. (2016). Commentary: what we can learn from science education in Asian countries? In M.-H. Chiu (Ed.), *Science education research and practice in Asia* (pp. 215–221). Singapore: Springer.

Lee, V. R. (2010). Adaptations and continuities in the use and design of visual representations in US middle school science textbooks. *Instructional Technology & Learning Sciences*, *32*(8), 1099–1126.

Lin, T.-C., & Tsai, C.-C. (2016). Innovative technology-assisted science learning in Taiwan. In M.-H. Chiu (Ed.), *Science education research and practice in Asia* (pp. 189–209). Singapore: Springer.

Liu, H. X. (2010). Centennial changes of basic education in Taiwan. *Education and Examination*, *2010*(6), 88–93. (in Chinese).

Liu, X., Liang, L. L., & Liu, E. (2012). Science education research in China: challenges and promises. *International Journal of Science Education*, *34*(13), 1661-1670.

Martínez-Gracia, M. V., Gil-Quýlez, M., & Osada, J. (2003). Genetic engineering: a matter that requires further refinement in Spanish secondary school textbooks. *International Journal of Science Education*, *25*(9), 1148–1168.

Millar, R., Le Maréchal, J.-F., & Tiberghien, A. (1999). "Mapping" the domain: Varieties of practical work. In J. Leach & A. C. Paulsen (Eds.), *Practical work in science education: recent research studies* (pp. 33–59). Dordrecht: Kluwer.

Ministry of Education (2003). *National upper secondary school chemistry curriculum standards*. Beijing: People's Education Press.

Ministry of Education (2017). *National upper secondary school chemistry curriculum standards*. Beijing: People's Education Press.

Ministry of Education (2018). Notice of the guidance of teaching books for upper secondary schools. Available at: http://www.moe.gov.cn/srcsite/A06/s3732/201808/t20180824_346056.html (accessed on 19 March 2019).

Obomanu, B., & Onuoha, C. (2012). Students conceptual difficulties in electrochemistry in senior secondary schools. *Journal of Emerging Trends in Educational Research and Policy Studies*, *3*(1), 99–102.

Osman, K. & Lee, T. T. (2014). Impact of interactive multimedia module with pedagogical agents on students' understanding and motivation in the learning of electrochemistry. *International Journal of Science and Mathematics Education*, *12*(2), 395–421.

Paik, S. H., Kim, S., & Kim, K. (2017). Suggestion of a viewpoint change for the classification criteria of redox reactions. *Journal of Chemical Education*, *94*(5), 563–568.

Peen, T. Y., & Arshad, M. Y. (2014). Teacher and student questions: a case study in Malaysian secondary school problem-based learning*. Asian Social Science, 10*(4). 174–182.

Raman, S. R., & Sua, T. Y. (2015). The development of Chinese education in Malaysia: problems and challenges. ISEAS Working Paper Series on *The Development of Chinese Education in Malaysia: Problems and Challenges*. Available at: https://www.iseas.edu.sg/images/pdf/WP2015-02.pdf (accessed on 22 May 2019).

Ramnarain, U., & Joseph, A. (2012). Learning difficulties experienced by grade 12 South African students in the chemical representation of phenomena. *Chemistry Education Research and Practice*, *13*(4), 462–470.

Roberts, D. A. (1982). Developing the concept of "curriculum emphases" in science education. *Science Education*, *66*(2), 243–260.

Roseman, J. E., Stern, L., & Koppal, M. (2010). A method for analyzing the coherence of high school biology textbooks. *Journal of Research in Science Teaching*, *47* (1), 47–70.

Roth, W. M., & Lee, S. (2004). Science education as/for participation in the community. *Science Education, 88*(2), 263–291.

Rusek, M., & Vojíř, K. (2019). Analysis of text difficulty in lower-secondary chemistry textbooks. *Chemistry Education Research and Practice*, *20*(1), 85–94.

Russell, J. W., Kozma, R. B., Jones, T., Wykof, J., Marx, N., & Davis, J. (1997). Use of simultaneous-synchronized macroscopic, microscopic and symbolic representations to enhance the teaching and learning of chemical concepts. *Journal of Chemical Education*, *74*(3), 330–334.

Schmidt, H.J., & Volke, D. (2003). Shift of meaning and students' alternative concepts. *International Journal of Science Education*, *25*(11), 1409–1424.

Shehab, S. S., & BouJaoude, S. (2015). Analysis of the Chemical Representations in Secondary Lebanese Chemistry Textbooks. *International Journal of Science and Mathematics Education*, *15* (5), 797–816.

Sjöström, J., & Talanquer, V. (2014). Humanizing chemistry education: from simple contextualization to multifaceted problematization. *Journal of Chemical Education, 91*(8), 1125–1131.

Souza, K. A. F., & Porto, P. A. (2012). Chemistry and chemical education through text and image: Analysis of twentieth century textbooks used in Brazilian context. *Science & Education*, *21*(5), 705–727.

Stern, L., & Roseman, J. E. (2004). Can middle-school science textbooks help students learn important ideas? Findings from Project 2061's curriculum evaluation study: life science. *Journal of Research in Science Teaching*, *41*(6), 538–568.

Stuckey, M., Hofstein, A., Mamlok-Naaman R., & Eilks, I. (2013). The meaning of 'relevance' in science education and its implications for the science curriculum. *Studies in Science Education, 49*(1), 1–34.

Talanquer, V. (2010). Macro, submicro, and symbolic: the many faces of the chemistry "triplet". *International Journal of Science Education*, *33*(2), 1–17.

Treagust, D. F., Chittleborough, G., & Mamiala, T. (2003). The role of submicroscopic and symbolic representations in chemical explanations. *International Journal of Science Education*, *25*(11), 1353–1368.

Upahi, J. E. & Ramnarain, U. (2019). Representations of chemical phenomena in secondary school chemistry textbooks. *Chemistry Education Research and Practice*, *20*(1), 146–159.

Van Berkel, B. (2005). *The structure of current school chemistry–a quest for conditions for escape*. Utrecht: CD-β.

Van Den Akker, J. (1998). The science curriculum: Between ideals and outcomes. In B. J. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (pp. 421–447). Dordrecht: Springer.

Van Driel, J. H., Bulte, A. M. W., & Verloop, N. (2007). The relationship between teachers' general beliefs about teaching and learning and their domain specific curricular beliefs. *Learning and Instruction, 17*(2), 156–171.

Vivien, W. (2018). The language medium policies: a study on the development of independent Chinese secondary schools (ICSS) in Malaysia. *KATHA*, *13*(1), 32–53.

Wang, L. (2010). Basic chemistry education curriculum reform progress and reflection in the past years (Volume I). *Chinese Journal of Chemical Education*, *31*(4), 15–21. (in Chinese).

Wang, L., Tang, J., Zhang, R., Hu, J., Zhi, Y., & Wei, R. (2015). Investigation of the use of new chemistry textbooks of senior high school and the influential factors. *Journal of Educational Studies*, *11*(4), 77–86.

Wang, L., Zhu, Y. J., Jiang, Y. X., Wei, R., Zhou, Y., Guo, Y. Y., Wei, X., Yang, W. Y., & Liu, E. S. (2016). Science education research in Mainland China. In M.-H. Chiu (Ed.), *Science education research and practice in Asia* (pp. 17–39). Dordrecht: Springer.

Wang, S. H., & He, C. X. (2012). The comparison of "chemical reaction rate" content represented in different high school chemistry textbooks. *Teaching and Learning Reference for Middle School Chemistry*, *2012*(4), 40–43. (in Chinese).

Wang, Y., Lavonen, J. M. J., & Tirri, K. A. H. (2018). Aims for Learning 21st century competencies in national primary science curricula in China and Finland. *Eurasia Journal of Mathematics, Science & Technology Education*, *14*(6), 2081–2095

Watson, J. R., Swain, J. R. L., & McRobbie, C. (2004). Students' discussions in practical scientific inquiries. *International Journal of Science Education*, *26*(1), 25–45.

Xia, N., Yang, Y. N., & Lee, Y. E. (2018). Chinese education in Malaysia under Malaysian ethnic politics. *Journal of Politics and Law, 11*(2), 23–36.

Xu, L. L., & Xu, P. (2016). The popularization of Chinese language in multilingual environment—based on the analysis of examples from Malaysia. Paper presented at *the 2nd International Conference on Modern Education and Social Science (MESS 2016).* China: Wuhan.

Yore, L. D. Shymansky, J.A., & Treagust, D. F. (2016). An international perspective on the people and events shaping science education in Taiwan—past, present, and future. In M.-H. Chiu (Ed.), *Science education research and practices in Taiwan* (pp. 397–419). Singapore: Springer.

Zhang, H., & Gao, Z. (2013). Curriculum studies in China: retrospect and prospect. In W. F. Pinar (Ed.), *International handbook of curriculum research* (2nd ed., pp. 118–133). New Jersey: Lawrence Erlbaum.

6 PUBLICATIONS

Publications related to this thesis:

Chen, X. G., & Eilks, I. (2018). Transformation of chemistry education in the People's Republic of China - A view on the chemistry education standards. In I. Eilks, S. Markic & B. Ralle (Eds.), Building bridges across disciplines for transformative education and a sustainable future (pp. 295–300). Aachen: Shaker.

Chen, X. G., Chiu, M.-H., & Eilks, I. (2019). An analysis of the orientation and emphasis of Intended Grade-10 chemistry curricula as represented in textbooks from different Chinese communities. *Eurasia Journal of Mathematics, Science and Technology* Education, *15*(2), em1663.

Chen, X. G., Goes, L. F., Treagust, D. F., & Eilks, I. (2019). An analysis of the visual representation of redox reactions in secondary chemistry textbooks from different Chinese communities. *Education Sciences*, *9*(1), 42.

Chen, X. G., & Eilks, I. (2019). An analysis of the representation of practical work in secondary chemistry textbooks from different Chinese communities. Submitted to *Science Education International*.

APPENDIX

Paper 1

An Analysis of the Orientation and Emphasis of Intended Grade-10 Chemistry Curricula as Represented in Textbooks from Different Chinese Communities

Accepted by

EURASIA Journal of Mathematics, Science and Technology Education

16 November 2018

Author Contributions: The conceptualization of this paper was made by Xiaoge Chen and Ingo Eilks. The methodology was evaluated by Ingo Eilks. The data were evaluated by Xiaoge Chen, Mei-Hung Chiu and Ingo Eilks. The first version of the manuscript was written by Xiaoge Chen and then finalized and reviewed by all authors.

MODESTUM
OPEN ACCESS
EURASIA Journal of Mathematics, Science and Technology Education, 2019, 15(2), em1663
ISSN:1305-8223 (online)
Research Paper https://doi.org/10.29333/ejmste/100642

An Analysis of the Orientation and Emphasis of Intended Grade-10 Chemistry Curricula as Represented in Textbooks from Different Chinese Communities

Xiaoge Chen [1*], Mei-Hung Chiu [2], Ingo Eilks [1]

[1] University of Bremen, Dept. of Biology and Chemistry, Institute for Science Education (IDN) - Chemistry Education, GERMANY
[2] National Taiwan Normal University, Graduate Institute of Science Education, TAIWAN

Received 13 August 2018 ▪ Revised 23 October 2018 ▪ Accepted 16 November 2018

ABSTRACT

This study presents an analysis of the representation of intended curricula in 10th grade chemistry textbooks from different Chinese communities, namely from the People's Republic of China, Taiwan, and the Chinese minority in Malaysia. The study aims to identify the commonalities and differences among seven textbooks concerning the emphasis and orientation of the intended curriculum. It also looks at any indications of how student-oriented these curricula are in terms of the presentation of content and the suggested activities. The findings indicate that the Taiwanese textbooks have a high degree of contextualization and socio-scientific issues orientation, supported by rich and colorful illustrations as well as the integration of macro- and submicroscopic aspects of chemistry concepts. The textbook from Malaysia uses a quite traditional approach. It basically follows a structure-of-the-discipline orientation, using less contextualization and fewer illustrations. The textbooks from the People's Republic of China lie somewhere in between the textbooks from Taiwan and Malaysia. They offer some indications of student-oriented learning and have some extent of daily life and socio-scientific issues orientation.

Keywords: chemistry education, curriculum, textbooks

INTRODUCTION

Ever since the 1980s new goals and standards for secondary chemistry education have emerged in both Western and non-Western countries. In Western countries the new standards intended to refine the chemistry curriculum from the pure learning of chemistry facts and theories towards learning from everyday life perspectives and societal contexts (Eilks et al., 2013). A corresponding change towards science learning with a starting point in everyday life has also gradually been suggested as an important issue in several Asian regions like the People's Republic of China (Wang et al., 2016), Taiwan (Guo & Chiu, 2016), Malaysia (Halim & Meerah, 2016) and Korea (Choi & Choi, 2016).

Textbooks are one of the main elements that influence what is taught in the classroom and how science is conveyed to students. A textbook can be seen as a go-between linking a domain of knowledge and the student (Devetak & Vogrinc, 2013). It represents not only the intended curriculum, the content matter and contexts, but also the beliefs of its authors and their view of science and which aspects of science should be considered (Seligardi, 2006). The textbook presents the subject to the learners and suggests to teachers how the topics are to be taught (Shehab & BouJaoude, 2015). It provides orientation in the curriculum and mirrors the emphasis behind it (Roseman et al., 2010). Textbooks serve as a handfast resource to support teachers with content, strategies and approaches for teaching and can also suggest how much support students need (Stein et al., 2001).

The most common research area involving science textbook analysis focuses on the construction of textbooks. It looks at the important ideas implemented in science textbooks (e.g. the nature of science), difficulties with textbooks, and the specific content structure used in textbooks. There are much fewer studies seeking to identify whether science textbooks are in line with modern theories of the curriculum. This is the case for science teaching

✉ chen@uni-bremen.de **(*Correspondence)** ✉ mhchiu@ntnu.edu.tw ✉ eilks@uni-bremen.de

Contribution of this paper to the literature

- This paper provides an analysis of secondary chemistry textbooks from different Chinese communities, namely from the People's Republic of China, Taiwan, and the Chinese minority from Malaysia. The analysis focuses the orientation and emphasis of the intended secondary chemistry curriculum.
- The analysis revealed a large variety in the representation of the secondary chemistry curriculum in textbooks from different Chinese communities, with textbooks from Taiwan being mostly in line with modern, international chemistry curriculum theory. Chinese chemistry textbooks from Malaysia are very traditional with having textbooks from the People's Republic of China indicating progress towards issues of modern chemistry textbooks.

in general. It also holds true when comparing chemistry textbooks from different cultures or regions. Not much is known about why the intended curricula as represented in textbooks from different countries look so different to one another. This occurs even if the countries in question share the same culture, regional background, or level of economic development (Khaddoor et al., 2017). Khaddoor et al. (2017) examined chemistry textbooks from seven cross-regional Arab countries and suggested that the influence of tradition and educational policy might be the main factor that counts. However, this finding was based on comparing different Arab communities. To date no transnational science textbook comparisons for Chinese communities with a similar focus exist. Former studies on Chinese chemistry textbooks mainly focused on the content (Wang & He, 2012), not so much on its representation.

This paper explores the characteristics of intended secondary chemistry curricula from different Chinese communities. It looks at 10th grade chemistry textbooks from the People's Republic of China, Taiwan, and the Chinese minority living in Malaysia. The textbooks chosen are either officially approved by the government in question or authorized by the regional educational authorities. The questions addressed in this article are as follows:

1. What are the commonalities and differences in the intended chemistry curricula as represented by 10th grade textbooks from different Chinese communities? What are the curriculum emphases and the orientations of the curriculum?
2. Are there any indications of modern, student-oriented chemistry curricula in terms of contextualization, societal issues orientation, and student-oriented activities?

THEORETICAL FRAMEWORK

The theoretical framework of this study was developed for a comparative analysis of secondary chemistry textbooks from different Arab countries by Khaddoor et al. (2017). Khaddoor et al. refer in their framework to the concepts of the curriculum emphases and curriculum orientations.

Curriculum emphasis was defined by Roberts (1982) as a set of hidden messages about the nature of science within a curriculum. He described curriculum emphasis as '… a coherent set of messages about science (rather than within science). Such messages constitute objectives which go beyond learning the facts, principles, laws and theories of the subject matter itself – objectives which provide answers to the student question: Why am I learning this?' (Roberts, 1982, p. 245).

Based on an analysis of science curricula from about 100 years in Northern America, Roberts identified seven curriculum emphases: 1) everyday coping, 2) the structure of science, 3) science, technology and decisions, 4) scientific skill development, 5) offering correct explanations, 6) the self as explainer and 7) solid foundation. However, Roberts had already made clear that curriculum emphases cannot always be sharply distinguished from one another. They can be combined in certain curricula and they often change.

In 2005, Van Berkel took Roberts' ideas and transformed the original seven curriculum emphases into three more general ones. Van Berkel called them fundamental chemistry, knowledge development in chemistry, and chemistry, technology and society (see also Khaddoor et al., 2017; Van Driel et al., 2007):

- **Fundamental Chemistry (FC)** puts the learning of theoretical concepts and facts at the fore. The curriculum is based on the view that facts and concepts need to be learned first for later application and provide the best ground for understanding the natural world.
- **Knowledge Development in Chemistry (KDC)** is based on the idea that students should learn both how chemistry knowledge emerged and changed over time. It also attempts to show how it was influenced by the corresponding socio-historical context, thus making chemistry a culturally-determined system.
- **Chemistry, Technology and Society (CTS)** puts the interrelationship between science, technology and society at the center of the curriculum. Students should learn how to make decisions on societal issues that are connected to chemistry and technology and to learn how to effectively communicate about them.

Eilks et al. (2013) recently described the idea of general orientations of the chemistry curriculum. Their work refers De Jong's (2006) idea that there are four basic domains from which the learning of chemistry can be approached. De Jong identified the personal, professional, professional-technological, and societal domains. His suggestion parallels what was recently identified as dimensions of relevance when it comes to science education: individual, societal and vocational relevance (see Stuckey et al., 2013).

Based on De Jong (2006), Eilks et al. (2013) identified six general orientations from which individual chemistry lessons might begin and from which curricula might be designed. In brief these are:

- **Structure of the discipline orientation:** The chemistry curriculum mirrors the inner structure of academic chemistry. The curriculum is designed for structured learning of scientific facts and theories. A corresponding school curriculum might look like a 'lighter' version of an academic general chemistry textbook.
- **History of chemistry orientation:** The chemistry curriculum is structured along episodes from the history of chemistry. The curriculum is designed to learn about the nature of chemistry and how chemistry knowledge emerged over time illustrated by references to the life of real chemists.
- **Everyday life orientation:** The chemistry curriculum is structured using everyday life topics and issues to provide meaningful contexts for learning chemistry concepts.
- **Environmental orientation:** The chemistry curriculum is structured by environmental issues and problems, including questions of environmental protection.
- **Technology and industry orientation:** The chemistry curriculum is structured by developments from chemical technology and industry. This might include the interplay of science and technology within society.
- **Socio-scientific issues (SSI) orientation:** The chemistry curriculum is structured by using controversial socio-scientific issues. It is suggested that students develop general skills to allow them to act as responsible citizens in society.

Khaddoor et al. (2017) suggest that all of the curriculum orientations described above can form a context of one type or another (see Gilbert, 2006) for the teaching and learning of chemistry. With reference to the theory of situated cognition (Greeno, 1998), they also state that contexts which should be meaningful to the student must be connected to the students' prior experiences. They argue that this is generally not true for both the structure of the discipline and history of chemistry orientations, at least for a majority of secondary school students. Contexts are believed to be more meaningful to students if taken from everyday life and environmental issues. It is also thought that corresponding contexts provide chances to illustrate the relevance of chemistry education to the individual learner (Childs et al., 2015). The same holds true for many technological and societal issues that offer links to demonstrate chemistry education's societal and vocational relevance (Hofstein & Kesner, 2015; Sjöström et al., 2015).

If one wishes to connect curriculum emphases (as suggested by Van Berkel, 2005) with the idea of curriculum orientations (Eilks et al., 2013), the structure of the discipline orientation has been recommended as being closely related to Fundamental Chemistry. Using the history of chemistry orientation might be inspired by an emphasis on Knowledge Development in Chemistry. A focus on technology and industry might intend the same, if the focus is on referring to the development of certain technologies during history. Chemistry, Technology and Society can hardly be employed without incorporating topics and issues from the students' individual lives and society at large. It has been suggested that this approach is most prominent in curriculum orientations centering on everyday life, the environment and socio-scientific issues.

BACKGROUND AND SAMPLE

In the People's Republic of China, curricula and teaching are generally based on nationally unified material. In one of the recent curriculum reforms, upper secondary school chemistry curriculum standards were released in 2003 (Wang, 2010). This reform led to a push in studies about the learning of science in the People's Republic of China. Many related studies became available, e.g., on science teaching in general (Hu & Wang, 2005), science teachers (Zhong, 2005), and scientific inquiry (Ding, 2010). Both the curriculum and textbooks became hot-button fields in science education in China (Wang et al., 2016).

This study focuses on three sets of upper secondary school chemistry textbooks from the People's Republic of China (with the exception of Shanghai), which were written according to the guidelines of the curriculum standards. They passed official review by the Ministry of Education[1]. These books were published by People's Education Press, Shandong Science and Technology Press and Jiangsu Education Press, respectively (Song, 2007a and b; Wang, 2007; Wang, 2014/2015). The three sets of textbooks are also known as the Renjiao Edition (later called CN1), Luke Edition (CN2) and Sujiao Edition (CN3). For each set of textbooks, there are two books for compulsory courses and six books for elective courses. The two compulsory courses (Chemistry 1 and 2) represent a curriculum to be learned by all grade 10 students.

In 1985, the Shanghai College Enrollment Office was allowed to abstain from the Chinese National College Entrance Examination (NCEE) in order to try out an independent proposition. Its textbooks are edited and reviewed by the Shanghai Primary and Secondary School Curriculum Reform Committee and Shanghai Primary and Secondary School Textbook Review Committee, respectively. In 1998 Shanghai started the second cycle of curriculum reform (Sun et al., 2016) and corresponding textbooks were printed. The Shangke Edition (CN4) (Yao, 2007a and b) published by Shanghai Scientific and Technical Publisher was recommended by the Shanghai municipal education committee. A special focus on Shanghai is justified here because Shanghai is one of the most industrialized areas in the People’s Republic of China.

Ever since the 1950s, basic education in Taiwan has been described as a development from transformation to innovation (Liu, 2010). Taiwan declared 1954 as the Year of Scientific Development (Liu & Chiu, 2012). Science education as an emphasis was starting to gain more attention from the government than in the past. Over the past decades, science textbooks in Taiwan were compiled by the National Translation and Compilation Center (NTCC). In 1994 rapid developments and changing societal needs led to an influential educational reform. This reform emphasized the eliciting of constructive learning and the cultivation of students as 21st century citizens was promulgated for grades 1-9. Science education was transformed from an elite education of the few to science for all. A major feature of the reform was the end of the NTCC monopoly on textbook compilation and publishing. Private publishers are now allowed to draft and publish textbooks for school use. Since 2001, the focus has shifted towards the needs of varying students groups. School-based curricula that are more flexible and creative were also allowed (Xiong & Chen, 2001). A new curriculum guideline (sometimes also called standards or syllabi) was launched in 2018 and will be fully implemented by 2020. The new guidelines for science curricula emphasize the cultivation of core scientific literacy. This includes scientific core concepts, inquiry-based practice, and a motivation towards science and the nature of science. For this study, we chose two sets of widely-used chemistry textbooks for 10th grade students in Taiwan, published by Lungteng Cultural (Huang, 2010) and Nan-I Book Enterprise (Yeh, 2010). Hereafter we will refer to them as the Lungteng Edition (TW1) and Nan-I Edition (TW2), respectively. [2] Both textbooks were based on the Compulsory Subject Basic Chemistry Curriculum Syllabus for Senior Secondary Schools, which was released by the Ministry of Education of Taiwan (2006).

Malaysia is a country with a Chinese minority which makes up roughly 25% of the whole population. The Chinese minority sector in Malaysia operates its own educational system and schools, teaching students mainly in Chinese (Karpudewan & Chua, 2016). Chinese education in Malaysia began in 1819. In 1954, the United Chinese School Committees’ Association of Malaysia (UCSCA or Dong Zong) was established to defend and develop Chinese language education and aims to achieve the sustainable development of Chinese education. It works with the United Chinese School Teachers’ Association of Malaysia (UCSTA or Jiao Zong) to uphold the ethnic rights of the Chinese minority. The two associations are known by the acronym of Dong Jiao Zong (Dong Zong and Jiao Zong) (Dong Zong, 2017). Independent schools are operated by Dong Jiao Zong instead of by the Ministry of Education in Malaysia. Any rules and regulations in these schools are different from those in the governmental schools. Students who go to Malaysian independent Chinese secondary school have an additional academic year of upper secondary school, similar to the secondary school system in the People’s Republic of China and Taiwan. The Malaysian high school chemistry book (Upper Secondary School Chemistry) is edited by the Malaysia Independent Chinese Secondary School Working Committee (MICSS) and is based on the chemistry syllabus for secondary schools. There are three volumes of upper secondary school chemistry textbooks for students from grade 10 to grade 12. In this study, the Upper Secondary School Chemistry Textbook for grade 10 students (MICSS, 1996; later called MY1) was analyzed. [3]

Altogether, the sample for the current study consists of seven textbooks for the first year of upper secondary education (grade 10) in different Chinese communities. There are three sets of textbooks (Renjiao Edition, Luke Edition and Sujiao Edition, CN1-CN3) that are widely used in many provinces in the People’s Republic of China. One other textbook (Shangke Edition, CN4) is mainly used in Shanghai. Two textbooks stem from Taiwan (Lungteng Edition and Nan I Edition, TW1-TW2) and one textbook is from Malaysia (MY1). All the textbooks are compiled either in simplified Chinese (CN1-4, MY1) or traditional Chinese (TW1-2). More information is available in **Appendix 1**.

METHOD

The textbooks were qualitatively and interpretatively analyzed in a cyclical approach as described by Khaddoor et al. (2017). All data were analyzed in an iterative, back-and-forth process (Teddlie & Tashakkori, 2009). A first cycle was carried out for technical aspects of the textbooks as inspired by Devetak and Vogrinc (2013). The first cycle of analysis focused on structural elements found in the textbooks, including the number of chapters, pages, pictures, etc. (**Table 1**).

Table 1. Criteria for the first cycle of analysis (adapted from Devetak & Vogrinc, 2013)

General criteria	Subcategory	Description
General structure	- Number of pages - Chapters - English words - Exercises	The structure of the textbook that is the focus in the analysis. Each element of the structure is analysed and categorized.
Textual material	- Learning goals - Instructions for practical work - Appearance of modern issues	This analysis identifies the frequency and placement of the subcategories. Is descriptive/narrative information about key facts, concepts, principles and laws, etc. more subject or scientific field driven? Does the text present, discuss, identify or reflect upon scientific knowledge on a harmonized level?
Numbers of visual representations	- Everyday life images - Sub-microscopic pictures - Pictures with human beings	This step looks for pictures from everyday life, about scientific models and sub-microscopic illustrations, or pictures with human beings.

A second cycle analysed the textbooks using an inductive approach, it was nevertheless inspired by the issues described in Khaddoor et al. (2017). The final categories include the representation of content, use of visual representations, suggestions for practical work and activities, issues of tasks and assessment, appearance of modern issues in chemistry, the curriculum emphases, and the orientation of the curriculum. Each category was checked for appearance of any potential sub-categories given in **Table 2**. All the main characteristics from **Table 2** were then interpretatively rated to which degree the corresponding feature and its sub-categories are present in the book and which role they play using a four-step scale as given in **Table 3**.

Table 2. Categories for developing the characterization of the textbooks adapted from Khaddoor et al. (2017)

Category	Subcategory
Content representation	- Chapters contain introductions and summaries - Chapters provide context-based overviews and describe prerequisite skills - Theories, facts and principles are embedded in meaningful contexts - Metaphors, analogies and models are used to support content - Texts are referred to non-textual representations - Interdisciplinary references are integrated - Vocational orientation is provided
Visual representation	- Visual aids and colourful pictures are used for illustration - Images/visual elements support text/explanation - Visualizations support sub-microscopic level understanding
Practical work and activities	- Practical activities are suggested - Experiments are suggested to resonate with students' interests - Inquiry-based experiments are suggested - Online learning is suggested
Tasks and assessment	- Real world applications are used in problem-solving tasks - Assessment uses multilevel type questions - English learning is integrated with science learning
Modern issues in chemistry	- Environmental and sustainability issues - Modern technologies, e.g. nano-chemistry
Curriculum emphasis	- Fundamental Chemistry - Knowledge Development in Chemistry - Chemistry, Technology, Society
Curriculum orientation	- Structure of the discipline orientation - History of science orientation - Everyday life orientation - Environmental orientation - Industry and technology orientation - Socio-scientific issues orientation

Table 3. Pattern to interpret the presence and role of certain features in the textbooks

Description	Example
The corresponding feature is present throughout the book and plays a central role in the appearance and character of the book.	Contexts or colorful illustrations are used throughout the whole book to approach content learning. The chapters start with contexts and illustrations leading to chemistry content.
The corresponding feature is present throughout the book, but it does not play a central role in the appearance and character of the book.	Contexts or colorful illustrations are regularly used in the book to support and illustrate content learning. But the learning does not really begin with the contexts and illustrations.
The corresponding feature is present in the book, but only in certain places and plays a minor role in the appearance and character of the book.	Contexts or colorful illustrations are used in the book to support learning, But the contexts and illustrations are only used here and there and not systematically.
The corresponding feature is absent or almost completely absent in the book.	Contexts or colorful illustrations are very rarely (or never) used in the book to support learning.

A final round of analysis based on a memo-approach. The memo-approach was done by writing a memo, a short characteristic text, of each of the textbooks that then was discussed in the research group to whether it sufficiently characterizes the textbooks in terms of the first two cycles of the analysis. This step of analysis captured links, looked for relationships, asked questions of the collective data, and identified the main concerns for each of the textbooks for later comparison. This analysis aimed to give a general description of the textbooks' characteristics in terms of content representation, suggested activity, modern topics, curriculum emphases, curriculum orientation, and any overall indicators for modern, student-centred science education. The memos were validated in a communicative process among the authors. Each memo was checked backward and forward across the data from the process of analysis in order to provide interpretation, express the main position and keep track of the train of logic. All the analyses were done by the first author under supervision of the third author and checked and discussed among all authors for final interpretations.

FINDINGS

Our findings suggest that a wide variety of characteristics exists among the textbooks concerning how the intended curriculum is presented to the teacher and learner. However, there are larger differences between the textbooks from different Chinese communities than there are within them. This holds true for the People's Republic of China, Taiwan and the Chinese minority in Malaysia. The main topics in the different textbooks can be found in **Appendix 2**. Selected characteristics from the first round of analysis are given in **Appendix 3**. **Table 4** provides a comparison of the different textbooks with reference to certain characteristics that emerged during the second cycle of analysis. The textbooks were interpreted to whether certain features are used in a high, medium, or low way, or are almost absent with respect to the characterization of **Table 3**. If certain characteristics appeared throughout the textbook, we coded this as "high". If the corresponding characteristics is very limited or even absent in the textbook, we coded it as "low". If the characteristic is used discontinuously this was coded as "medium". **Table 5** provides an overview about the dominant curriculum emphasis and the prevalent curriculum orientations operated in each of the textbooks.

Table 4. Rating of certain characteristics of the textbooks

Textbook	Meaningful textual contextualisation of content	Meaningful and rich use of visual representations	Suggestions for practical work	Use of tasks and assessment	Appearance of modern issues
CN1	medium	medium	high	medium	medium
CN2	medium	medium	high	medium	medium
CN3	medium	medium	medium	medium	medium
CN4	medium	medium	medium	medium	low
TW1	high	high	low	high	high
TW2	high	high	medium	high	medium
MY1	low	low	low	medium	low

Table 4 indicates the contextualization of content and the rich use of visual representation in Taiwanese textbooks, while contextualization in the Malaysian textbook is quite limited. Textbooks from China lie in between. The structure of discipline curriculum orientation in the Malaysian textbook is dominant. This orientation is lower in textbooks from the Peoples Republic of China. Also in Taiwan it is not very dominate while the chemistry, technology and society emphasis is considered being more important (**Table 5**).

Table 5. Prevalent curriculum emphasis and used curriculum orientations

Textbook	Main curriculum emphasis	Use of orientations of the curriculum operated in the book
CN1	FC	• structure of the discipline (medium) • everyday life (medium) • history of chemistry (low) • SSI (low) • industry and technology (low) • environmental (low)
CN2	FC	• everyday life (high) • structure of the discipline (medium) • industry and technology (medium) • history of chemistry (low) • SSI (low) • environmental (low)
CN3	FC	• SSI (high) • structure of the discipline (medium) • everyday life (medium) • industry and technology (medium) • history of chemistry (low) • environmental (low)
CN4	FC	• structure of the discipline (high) • history of chemistry (high) • everyday life (low) • industry and technology (low) • environmental (low)
TW1	CTS	• everyday life (high) • history of chemistry (high) • SSI (high) • industry and technology (medium) • structure of the discipline (low) • environmental (low)
TW2	CTS	• everyday life (high) • history of chemistry (high) • SSI (high) • environmental (medium) • industry and technology (low) • structure of the discipline (low)
MY1	FC	• structure of the discipline (high) • history of chemistry (low) • everyday life (low) • environmental (low)

People's Republic of China

The textbooks from the People's Republic of China have many similarities in their intended curriculum structure, content framework, and visual representation. Charts, tables, diagrams, pictures are provided to support learning from the texts. Submicroscopic models aid learning about theories and laws in certain places, but their use is limited.

Indications of context-based learning can be found in all the textbooks CN1-4, but they generally do not aid learning as a starting point. The Luke (CN2) textbook offers more everyday life pictures compared to the other three textbooks and practical activities related to everyday life are suggested by this book in certain places. Examples include looking at the labels on food, condiments, household cleaners, pill bottles and cosmetics and in listing the names of substances which contain chlorine, bromine or iodine. Everyday life pictures are linked to theoretical learning. For example, the use of sodium hypochlorite disinfectant is taken as the context for approaching chlorine containing compounds. Environmental issues are quite limited in these four textbooks. Green chemistry and nanotechnology are briefly mentioned in certain places.

In terms of content representation, theories, concepts, facts, principles and laws are embedded in contexts at specific points. Interdisciplinary approaches can be found in the Renjiao/Luke/Sujiao (CN1/CN2/CN3) textbooks, mainly dealing with chemistry-biology, chemistry-pharmacy, except for the Shangke textbook (CN4). The Shangke textbook focuses more on chemistry-English interdisciplinary learning. The textbook applies English tasks consistently throughout the book. For example, a short essay related to acid rain is provided for students' reading comprehension skills and an essay related to chlorine asks students to write down related chemical equations in combination with their English reading comprehension and chemistry knowledge. All of the other textbooks apply English terms in differing degrees, most of them, however, involve English learning only at the level of providing essential key words.

Pictures of human beings are used in each textbook, with the Shangke textbook (CN4) having the lowest number of representations. A Chinese chemical industrialist, Wu Yunchu, and a Chinese revolutionary, Fang Zhimin, are mentioned by this book, but no Chinese scientists are mentioned. The Sujiao textbook (CN3) presents aspects of the history of science in connection with chemical theory development using examples like the chronological progression of models of atomic structure, the construction of the periodic table, etc. One aspect refers to the Hou's process for soda production, which was developed by the Chinese chemist, Hou Debang. Other examples include the synthesis of aspirin and the application of penicillin in the Second World War. Historical science is employed in the Shangke textbook (CN4), which discusses the discovery of batteries, covers the story of human beings recognizing the function of catalysts, and tells individual scientists' stories with pictures.

Experiments in all the four textbooks are clearly described with specific reagents and detailed instructions. Charts with blank fields are provided for students to write down experimental records. Inquiry-based learning can be found in certain places, but is limited in scope. Internet searches are mainly suggested as online learning exercises to find more information on topics like the elements, health issues, acid rain, the periodic table of the elements, etc. Diversified vocations are mentioned widely by the Luke textbook (CN2), which assigns equal emphasis in terms of vocational status. Common vocations described included: researcher, chemist, doctor, fireman, athlete, engineer, technician, teacher, and policeman.

Basically, all the textbooks from the People's Republic of China focus on fundamental knowledge. Theories, concepts, facts, principles and laws are connected to meaningful contexts, but the contexts are generally not discussed on their own right. Indications for student-active learning can be found, e.g. industry visits (CN4), essay writing, brainstorming, role play tasks (CN1), hands-on creation work (CN2), but are quite limited in extent. Some topics are also connected to socio-scientific issues, for example, exhausts from cars or the context that coal burning in power plants can lead to nitrogen oxides and sulfur dioxide that can cause acid rain (CN4). In addition, one chapter introduces issues of chemistry in connection to human civilization and the use of new energy supplies and sustainable development (CN3), but this does not play a central role in the intended curriculum. The representation of technology and society issues is also linked to theoretical learning at certain places.

The differences between CN1-3 and the textbook from Shanghai (CN4) lie mainly in the more intense use of contextualization provided at the beginning of each chapter, more use of English language tasks, and more references to the historical development of chemistry in CN4. Nevertheless, the Shangke (CN4) textbook maintains a content-based rather than context-based approach and thus is not substantially different from the CN1-3 textbooks.

Taiwan

In terms of the presentation of the intended curriculum, both Taiwanese textbooks provide thorough contextual introductions and illustrations. Every chapter is based on textual and pictorial contextualization. It is notable that both Taiwanese textbooks include more visual representations than the textbooks from the other Chinese communities. The modes of representation include links between the macro- and submicroscopic levels. They also use macro-symbolic and macro-submicro-symbolic representations. These linkages allow learners to visualize and construct unobservable chemical knowledge meaningfully. This unique adoption of representations is found throughout the textbooks, and the representations are also aligned with the three important representational levels of chemistry, namely macroscopic, submicroscopic, and symbolic representations (Johnstone, 1993, 2000; Talanquer, 2011).

Theories, concepts, facts, principles and laws are embedded in consistent and meaningful contexts in the Taiwanese textbooks. Contextualized metaphors and analogies are arranged to support the learning of basic concepts. Images of submicroscopic models are integrated as scaffolding tools to enhance visualization and understanding of the chemical knowledge (such as balancing chemical equations). For example, the process of making a cup of tea and the different character of moorstone and stainless steel (TW1) are described by the text. Pictures illustrate the production and molecular representations of the processes to promote students' understanding of the classification of matter and the difference between homogeneous and heterogeneous mixtures of substances. Similar contextualized examples (such as hand warmers) can be found throughout the book. This can be viewed as an indicator of context-based learning that relates to students' lives. Everyday life applications appear in the Taiwanese textbooks in each chapter. Gender balance is also taken into consideration for human character illustrations. Socio-scientific issues such as the alleged energy crisis and renewable energy exploitation are also included. However, the socio-scientific issues focus the scientific content and do not provide any socio-economic reflection. Genetic engineering is mentioned in TW1. Green chemistry is also discussed in one of the Taiwanese textbooks (TW2).

The design of the Lungteng Edition (TW1) offers a concept map at the very beginning of the textbook and provides an overview of the key concepts to be learned in each chapter. At the end of each chapter, in addition to a summary, the Nan-I Edition (TW2) provides an extra concept tree to summarize key concepts/laws/theories; it also explicitly highlights learning objectives in terms of concepts and competence with different levels of epistemic understanding, such as knowing, understanding, describing, explaining, etc. Examples are (1) to *know* the difference between pure substance and mixture, (2) to *understand* the meaning of valence electron and valence shell, (3) to *describe* the 18 groups in the periodic table, and (4) to *explain* the properties of metal elements. There is also limited integration of interdisciplinary references.

Both Taiwanese textbooks provide also a glossary of chemical terms with their English equivalents. The purpose of the English translation is to prepare students for university level coursework, in which English terminology is often used. The history of science is described chronologically, with TW1 focusing basically on the knowledge development in science and TW2 targeting the scientists and their contributions to the development of science.

The two textbooks seem to place less emphasis on student participation in experiments, except for a few demonstrations like chromatography in TW2. Experiments are mostly presented by colorful images without much description of the procedures. No observational details for the experiments are mentioned. Practical activities like making a weather bottle or building a hydrogen oxygen fuel battery car are mentioned as supplementary resources but include few instructions. This lack of hands-on activities in the textbooks was not due to an ignorance about the importance of experiments on Taiwan's part. On the contrary, experiments are considered to be a central pillar of scientific disciplines. A separate book for laboratory activities is suggested to be used by the students.

Although the Taiwanese textbooks cover key concepts in chemistry, the depth of the content does not match that found in the Chinese textbooks. The topics provided by both of the two Taiwanese textbooks for grade 10 (**Appendix 2**) is nearly half the amount of the content in the textbooks from Mainland China (CN1-4). When compared to the Malaysian textbooks, where 14 chapters appeared in grade 10, the topics in the Taiwanese textbook are not dealt with in a similar depth. This is not to say that Taiwanese textbooks have "easier" content, since in the Taiwanese curriculum the deeper content found in the Chinese textbooks were moved to Grades 11 and 12 as electives for science majors. The focus of 10th grade science in Taiwan is not stuffing as much information into the students as possible. As the characteristic of the textbooks showed in **Table 4** and the curriculum emphasis and orientation demonstrated by **Table 5**, it can be seen that contextualization in the Taiwanese textbooks is high, while the textbooks from Mainland China are to be considered as medium contextualized. Rather it is to strengthen the foundations upon which students can build, should they choose to become science majors the following year. Further data shows that the 10th grade Taiwanese textbooks aim at providing basic chemical principles and applications rather than focusing practical skills development or using demonstrations (**Appendix 3**). Consequently, the textbooks from Taiwan focus more on conceptual understanding as compared to the textbooks from China, which focus more on algorithmic problem solving.

Malaysia

The textbook from Malaysia is quite traditional and focuses mainly on fundamental chemistry learning. Images/visual elements are provided to help text comprehension, but occur mostly in gray-scale. Almost no colorful, high resolution illustrations can be found. Theoretical perspectives are emphasized much more than everyday life events. Students' present and anticipated interests are insufficiently embodied.

Five out of the fourteen chapters begin chemistry learning without using any meaningful context as an introduction. The rest of the chapters are supported by simplified contextualization, which at least tries to connect learning of chemistry with everyday life applications to a limited extent. Metaphors, analogies and models can be found, but only in limited places. At several points the curriculum refers to technological and environmental issues such as hydrogen energy, solar energy, embryo cryogenics, fiber-optic cables, and acid rain. Essential academic English terms are provided throughout the textbook. Both men and women are shown in pictures in the textbook. The history of science can be found in references to alchemy, the progression of models of atomic structure, and the milestones of modern chemical theories.

Practical activities and online learning are less-well represented. Exercises given by the Malaysian textbook focus almost completely on basic theories, facts and laws, rather than on real world applications and problem-solving activities. Inquiry-based learning is absent. Some experimental descriptions are difficult to image because they are only presented in black-and-white or gray-scale pictures. Summaries at the end of each chapter are provided with simplified overviews. Overall, the textbook from Malaysia presents chemistry in the least contextualized and illustrated manner of all seven textbooks in the sample.

DISCUSSION AND CONCLUSION

As mentioned before, there are larger differences between the textbooks from different Chinese communities than within them. This is especially the case in terms of the Taiwanese books. Both the two Taiwanese textbooks almost share the same amount of page number (see **Appendix 3**) and very similar topics (see **Appendix 2**). This is also the case for the CN1-3 textbooks (see **Appendix 2** & **3**), but not for the case of CN4. The reason might be that the books in this study are each written according to different official curriculum standards released by corresponding Ministries of Education. The textbook editing community generally consists of education specialists, teachers and researchers, while the editors (mostly education specialists) are in charge of decision-making, designing, organizing and implanting of the textbook editing (Sun et al., 2016).

Our findings indicate a wide range of different curriculum emphases and orientations in the seven selected textbooks, as it was also described for a set of Arab countries by Khaddoor et al. (2017). Some of the intended curricula can be considered to be driven by applications of chemistry, relevant issues, and processes as described by Holman (1987). This is the case for the textbooks from Taiwan and to a certain extent, by several textbooks from the People's Republic of China. There are, however, indications that the textbooks from the People's Republic of China could be better align the learning of chemistry with everyday life contexts and societal views on the applications of chemistry as it is suggested in reform for science education in the People's Republic of China (Wang et al., 2016). The textbook from Malaysia is the most traditional of the group. It operates mainly as a vehicle conveying a fundamental chemistry emphasis and a structure-of-the-discipline orientation of the curriculum as it was prevalent in Western science education up to the 1970s (Eilks et al., 2013) and still is in many other countries of the world until today (Khaddoor et al., 2017). It makes very little use of meaningful contexts from everyday life, technology, the environment, or society and thus is not in line with modern trends for chemistry curricula (Eilks et al., 2013).

In this sample, the textbooks from Taiwan seem to best fit what modern research prescribes for chemistry curricula and their representations, namely student-active learning embedded in meaningful contexts (Eilks et al., 2013) with rich and helpful illustrations (Devetak & Vogrinc, 2013). Both Taiwanese textbooks try to embed chemistry into the details of students' lives in order to make it more relevant or at least to promote the perception of relevance as e.g. discussed in Childs, Hayes and O'Dwyer (2015). In addition, linkage between phenomena at the macroscopic, microscopic, and symbolic levels are effectively used in order to promote a better understanding of chemistry (Johnstone, 1991). Basically, these representations support a chemistry-technology-society curriculum emphasis and orientation which is suggested to go beyond simple contextualization by everyday life orientation (Hofstein, Eilks & Bybee, 2011). Based upon PISA results, students from Taiwan and some other Asian countries and regions outperformed other participating countries. But they also showed lower interest and motivation in learning science. A context-based approach in textbooks might be a solution to move students from rote memorization to active application when learning (King, 2012). Textbooks from the People's Republic of China are more limited in this respect compared to the textbooks from Taiwan. Yet the People's Republic of China has recently started curriculum reform towards a more context-based education (Huang, 2004). Indications of more contextualization in textbooks seem to emerge from this movement assumed that older textbooks were more traditional in this respect as they were in many countries of the world (Eilks et al., 2013). The textbooks from the People's Republic of China today show indications of beginning focus on context-based and societal-oriented chemistry education, which is now starting to be implemented. The same cannot yet be said for the Chinese minority textbooks from Malaysia.

Taiwan has been closely following the research and development of science curricula started in Western countries since the 1970s. Taiwanese science educators have also been actively participating in and contributing to the international science education community since then (Chiu, 2016). This may have influenced the Taiwanese curriculum and the style of textbooks designed to a large extent. The People's Republic of China started this process later. In the last few decades, however, science education researchers from the People's Republic of China have also made great efforts and shown progress in the internationalization of science education research (e.g. Liu, Liang & Liu, 2012). Researchers from the People's Republic of China started reflecting both their own traditions in science education as well as how it relates to Western view on the science curriculum with in the international science education community (Wang, Wang, Zhan, Lang & Mayer, 1996). The textbooks from the People's Republic of China seem to integrate international trends into the chemistry curriculum, such as a stronger focus on context-based and societal-oriented chemistry education. It appears, however, that the corresponding changes have only started to be implemented. Time will tell. This process is one that Chinese chemistry education in Malaysia might consider to imitate.

LIMITATIONS

This study has tried to provide insight into the large variety of Chinese chemistry curricula found in textbooks from several Chinese communities. It did not analyze all available textbooks. Instead it focused only on textbooks from compulsory modules of 10th grade chemistry education and analyzed only selected aspects of the textbooks. In its current form, our study can make no predictions about how and in what manner the textbooks are being used by teachers. Nor can it address the extent to which teachers use additional resources in their chemistry classes. This would be an interesting starting point for further research efforts.

NOTES

[1] The Ministry of Education of the People's Republic of China guides national education reform, development, language policy as well as international communicating and operating. The newest upper secondary school chemistry curriculum standard was released in the end of 2017 and suggested to promote in 2018 fall. The samples in this study are based on the upper secondary school chemistry curriculum standards released in 2003.

[2] By the time we conducted the study, TW2 textbook is still used in Taiwan, from 2017 to 2018, a new version is edited and updated and go into market in August 2018.

[3] By the time we conducted the study, the Upper Secondary School Chemistry Textbook is still used in Malaysia independent Chinese secondary school, from 2018, a new version is implied.

ACKNOWLEDGEMENTS

This research is supported by a PhD grant from the China Scholarship Council (CSC). We would also like to thank Professor Mageswary Karpudewan (Malaysia) for cooperating with us on this project.

REFERENCES

Childs, P. E., Hayes, S. M., & O'Dwyer, A. (2015). Chemistry and everyday life: relating secondary school chemistry to the current and future Lives of students. In I. Eilks & A. Hofstein (Eds.), *Relevant chemistry education* (pp. 33-54). Rotterdam: Sense. https://doi.org/10.1007/978-94-6300-175-5_3

Chiu, M.-H. (Ed.). (2016). *Science education research and practices in Taiwan*. Dordrecht: Springer. https://doi.org/10.1007/978-981-287-472-6

Choi, B.-S., & Choi, A. (2016). Overview of science education research and practice in Korea. In M.-H. Chiu (Ed.), *Science education research and practice in Asia* (pp. 245-273). Dordrecht: Springer. https://doi.org/10.1007/978-981-10-0847-4_14

De Jong, O. (2006). Making chemistry meaningful: conditions for successful context-based teaching. *Educación Química, 17*, 215–226. https://doi.org/10.22201/fq.18708404e.2006.4e.66010

Devetak, I., & Vogrinc, J. (2013). The criteria for evaluating the quality of the science textbooks. In M. S. Khine (Ed.), *Critical analysis of science textbooks* (pp. 3-15). Dordrecht: Springer. https://doi.org/10.1007/978-94-007-4168-3_1

Ding, B. P. (2010). On the typologies and essential characteristics of inquiry-oriented science teaching. *Educational Research, 2010*(10), 81-85.

Dong Zong (2017). The background of Dong Zong's establishment. Retrieved on June 30, 2018, from http://www.dongzong.my/eindex.php

Eilks, I., Rauch, F., Ralle, B., & Hofstein, A. (2013). How to allocate the chemistry curriculum between science and society. In I. Eilks & A. Hofstein (Eds.), *Teaching chemistry–A studybook* (pp. 1-36). Rotterdam: Sense. https://doi.org/10.1007/978-94-6209-140-5_1

Gilbert, J. K. (2006). On the nature of context in chemical education. *International Journal of Science Education*, *28*(9), 957–976. https://doi.org/10.1080/09500690600702470

Greeno, J. G. (1998). The situativity of knowing, learning, and research. *American Psychologist*, *53*(1), 5–26. https://doi.org/10.1037/0003-066X.53.1.5

Guo, C.-J., & Chiu, M.-H. (2016). Opportunities and challenges for science education in Asia: Perspectives based on the Taiwan experience. In M.-H. Chiu (Ed.), *Science education research and practice in Asia* (pp. 175-196). Dordrecht: Springer. https://doi.org/10.1007/978-981-10-0847-4_10

Halim, L., & Meerah, T. S. M. (2016). Science education research and practice in Malaysia. In M.-H. Chiu (Ed.), *Science education research and practice in Asia* (pp. 71-93). Dordrecht: Springer. https://doi.org/10.1007/978-981-10-0847-4_5

Hofstein, A., Eilks, I., & Bybee, R. (2011). Societal issues and their importance for contemporary science education: a pedagogical justification and the state of the art in Israel, Germany and the USA. *International Journal of Science and Mathematics Education, 9*(6), 1459-1483. https://doi.org/10.1007/s10763-010-9273-9

Hofstein, A., & Kesner, M. (2015). Learning from and about Industry for Relevant Chemistry Education. In I. Eilks & A. Hofstein (Eds.), *Relevant chemistry education* (pp. 285-299). Rotterdam: Sense. https://doi.org/10.1007/978-94-6300-175-5_15

Holman, J. (1987). Resources or courses? Contrasting approaches to the introduction of industry and technology to the secondary curriculum. *School Science Review, 68*(244), 432-438.

Huang, D. S. (2010). *Basic Chemistry 1* (1st ed.). Taiwan: LungTeng Culture Co., Ltd.

Huang, F. Q. (2004). Curriculum reform in contemporary China: seven goals and six strategies. *Journal of Curriculum Studies, 36*(1), 101-115. https://doi.org/10.1080/0022027032000004742000174126

Hu, J. H., & Wang, L. (2005). Scientific teaching exploration - an inquiry-based constructive teaching. *Education Science Research, 2005*(4), 35-37.

Johnstone, A. H. (1991). Why is science difficult to learn? Things are seldom what they seem. *Journal of Computer Assisted Learning*, *7*(2), 75-83. https://doi.org/10.1111/j.1365-2729.1991.tb00230.x

Johnstone, A. H. (1993). The development of chemistry teaching: A changing response to changing domain. *Journal of Chemical Education*, *70*(9), 701-705. https://doi.org/10.1021/ed070p701

Johnstone, A. H. (2000). Teaching of chemistry-logical or psychological? *Chemistry Education Research and Practice in Europe, 1*(1), 9-15. https://doi.org/10.1039/A9RP90001B

Karpudewan, M., & Chua, K. E. (2016). Cultural background and the science laboratory learning environment: The Malaysian lower secondary students' perspective. In I. Eilks, S. Markic & B. Ralle (Eds.), *Science education research and practical work* (pp. 93-104). Aachen: Shaker.

Khaddoor, R., Al-Amoush, S., & Eilks, I. (2017). A comparative analysis of the intended curriculum and its presentation in 10th grade chemistry textbooks from seven Arabic countries. *Chemistry Education Research and Practice, 18*, 375-385. https://doi.org/10.1039/C6RP00186F

King, D. (2012). New perspectives on context-based chemistry education: using a dialectical sociocultural approach to view teaching and learning. *Studies in Science Education, 48*(1), 51-87. https://doi.org/10.1080/03057267.2012.655037

Liu, C. K., & Chiu, M. -H. (2012). Review and prospect of the development of our secondary school science curriculum over the past century. *Science Education Monthly, 347,* 2-20.

Liu, H. X. (2010). Centennial changes of basic education in Taiwan. *Education and Examination*, *2010*(6), 88-93. https://doi.org/10.16391/j.cnki.jyks.2010.06.007

Liu, X., Liang, L. L., & Liu, E. (2012). Science education research in China: challenges and promises. *International Journal of Science Education, 34*(13), 1661-1670. https://doi.org/10.1080/09500693.2012.709330

MICSS. (1996). *Upper secondary school chemistry* (1st ed.), Malaysia: United Chinese School Committees' Association of Malaysia (Dong Zong).

Roberts, D. A. (1982). Developing the concept of "curriculum emphases" in science education. *Science Education, 66*(2), 243-260. https://doi.org/10.1002/sce.3730660209

Roseman, J. E., Stern, L., & Koppal, M. (2010). A method for analyzing the coherence of high school biology textbooks. *Journal of Research in Science Teaching, 47*(1), 47-70. https://doi.org/10.1002/tea.20305

Seligardi, R. (2006). Views of chemistry and chemical theories: A comparison between two university textbooks in the Bolognese context at the beginning of the 19th century. *Science & Education, 15*, 713-737. https://doi.org/10.1007/s11191-005-2486-6

Shehab, S. S., & BouJaoude, S. (2017). Analysis of the chemical representations in secondary Lebanese chemistry textbooks. *International Journal of Science and Mathematics Education, 15*(5), 797-816. https://doi.org/10.1007/s10763-016-9720-3

Sjöström, J., Rauch, F., & Eilks, I. (2015). Chemistry education for sustainability. In I. Eilks & A. Hofstein (Eds.), *Relevant chemistry education* (pp. 163-184). Rotterdam: Sense. https://doi.org/10.1007/978-94-6300-175-5_9

Song, X. Q. (Ed.). (2007a). *Chemistry 1* (3rd ed.). Beijing: People Education Press.

Song, X. Q. (Ed.). (2007b). *Chemistry 2* (3rd ed.). Beijing: People Education Press.

Stein, M., Stuen, C., Carnine, D., & Long, R. M. (2001). Textbook evaluation and adoption. *Reading & Writing Quarterly, 17*(1), 5-23. https://doi.org/10.1080/105735601455710

Stuckey, M., Hofstein, A., Mamlok-Naaman, R., & Eilks, I. (2013). The meaning of 'relevance' in science education and its implications for the science curriculum. *Studies in Science Education, 49*(1), 1-34. https://doi.org/10.1080/03057267.2013.802463

Sun, Y. Q., Xu, D. F., Zhang, F. S., & Zhao, C. X. (Eds.). (2016). *25 Years of Shanghai curriculum reform*, Shanghai: Shanghai Educational Publishing House.

Talanquer, V. (2011). Macro, submicro, and symbolic: the many faces of the chemistry "triplet", *International Journal of Science Education, 33*(2), 179-195. https://doi.org/10.1080/09500690903386435

Teddlie, C. & Tashakkori, A. (Eds.). (2009). *Foundations of mixed methods research: Integrating quantitative and qualitative approaches in the social and behavioral sciences.* Thousand Oaks: Sage.

Van Berkel, B. (2005). The structure of current school chemistry – a quest for conditions for escape. Utrecht: CD-β.

Van Driel, J. H., Bulte, A. M. W., & Verloop, N. (2007). The relationship between teachers' general beliefs about teaching and learning and their domain specific curricular beliefs. *Learning and Instruction, 17*(2), 156–171. https://doi.org/10.1016/j.learninstruc.2007.01.010

Wang, L. (Ed.). (2007a). *Chemistry 1* (3rd ed.). Shandong: Shandong Science and Technology Press.

Wang, L. (Ed.). (2007b). *Chemistry* 2 (3rd ed.). Shandong: Shandong Science and Technology Press.

Wang, L. (2010). Basic chemistry education curriculum reform progress and reflection in the past years (Volume I). *Chinese Journal of Chemical Education, 31*(4), 15-21.

Wang, L., Zhu, Y. J., Jiang, Y. X., Wei, R., Zhou, Y., Guo, Y. Y., Wei, X., Yang, W. Y., & Liu E. S. (2016). Science education research in mainland China. In M.-H. Chiu (Ed.). *Science education research and practice in Asia* (pp. 17-39). Dordrecht: Springer. https://doi.org/10.1007/978-981-10-0847-4_2

Wang, S. H., & He, C. X. (2012). The comparison of "chemical reaction rate" content represented in different high school chemistry textbooks. *Teaching and Learning Reference for Middle School Chemistry*, *2012*(4), 40-43.

Wang, Z. H. (Ed.). (2014). *Chemistry 1* (6th ed.). Nanjing: Jiangsu Education Press.

Wang, Z. H. (Ed.). (2015). *Chemistry 2* (6th ed.). Nanjing: Jiangsu Education Press.

Wang, W. J., Wang J. Y., Zhang G. Z., Lang Y., & Mayer V. J. (1996). Science education in the People's Republic of China. Science Education, *80*(2), 202-223. https://doi.org/10.1002/(SICI)1098-237X(199604)80:2<203::AID-SCE5>3.0.CO;2-K

Xiong, Z. D., & Chen, J. C. (2001). A brief history of the evolution of science education in primary and secondary schools in Taiwan. *Asia-Pacific Forum on Science Learning and Teaching*, *2*(1), 1-6.

Yao, Z. P. (Ed.). (2007a). *Chemistry Volume 1* (1st ed.). Shanghai: Shanghai Scientific and Technical Publishers.

Yao, Z. P. (Ed.). (2007b). *Chemistry Volume 2* (1st ed.). Shanghai: Shanghai Scientific and Technical Publishers.

Yeh, M. C. P. (Ed.). (2010). *Basic Chemistry 1* (1st ed.). Taiwan: Nan I Book Enterprise Co., Ltd.

Zhong, X. M. (2005). Challenge and development. *Curriculum, Teaching Material and Method, 25*(8), 79-83.

APPENDIX 1

Overview about the Textbooks

Country	Chief Editor	Title	Publisher	Version	Publication Date	Edition
People's Republic of China	Xinqi Song	Chemistry 1	PEP	Renjiao Edition	March 2007	3rd
	Xinqi Song	Chemistry 2	PEP	Renjiao Edition	March 2007	3rd
	Zuhao Wang	Chemistry 1	JEP	Sujiao Edition	June 2014	6th
	Zuhao Wang	Chemistry 2	JEP	Sujiao Edition	June 2015	6th
	Lei Wang	Chemistry 1	SSTP1	Luke Edition	July 2007	3rd
	Lei Wang	Chemistry 2	SSTP1	Luke Edition	July 2007	3rd
	Zipeng Yao	Chemistry	SSTP2	Shangke Edition	July 2007	1st
	Zipeng Yao	Chemistry	SSTP2	Shangke Edition	January 2007	1st
Taiwan	Ded-Shih Huang	Basic Chemistry 1	LTC	Lungteng Edition	March 2010	1st
	Ming-Chang P. Yeh	Basic Chemsitry 1	Nan I	Nan I Edition	April 2010	1st
Malaysia	MICSS	Upper Secondary School Chemistry	Dong Zong	Malaysia	November 1996	1st

Note. PEP=People's Education Press, JEP=Jiangsu Education Press, SSTP1=Shandong Science and Technology Press, SSTP2=Shanghai Scientific and Technical Publishers, LTC=LungTeng Culture Lungteng Cultural Co., Ltd, Nan I= Nan I Book Enterprise Co., Ltd, Dong Zong=United Chinese School Committees' Association of Malaysia.

APPENDIX 2

Main Topics of the Curriculum Referring to the Textbooks

Textbook	topic
CN1	• chemistry from the experiment • chemical substances • non-/metals and their compounds • the periodic table • chemical reactions and energy • organic compounds • chemistry and natural resources
CN2	• chemical sciences • 3 chapters related to elements • atomic structure and the periodic table • chemical bond, chemical reaction and energy • organic compounds
CN3	• the material world • seawater resources • mineral and foundation material • sulphur, nitrogen and sustainable development • macrostructure and material diversity • chemical reaction and energy • organic compounds • chemistry and human civilization
CN4	• atomic structure • halogen resources in seawater • chemical substances built by atoms • the change of energy in changes of substances • nitrogen and sulphur • chemical equilibrium and rate • electrolytic solutions
TW1	• composition and properties of matter • atomic structure and periodic table • chemical reactions • chemistry and energy
TW2	• composition of matter • atomic structure and periodic table • chemical equations and chemical calculation • chemistry and energy
MY1	• introduction • water and hydrogen • molecules and atoms • chemical equations and calculations • atomic structure • periodic table • chemical bonds • redox reactions • halogens • 2 chapters of metals and their compounds • 3 chapters of non-metals and their compounds

APPENDIX 3

Selected Findings from the First Round of Analysis

Criteria	People's Republic of China				Taiwan		Malaysia
	CN1	**CN2**	**CN3**	**CN4**	**TW1**	**TW2**	**MY1**
Pages	223	242	220	185	189	180	347
Chapters	8	7	8	7	4	4	14
Pictures	155	277	161	138	148	106	201
Pictures from everyday life	59	124	61	33	62	34	65
Pictures with human beings	4	5	3	2	4	2	7
Pictures using the sub-microscopic level	13	31	29	15	17	19	16
References to modern challenges related to chemistry, e.g. sustainability issues or modern technologies	13	11	15	7	25	14	5
Reference to experiments (simple experiments, inquiry experiments, demonstrations)	52	71	44	62	17	20	40
Practical activities (e.g. building molecular structures, site visits, pH test of rainwater, etc.)	9	5	2	3	2	1	0

PAPER 2

An Analysis of the Visual Representation of Redox Reactions in Secondary Chemistry Textbooks from Different Chinese Communities

Accepted by

Education Sciences

11 February 2019

Author Contributions: The conceptualization of this paper was made by Xiaoge Chen, Luciane F. de Goes and Ingo Eilks. Xiaoge Chen completed the textbook analyses with an initial pilot analyzing with Luciane F. de Goes and Ingo Eilks. The methodology was evaluated by David F. Treagust and Ingo Eilks. The first version of the manuscript was written by Xiaoge Chen and then finalized and reviewed by all authors.

education sciences

MDPI

Article

An Analysis of the Visual Representation of Redox Reactions in Secondary Chemistry Textbooks from Different Chinese Communities

Xiaoge Chen [1,*], Luciane F. de Goes [2], David F. Treagust [3] and Ingo Eilks [1]

1 Department of Biology and Chemistry, Institute for Science Education, University of Bremen, Leobener Str. NW2, 28359 Bremen, Germany; ingo.eilks@uni-bremen.de
2 Institute of Chemistry, University of São Paulo, Av. Prof. Lineu Prestes, 748, Butantã, São Paulo, SP 05508-000, Brazil; luciane.goes@usp.br
3 STEM Education Research Group, Curtin University, Perth WA 6845, Australia; D.Treagust@curtin.edu.au
* Correspondence: chen@uni-bremen.de; Tel.: +49-421-218-63276

Received: 4 December 2018; Accepted: 11 February 2019; Published: 19 February 2019

Abstract: This study provides an analysis of selected aspects of the intended curriculum related to redox reactions as represented in secondary chemistry textbooks from the People's Republic of China, with a special view also on Hong Kong, Shanghai, Taiwan, and the Chinese minority in Malaysia. This study reveals how chemistry textbooks deal with visual representations related to redox reactions and whether or not the visualizations provide any indication for the orientation of the intended curriculum, characterized by contexts suggested for chemistry learning. Specific criteria were derived from a literature review of the discussion on different levels of chemical representations and from a total of 346 visual representations related to redox reactions identified and analyzed from the textbooks. Based on the frequencies and levels of visual representations in the textbooks, this study showed that representations in textbooks from the People's Republic of China mostly focus on the macro and macro-symbolic levels and indicate some aspects of everyday life as well as orientations towards industry and technology. The findings show that the textbook from Taiwan uses multiple macroscopic, submicroscopic, and symbolic representations to illustrate the redox reactions. The textbook from Hong Kong has a strong orientation along the content structure of chemistry, with mostly macro level representations. The textbook from the Chinese minority in Malaysia follows a strong structure-of-discipline orientation with limited visual support.

Keywords: chemistry education; redox reactions; textbooks; visual representations

1. Introduction

A central concept of understanding common difficulties in teaching and learning chemistry suggested in 1991 by Johnstone [1] concerns the chemical thinking needed between three representational levels, namely, the macroscopic, submicroscopic, and symbolic levels. This central concept has been used for analysis of chemistry textbooks [2]. Macroscopically, students are required to observe, for example, combustion. In parallel, they are expected to imagine electron movements to provide an explanation at the particulate submicroscopic level. At the symbolic level, students are asked to represent the reaction by writing an equation of the chemical reaction by interrelating the symbolic level with both the macroscopic substances and submicroscopic chemical entities. Indeed, this is not an easy task and many students tend to most frequently focus their thinking at the macroscopic level because they live in a macroscopic world and can make experiences and observations at this level [3]. The concept of Johnstone's triangle of representational levels is not without critics and does need careful reflection, especially when planning assessment decisions on the use of the different representational levels [4] or how it is used by teachers [5]. Nevertheless, the triangle has become a standard in chemistry education because it sheds light on chemical thinking and learning by attending to the three different levels. The triangle has also been further discussed and enriched, e.g., by Sjöström and Talanquer [6], based on Mahaffy's work [7], to form a tetrahedron which has an apex representing the human or contextual element of chemistry.

Österlund, Berg and Ekborg [8] argue that chemical reactions can explain a large degree of the world we live in and redox reactions provide a wide range of daily applications of the corresponding content being studied. Redox reactions such as combustion belong to the central concepts taught in almost every secondary school chemistry curriculum [9] and this is the case for chemistry education in the People's Republic of China, with a special view also on Hong Kong, Shanghai, Taiwan and Malaysia. Redox reactions are related to, and important for, understanding everyday issues such as corrosion, the functioning of a battery, and electroplating [10]. Redox reactions provide fundamental knowledge for later learning in chemistry, for example, advanced electrochemistry or organic chemistry, and other subjects such as biology [8]. Redox reactions are, however, widely perceived as being difficult to comprehend both for secondary school pupils and university students [11–14] as well as being difficult to teach [15].

Redox reactions cannot be fully understood without integrating macroscopic and submicroscopic perspectives. They represent one type of chemical reaction that is based on the gain or loss of electrons. Redox reactions occur by electron transfer between different chemical species, namely, atoms, molecules or lattice structures. Shibley Jr. et al. [16] summarized different approaches of teaching redox reactions and suggested more straightforward ways to help students' learning chemistry based on understanding instead of rote memorization.

Problems in understanding redox reactions among students are often situated at the different representational levels of chemistry and their inter-relations, e.g., macroscopic (the identification of the reacting compounds, e.g., if gases are employed), submicroscopic and symbolic (redox process and reaction equations), or all three levels (reaction processes represented by compounds, particles, and formulae) [17]. Particularly when it comes to connecting the macroscopic and contextual levels with the submicroscopic and symbolic levels, a careful selection of models and related visual representations becomes important to avoid further misunderstanding [18]. A great deal of effort has been made in the past to analyze the application of different models of redox reactions, different teaching and learning difficulties and various teaching strategies [15]. There has been less discussion on the analysis of visual representations of redox reactions and their connection to the contextual domain shown in textbooks.

As already noted, research indicates that students often have difficulties in correctly relating the different levels of representations to one another [19] even when visual representations should help students make the right connections. Therefore, it is recommended to thoroughly use visual representations of the different representational levels of chemistry in chemistry teaching and learning [2]. To meet this recommendation, it is important for teachers to know how to deal with and how to connect the different representational levels in chemistry, and how to use different representations of redox reactions content [20]. However, studies have revealed that teachers can also have difficulties in dealing with the different representational levels by either moving between the levels in a non-reflective way or, as their students do, by prioritizing the macroscopic level [3]. Visualization can offer help in better dealing with the different representational levels [21], but this is only the case if students are guided on how to interpret the three levels [22]. Visual representations also have the potential to contribute to a better comprehension of the textbooks [23].

Pintó and Ametller [22] claim that an image goes beyond a thousand words, but this adage only applies when the viewer knows how to recode and interpret the image. One example where the image does not always help learning is when students are exposed to different historical representations of the models of the atom without clearly understanding the reason why they are being exposed to so many different models [24]. Recent research shows that one reason for the lack of understanding is that students often have difficulties in recoding and translating representations [25] and that more consideration should be given to aiding students' interpretation of images [26]. In this respect, unfortunately, sometimes teachers confuse the different models in their instruction [27].

Modern chemistry education should embed the learning of abstract content into meaningful and relevant contexts [28–30]. In doing so, chemistry education should combine learning about submicroscopic entities and processes with the relevant macroscopic phenomena [1]. Both representational levels can benefit from visual support because a lot of the concepts in science, technology, engineering and mathematics (STEM) are visual–spatial in nature [31]. Visual representation can significantly improve learning when learners interact with the representation appropriately [32]. Many students, however, also have difficulties in understanding and making sense of certain visual representations especially when there is more than one representation [33].

Different curriculum structures and orientations [34] enable different views on the relevance of science education [28] to be transferred to chemistry textbooks. Textbooks are influenced by the authors' writing and explanation styles and transmit the authors' interpretation of the national curriculum. However, if textbooks are approved officially by educational authorities, such as the given ministries of education, they then represent an intended official curriculum [35]. Textbooks, however, are also influenced by commonly used practices when written by experienced teachers. In this way, Devetak and Vogrinc [36] suggest that textbooks also provide indicators of common classroom practices.

Textbooks have an important place in education; they provide a particular resource for teachers and students. Textbooks define a subject to the students and help to represent a school subject as students experience it [36]. Textbooks present both the content and the orientation of the curriculum [37] by forming a bridge for the translation of the official standards or syllabi into the implemented chemistry curriculum [38]. Textbooks offer both text content and visual representation to students. It is hard to say how the individual teacher will use a certain textbook but the teachers´ usage of chemistry textbooks in many countries, e.g., in the People's Republic of China, is generally quite high [39]. Nothing, however, guarantees that teachers will follow the suggested path and activities [40]. Nevertheless, the textbook represents a kind of ideal and formal curriculum [41] that the teachers are expected to implement.

Since chemistry textbooks are the medium between chemistry and the learner [42], textbook analysis is gaining increasing interest in chemistry education in general (e.g., [2,25,43]), and in this journal in particular (e.g., [44,45]). Textbook analysis of visual representations can help to ensure that they are better used in future textbooks. The purpose of the current study is to analyze how grade 10 chemistry textbooks from different Chinese communities represent content related to redox reactions. The focus of this study is not to indicate conceptual errors but rather to characterize how the textbooks adapt visual representations related to redox reactions. This paper explores the visual representations of redox reactions and related content at the macroscopic, microscopic and symbolic levels as provided in grade 10 Chinese textbooks from the People's Republic of China, with a special view on Hong Kong, Shanghai, Taiwan and the Chinese minority in Malaysia to inform editors, authors or evaluators of chemistry textbooks about differences among the textbooks from this sample in order to identify areas for improvement. Analysis also focusses on whether the visual representations provide indications of the intended curriculum orientation [43]. Consequently, we investigated the following research questions:

1. Concerning visual representations (macroscopic, microscopic and symbolic)
    a. Are these present in Chinese chemistry textbooks related to redox reactions?
    b. How are they used?
    c. How are the different representational levels represented and related to one another?
2. Are there any indicators in the visual representations in the textbooks of a modern chemistry curriculum that use everyday life and societal illustrations to contextualize chemistry learning?

2. Materials and Methods

Chinese people account for one of the largest ethnic groups in the world. Aside from the People's Republic of China with about 1.4 billion citizens, there are Chinese communities in many countries or regions. In some environments, Chinese people form the majority, such as in Taiwan or Hong Kong. There are also many minorities of Chinese people in different countries of the world. In most countries, the Chinese minorities are integrated into the national educational systems. This is not the case for Malaysia, where the Chinese community forms 23.2% out of 32.0 million Malaysian citizens [46]. Independent Chinese Secondary Schools (ICSSs) use the Chinese language as the main medium of instruction in Malaysia and operate a self-standing school system to provide mother-tongue education with the intention to preserve cultural identity. The educational systems in the People's Republic of China, Hong Kong, Taiwan and the Chinese minority in Malaysia do have some commonalities in their structures in that grade 10 forms the first year of upper secondary education. Chemistry is a compulsory subject and redox reactions are a common topic, mainly starting in grade 10.

In the People's Republic of China, different textbook series are launched in the market. The books are approved by the national school textbook authorized committee's review. Currently, three versions of chemistry textbooks for upper secondary school have passed the review. They are compiled by the People's Education Press, Shangdong Science and Technology Press, and Jiangsu Education Press (see Table 1; CN1-CN3). Fundamental redox reactions knowledge is explained in all these editions in the grade 10 textbooks. These three sets of textbooks form the first sub-sample in this study. In 1985, Shanghai was allowed to abstain from the Chinese National College Entrance Examination (NCEE) and apply an independent proposition [47]. The textbooks analyzed in the present study are edited and reviewed by the Shanghai Primary and Secondary School Curriculum Reform Committee and Shanghai Primary and Secondary School Textbook Review Committee. One corresponding textbook is the Shanghai Edition (CN4).

Hong Kong, as a special administrative region of the People's Republic of China, has been deeply influenced by western countries, mainly during the colonial time under the United Kingdom. The Hong Kong Education Bureau recommends textbooks for senior secondary school students [48]. We chose the textbook from Jing Kung Educational Press, that is one of the popular textbook publishers in Hong Kong (HK).

Nine years of compulsory education were implemented in Taiwan in 1968. In 2014, a new policy of 12 years Basic Education Curricula was introduced and is intended to be fully implemented in the 2019 academic year [49]. We chose the textbook from LungTeng Cultural (later called TW1), which is one of the textbooks that passed the official review by the National Academy for Educational Research (NAER). Basic Chemistry 1, Basic Chemistry 2 and Selective Chemistry 1 (see Table 1) were chosen as they contain redox reactions content. Table 1 references the textbooks where most of the redox reactions content is covered in the textbooks from the four different Chinese communities.

In the context of Malaysia, Dong Jiao Zong is an allied organization of the United Chinese School Committees' Association of Malaysia, named as UCSCA or Dong Zong, and the United Chinese School Teachers' Association of Malaysia, named as UCSTA or Jiao Zong, which is responsible for the Chinese-community-run education that organizes Chinese Education in Malaysia and provides an unified curriculum and examination to ICSSs [50]. In our study, as our sample (MY), we chose the Chinese chemistry textbook used among ICSS students published by the United Chinese School Committees' Association of Malaysia (see Table 1), the Upper Secondary School Chemistry (volume 1) and Upper Secondary School Chemistry (volume 2), that contain the main redox reactions section.

Table 1. Information of the textbooks which include redox reactions content.

Textbook	Reference
CN1	Song, X. Q. (Ed.). (2007). Chemistry 1 (3rd ed.). Beijing: People Education Press.
	Song, X. Q. (Ed.). (2007). Chemical reaction mechanism (3rd ed.). Beijing: People Education Press.
CN2	Wang, L. (Ed.). (2007a). Chemistry 1 (3rd ed.). Shandong: Shandong Science and Technology Press.
	Wang, L. (Ed.). (2011). Chemical reaction mechanisms (4th ed.). Shandong: Shandong Science and Technology Press.
CN3	Wang, Z. H. (2014). Chemistry 1 (6th ed.). Nanjing: Jiangsu Education Press.
	Wang, Z. H. (2014). Chemical reaction mechanisms (5th ed.). Nanjing: Jiangsu Education Press.
CN4	Yao, Z. P. (Ed.). (2007). Chemistry (Volume 1) (1st ed.). Shanghai: Shanghai Scientific and Technical Publishers.
	Yao, Z. P. (Ed.). (2008). Chemistry (Volume 3) (1st ed.). Shanghai: Shanghai Scientific and Technical Publishers.
HK	Zhong, H. M. (2009). New 21st Century Chemistry 2B (1st ed.). Hong Kong: Jing Kung Educational Press.
TW	Huang, D. S. (Ed.). (2010). Basic Chemistry 1 (1st ed.). Taiwan: LungTeng Culture Lungteng Cultural.
	Huang, D. S. (Ed.). (2011). Basic Chemistry 2 (1st ed.). Taiwan: LungTeng Culture Lungteng Cultural.
	Huang, D. S. (Ed.). (2012). Selective Chemistry 1 (1st ed.). Taiwan: LungTeng Culture Lungteng Cultural.
MY	MICSS (1996). Upper secondary school chemistry (volume 1) (1st ed.). Malaysia: United Chinese School Committees' Association of Malaysia.
	MICSS (1997). Upper secondary school chemistry (volume 2) (1st ed.). Malaysia: United Chinese School Committees' Association of Malaysia.

This study focuses on visual representations related to redox reactions in Chinese textbooks which may be considered as a model of analysis from the chemistry curriculum. A glimpse at other topics from the chemistry curriculum did not provide any indications that other content is visually represented in different ways.

Basic tenets of qualitative content analysis were employed to analyze visual representations from the textbooks. In order to develop criteria for the analysis of the representational levels of the redox reactions, we adopted a scheme using criteria developed by Gkitzia et al. [25]. The criteria were employed to our three level representational framework and revised accordingly after several readings of the textbooks. The criteria looked at all levels of visual representations including figures, photos, and diagrams. Tables and straightforward chemical equations were not considered as being visual representations. Chemical reaction equations only became part of the analysis as part of figures, not when they were used as part of the text. In an iterative process, the criteria were applied to the sample in each round to a sub-sample of illustrations by three raters (first, second and forth author) until a fit of the coding scheme (Table 2) was achieved. The reliability of the data analysis was checked by independent rating (first and fourth author), and in the case of disagreement, re-rating was performed. The agreement rates were generally high in all three rounds from the beginning (above 90%) and rose to 97% due to joint re-rating of disagreed interpretations of the visual representations shown in Table 2.

Table 2. Criteria for evaluation on visual representation characteristics (adapted from Gkitzia et al. [25]).

Category	Subcategory	Description
Levels of representation	Macro	Presents only observable and realistic aspects (M)
	Submicro	Illustrates unobservable entities and abstract aspects (S)
	Symbolic	Uses symbols and codes of chemistry (S)
	Macro and submicro	Represents two levels: macro and submicro (M+S)
	Macro and symbolic	Represents two levels: macro and symbolic (M+S)
	Submicro and symbolic	Represents two levels: submicro and symbolic (S+S)
	Macro, submicro and symbolic	Represents the three levels: macro, submicro and symbolic (M+S+S)
Degree of correlation between representations comprising multiple ones	Sufficiently linked	Equivalence of the surface features of the components is clearly indicated
	Insufficiently linked	Equivalence of only some surface features is indicated clearly
	Unlinked	Includes subordinate representations that are placed next to one another and there is no indication of the equivalence of their surface features
Relation to text	Completely related	Representation depicts the exact text content
	Partially related	Representation depicts the subject or a familiar subject to the text, text does not direct the reader to the relationship between text and representation
	Unrelated	Representation is irrelevant to the text content. The text describes the content without mentioning the correspondence with the representation

In the first round, we mainly focused on three different categories (see Table 2). First, levels of representation according to the Johnstone [1] triangle, i.e., macroscopic, submicroscopic, symbolic, and multilevel representations were selected as the initial data. The textbooks were coded and analyzed using the criteria described in Table 2. Second, we examined the degree of the multiple correlations between representations to see if the multiple levels were sufficiently linked, insufficiently linked, or unlinked. Third, the relation between visual representations to the main text was also evaluated.

A second round of the analysis focused on the function of images in relation to the text related to redox reactions. We evaluated how much of the visual representation is connected to the text for providing support to better understand the content, aside from just having a decorative function. Subsequently, we categorized the evaluation of image representation into decorative, organizational, or interpretational (see Table 3), which is an adaptation from Carney and Levin [51], and this was also interpreted by Nyachwaya et al. [52].

Table 3. Criteria for the evaluation of the function of the images (adapted from Carney and Levin [51]).

Category	Subcategory	Description
Function of images	Decorative	Not relevant to the text—illustrations only help the reader enjoy the textbook by making it more attractive
	Organizational	Illustrations help the reader organize information into a coherent structure and encourage more detailed processing of text; captions name the fact but do not provide extra information to the text
	Interpretational	Strong relationship to the content—illustrations explain and help the reader understand concepts and ideas in the text; captions name the fact and add extra information about the fact

It is widely known that textbooks provide orientations of the curriculum and mirror the emphases behind them [53]. The third step of the analysis focused on the curriculum orientation transmitted by visualizations which were related to redox reactions obtained from the different textbooks. The scheme to analyze the curriculum orientations was adapted from the six categories related to curriculum orientation explicated by Eilks et al. [34] in the interpretation of Khaddoor, Al-Amoush and Eilks [43] (see Table 4). We analyzed the visual representation to see if the images represented the structure of the discipline orientation, history of science orientation, everyday life orientation, environmental orientation, or industry and technology orientation. The issue of socio-scientific orientation was also checked in relation to the text.

Table 4. Criteria for the evaluation of curriculum orientation (adapted from Eilks et al. [34]).

Category	Subcategory	Description
Curriculum orientation	Structure of the discipline orientation	Illustrations represent scientific theories and facts and their relation to one another
	History of science orientation	Illustrations represent scientific content as it emerged in the past or its historical development
	Everyday life orientation	Illustrations represent entities from everyday life
	Environmental orientation	Illustrations represent scientific content behind questions of environmental protection
	Industry and technology orientation	Illustrations represent chemical technology and its application in industry
	Socio-scientific issues orientation	Illustrations provoke the learning allowing the students to develop general educational skills to prepare them to become responsible citizens in future

3. Results

A total of 346 visual representations related to redox reactions were identified in the textbooks from Mainland China, Hong Kong, Taiwan, and Malaysia. In terms of the general content organization and structure, the differences in the textbooks between different Chinese communities are larger than the differences within the communities. From Figure 1, we can see that representations of the macroscopic (maximum 68%), symbolic (maximum 45%), and macro-symbolic (maximum 50%) levels are more prominent than other levels of representation.

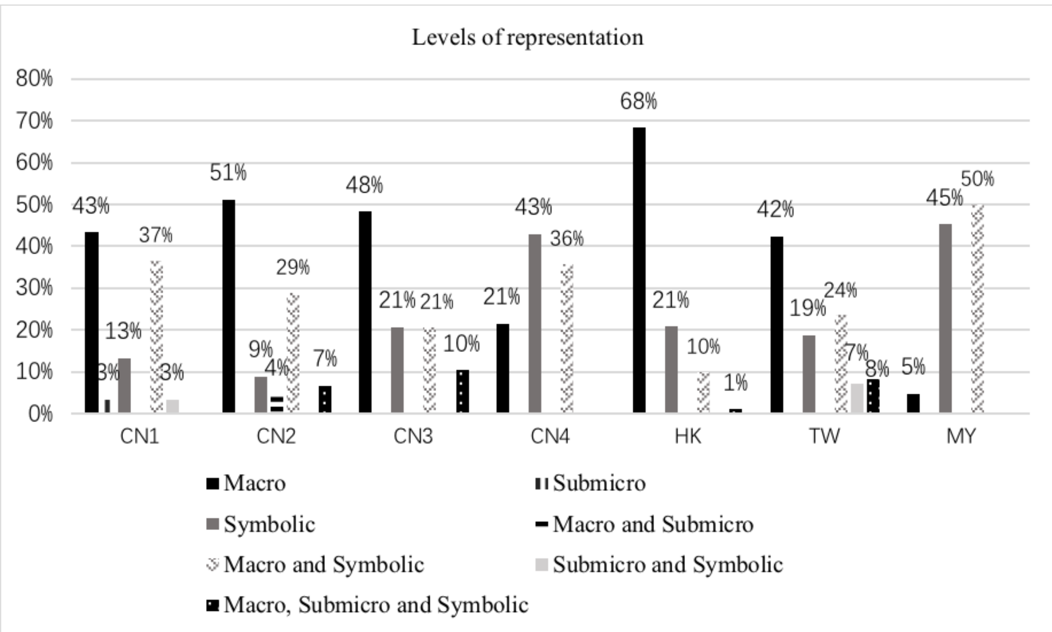


Figure 1. Distribution of different levels of visual representations in the textbooks. (Note: due to the numerical value limit, the sum value of CN1 is 99%).

Among the mentioned textbooks, the Taiwanese textbook and two of the textbooks from the PR of China (CN1 and CN2) cover a broader variety of representational levels than the textbooks from Hong Kong, Malaysia and two of the Chinese textbooks (CN3 and CN4).

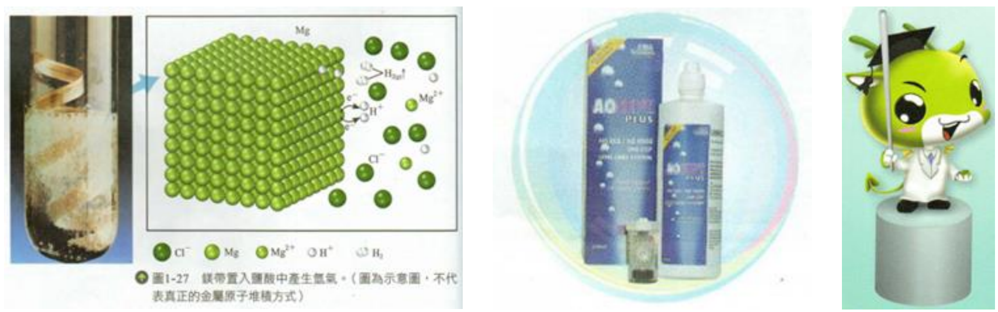
Initially, we considered the first research question: What visual representations (macroscopic, microscopic and symbolic) are present in Chinese chemistry textbooks related to redox reactions, how are they used, and how are the different representational levels represented and related to one another? The data show that the way the textbooks illustrate redox reactions are different.

3.1. Levels of Representation

The analysis indicates that all textbooks show a high use of macro representations, except the Shanghai and Malaysian textbooks (Figure 1). The Shanghai and Malaysian textbooks use more symbolic and macro-symbolic level representations than the other Chinese textbooks. The Taiwanese textbook and one of the books from the PR of China (CN3) show a higher degree of multiple visual representations with the combination of the macro, submicro, and symbolic levels compared to the rest of the textbooks. The Hong Kong textbook tends to employ mainly macro and symbolic representations to explain fundamental chemistry knowledge related to redox reactions and visual representations in the Hong Kong textbook, in terms of the macro level, mostly refer to experiments. The Malaysian textbook uses visual representations at the symbolic level to explain the oxidation/reduction number, gain/loss of electrons, higher/lower valence, and oxidation/reduction. In terms of electrochemistry, the Malaysian textbook uses many macro-symbolic visual representations to illustrate advanced knowledge related to redox reactions of different electrochemical cells.

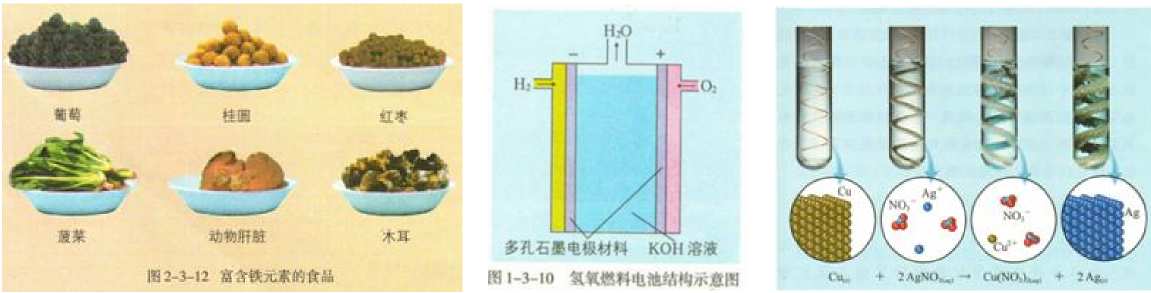
3.2. Multiple Visual Representations and Degree of Correlation between Representations

In terms of multiple representations, the Taiwanese textbook contains more multiple visual representation levels than the other books (Figure 1). A combination of macro-symbolic representations is notable in most of the mentioned textbooks, followed by macro–submicro–symbolic combinations. Most of the textbooks use arrows and lines to connect different representational levels when they contain more than one representation (e.g., Figures 2a and 3b). The correlation between the different levels is generally sufficiently linked (Figure 4), for example, Figure 2a is an image with multiple representations including the macro, submicro and symbolic levels (the reaction of hydrochloric acid and magnesium). The reaction at the macro level, which happens inside the test-tube, is connected to digital simulated atoms and ions by an arrow, and atoms and ions are connected to correspond to chemical symbolic representations by more arrows. Textbooks from Hong Kong, Taiwan and one from the PR of China have visual representations that are insufficiently linked, but these numbers are small (average 10%).



(a) (b) (c)

Figure 2. Example of a completely related (**a**), a partially related (**b**), and an unrelated (**c**) representation (reproduced with permission by Lungteng Cultural Company [Taiwan]).



(a) (b) (c)

Figure 3. Example of a decorative (**a**), organizational (**b**), and interpretational (**c**) image (reproduced with permission by [Lungteng Cultural Company (Taiwan)] and [Shandong Science and Technology Press (PRC)]).

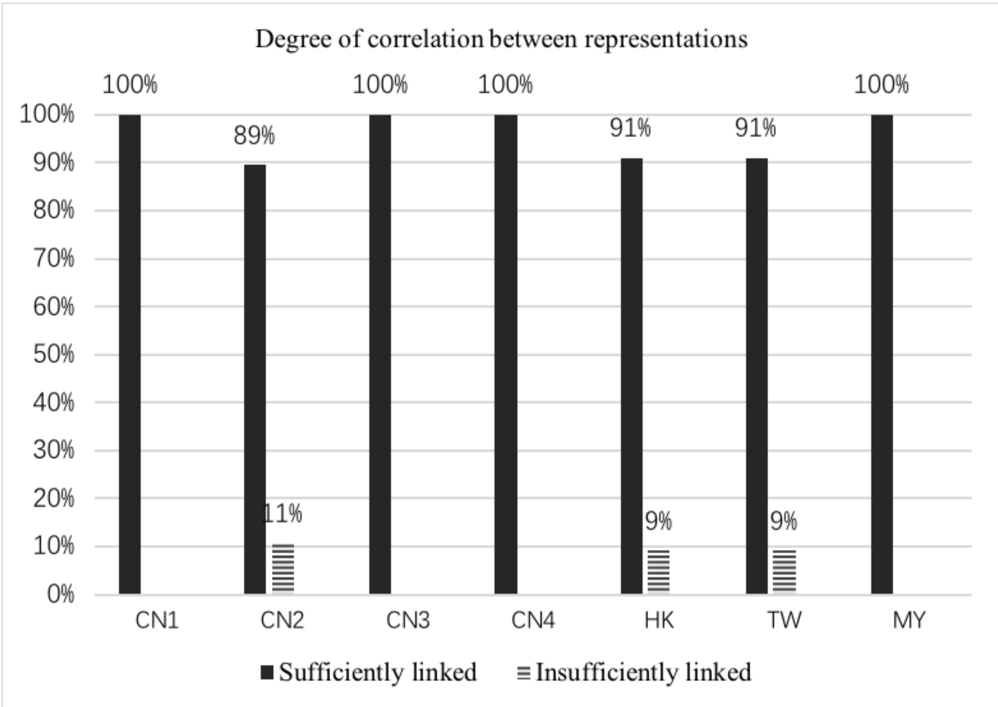


Figure 4. Degree of correlation between multiple representations in the textbooks.

3.3. Relation to Text

In terms of the relationship between pictures and text, most of the textbooks show a high relation to the text (Figure 5), with concrete references in the text and captions connecting the pictures with the text. Only the Taiwanese textbooks and one from the PR of China (CN1) contain a few pictures that are unrelated to the text. For example, Figure 2c is an unrelated representation in the Taiwanese textbook; the main text is about oxidation numbers but the picture is decorative, only providing visual enjoyment. It does not provide further help for deeper understanding. Figure 2a is an example of a visual representation that is completely related to the text and aids learners' understanding of redox reactions; the text is about the electron transfer of a reaction between magnesium and hydrochloric acid. The picture provides a comprehensive model that combines the macro, submicro, and symbolic levels. Figure 2b is an example of a visual representation that is partially related to the text. The text mentions that oxidizing agents can be used for sterilization and the picture illustrates this with a bottle of contact lens care solution. The caption of the picture refers to the main constituent (hydrogen peroxide).

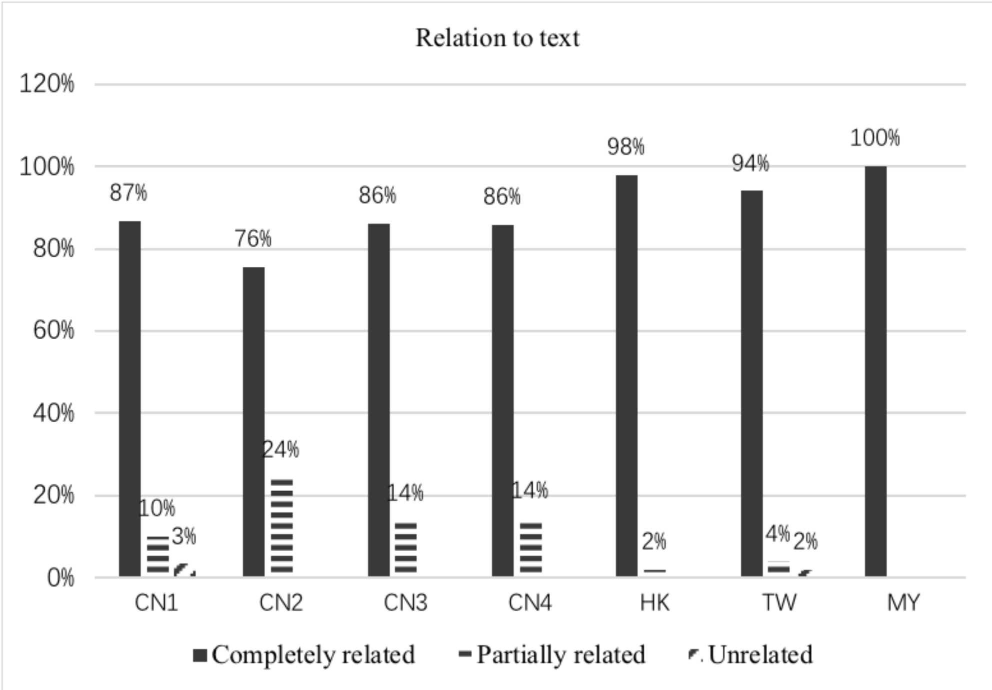


Figure 5. Degree of relation to text in the textbooks.

3.4. Function of Images

In terms of the function of images, decorative, organizational, and interpretational images appear in all the textbooks (Figure 6). The Shanghai textbook (CN4) has the highest use of images that focus on help for the learners to understand the text that are organizational. The Malaysian textbook has the highest rate of interpretational figures and the textbook from Hong Kong as well as one of the textbooks from the PR of China (CN2) have the highest degree of decorative pictures. Figure 3 shows examples of decorative, organizational, and interpretational representations from the different textbooks. Figure 3a shows an image of different iron-rich foods that plays a decorative role in enhancing the readers' imagination. Figure 3b aids the understanding of a hydrogen–oxygen fuel cell by showing the cell structure that reflects a redox reaction. Figure 3c is an example of an interpretational image that illustrates the reactions of copper wire and silver nitrate solution at the macroscopic, submicroscopic and symbolic levels, which aids in deeper comprehension for students.

3.5. Curriculum Orientation

Concerning the second research question, looked at as a whole, the results indicate that all the textbooks basically follow a structure of the discipline orientation (Figure 7), especially the textbooks from Shanghai and Malaysia. Everyday life orientation is covered by images in all textbooks to a certain extent, except in the Shanghai textbook. Industry and technology illustrations can be found in all textbooks. Environmental issues are addressed in the Hong Kong textbook and one of the textbooks from the PR of China (CN1) by pictures. History of science is represented only by visual representations in the Taiwanese textbook.

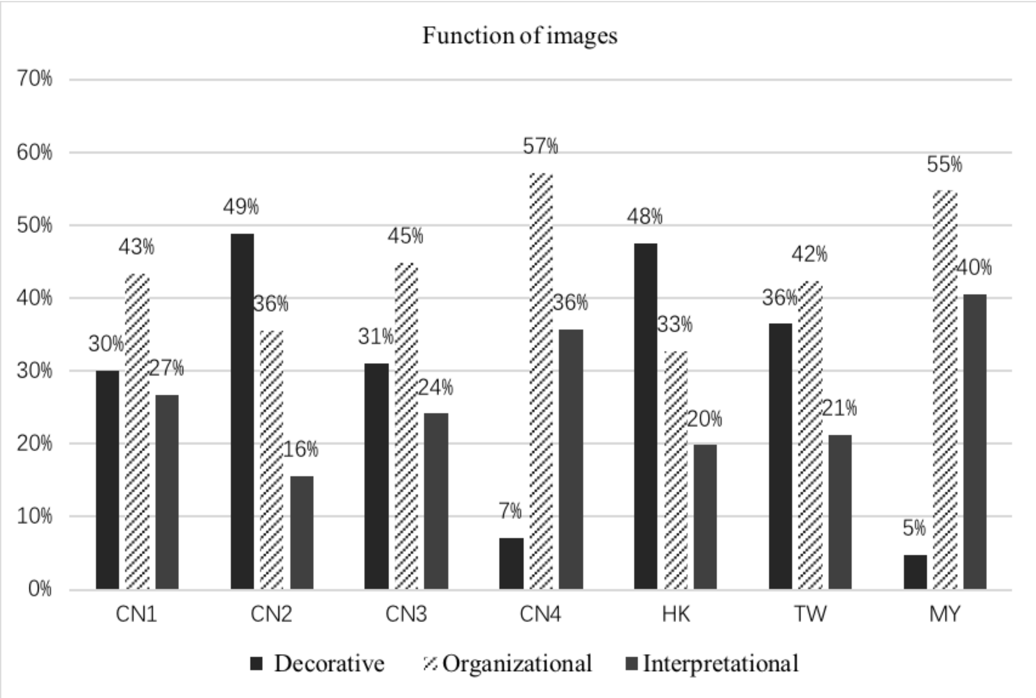


Figure 6. Degree of the function of images in the textbooks. (Note: due to the numerical value limit, the sum value of HK and CN2 are both 101% and the sum value of TW is 99%).

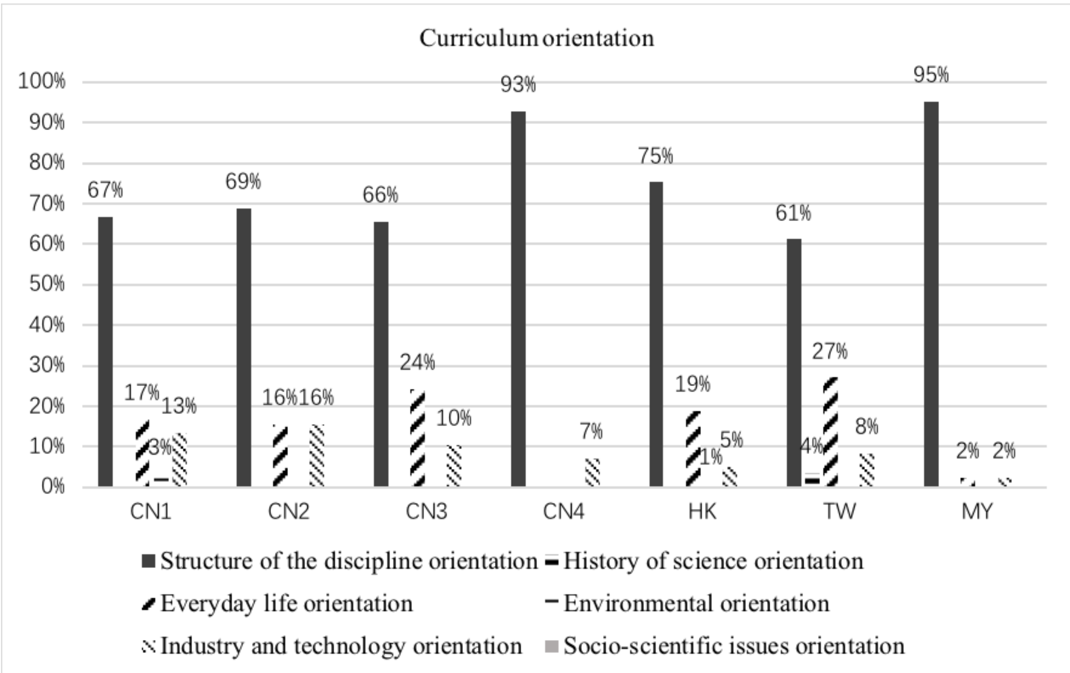


Figure 7. Degree of curriculum orientation in the textbooks. (Note: due to the numerical value limit, the sum value of CN2 is 101% and the sum value of MY is 99%).

4. Discussion

The abstract nature of modern chemistry expects that learners' understanding of macroscopic phenomena be enhanced by submicroscopic and symbolic explanations [54]. Johnstone's triangle [1] approaches teaching and learning with a thorough combination of these three representational levels.

Although chemistry experts, persons with fluent and flexible performance [55], can easily switch between the different representational levels, studies on students show that learners regularly have difficulties in correctly relating representations from the different representational levels [56], because students generally have conceptual difficulties when dealing with visual representations [33].

As stated by Mahaffy [57], chemistry education differs from country to country, school to school, and culture to culture; there are no universal solutions when the level of the learner, the learning objective, and the teaching style are not in the same context. Inevitably, the intended, implemented and attained curricula have a mismatch between each other [58]. However, the data in this study provide some ideas about the ways in which different Chinese textbooks address representations of redox reactions. The representations might potentially be useful to teachers.

In terms of the distribution of the different levels of representation from this sample, macroscopic representation is dominant among other visual representations. This finding is very different from recently reported findings on chemistry textbooks from Africa, for example, Upahi and Ramnarain [2] reported a dominance of symbolic representations for the textbooks in Nigeria. To suggest reasons for this difference, however, would be highly speculative, but the reasons may lie in different curriculum traditions and lack of practical work, more than in the aspects of culture or socio-economic development [43]. However, the curriculum orientation [34] and the function of visual representations [51] concerned with redox reactions were not defined [2]. Treagust et al. [54] suggest that macroscopic representations are the basis of chemistry learning, but macroscopic understanding relies on an explanation at the submicroscopic level. Combined representations could be helpful. Combined visual representations are, however, limited in the sample of textbooks in this study. But the degree of correlation between the representational levels is high (above 89%). The high correlation between multiple representations might be helpful. Russell et al. [59] suggest that the simultaneous use of macroscopic, submicroscopic and symbolic representations can help to reduce students' alternative conceptions in learning chemistry.

The curriculum orientation in the different textbooks shows that the structure of discipline orientation is dominant in the textbooks from this sample. Decontextualized chemistry representations are still prominent in many countries around the world [6]. As Eilks and Hofstein [60] state, "science learning should start from contexts that are connected to the life of the students, their prior experiences, their interests [...] everyday lives of students and the society which they live in have the potential to offer meaningful contexts to the students" (p. 17). This claim is in line with the works of Holman [29], Stuckey et al. [28], and Sjöström et al. [6]. Our findings indicate that everyday life application and industry and technology orientation are already observable in the textbooks from this sample. It seems, however, that more everyday and societal life orientation is needed in the visual stimuli in the textbooks because the proportion is small (no more than 27%). Socio-scientific issues and environmental orientation remain scarce. Visual support for these perspectives might also be strengthened in the future to better support a broader contextualization of learning with textbooks in Chinese chemistry education.

Even though all the textbooks placed more emphasis on the structure of the discipline, in terms of the way that science knowledge is represented, the textbook from Taiwan and one textbook from China (CN3) use a more comprehensive way to illustrate the abstract concept of redox reactions via multiple macro–submicro–symbolic representations. The Malaysian and Shanghai textbooks tend to focus on pure science by visual representations. The other textbooks from the PR of China (CN1-3), Hong Kong and Malaysia embed everyday life issues, but mainly with a focus on pure science learning. The Hong Kong textbook provides a pleasurable visual experience with colorful macro pictures but still mostly focuses on fundamental knowledge learning.

This study has attempted to identify the use of visual representation in chemistry textbooks produced for and used in grade 10 classes from different Chinese communities. There are several limitations. It was not possible to analyze all textbooks available and changes in textbooks occur over time. Currently, new textbooks have been announced for chemistry education in Taiwan and

Malaysia and further analysis might show whether or not they will be different from the current ones analyzed in this study. Another limitation is that the focus of this study was only on one topic in chemistry education, namely, redox reactions. This study also focused on selected aspects and cannot state anything about how and with what intensity the textbooks are used by the teachers, as well as to what extent teachers use other resources in chemistry classes.

5. Conclusions

To date, little is known about secondary chemistry textbooks from different Chinese communities. The present study shows the variety of chemistry textbooks from the selected regions although there is basically the same culture and language behind the four Chinese communities. The purpose of this study was not to evaluate whether the visual representations related to redox reactions and given in the textbooks are right or wrong, and was not intended to recommend one "best" textbook. The aim was to show how visual representations related to redox reactions are used and how textbooks might be improved by comparing them systematically to each other.

In this article, we examined visual representations related to redox reactions in secondary chemistry textbooks from different Chinese communities. This study has attempted to contribute to an understanding of the intended curriculum of secondary chemistry education in different Chinese communities based on the assumption that textbooks are important resources for teaching and learning [8,61].

Most Asian countries are making substantial efforts to improve the quality of science education and invest in corresponding research [62]. Specifically, since the late 1980s, Taiwan science education has developed substantially because of its economic boom. Since that time, Taiwan has built an active chain of researchers within East Asia [63] and western countries [64] for the development of science education. This might be a reason why the Taiwanese textbooks provide the richest representation content because it is based on research findings. These rich representations can provide ideas and directions for textbooks published in other Chinese communities. Specifically, one recommendation is to present rich illustrations of the redox content using visualizations that show a good balance between the relationships of the three representational levels of chemistry. Much research has shown that learners benefit when the relations of the different levels are clear and explicit, well connected to the text, and are related to meaningful contexts for the students. In most Asian countries, however, central examinations are still considered as the main component in educational assessment and promotion [65]. These central examinations mostly focus on the science content, with an emphasis on students being able to know information rather than understanding the relationships between concepts, and rarely refer to contexts and socio-scientific implications. Consequently, this might be the reason why most textbooks still tend to follow a structure of discipline approach. Perhaps there should be reflection on the central examinations to promote further development of the textbooks.

Author Contributions: Conceptualization, X.G.C. and L.F.G.; methodology, X.G.C., L.F.G. and I.E.; validation, X.G.C., L.F.G., D.F.T. and I.E.; formal analysis, X.G.C. and I.E.; writing original draft, X.G.C.; writing—review and editing, X.G.C., L.F.G., D.F.T. and I.E., supervision and project administration, I.E.; funding acquisition, X.G.C.

Funding: This research was funded by the China Scholarship Council (CSC), grant number 201608080083.

Acknowledgments: The authors would like to acknowledge the China Scholarship Council (CSC) for funding this research, Chua Kah Heng (Malaysia) for cooperating with us and the Lungteng Cultural Company (Taiwan) and Shandong Science and Technology Press (PRC) for permission to reproduce pictures from their books.

Conflicts of Interest: There are no conflict of interest to declare.

References

1. Johnstone, A.H. Why is science difficult to learn? Things are seldom what they seem. *J. Comput. Assist. Learn.* **1991**, *7*, 75–83. [CrossRef]
2. Upahi, J.E.; Ramnarain, U. Representations of chemical phenomena in secondary school chemistry textbooks. *Chem. Educ. Res. Pract.* **2019**, *20*, 146–159. [CrossRef]

3. Gabel, D. Improving teaching and learning through chemistry education research: A look to the future. *J. Chem. Educ.* **1999**, *76*, 548. [CrossRef]
4. Talanquer, V. Macro, submicro, and symbolic: the many faces of the chemistry "triplet". *Int. J. Sci. Educ.* **2011**, *33*, 179–195. [CrossRef]
5. Taber, K.S. Revisiting the chemistry triplet: Drawing upon the nature of chemical knowledge and the psychology of learning to inform chemistry education. *Chem. Educ. Res. Pract.* **2013**, *14*, 156–168. [CrossRef]
6. Sjöström, J.; Talanquer, V. Humanizing chemistry education: from simple contextualization to multifaceted problematization. *J. Chem. Educ.* **2014**, *91*, 1125–1131. [CrossRef]
7. Mahaffy, P. The future shape of chemistry education. *Chem. Educ. Res. Pract.* **2004**, *5*, 229–245. [CrossRef]
8. Österlund, L.-L.; Berg, A.; Ekborg, M. Redox models in chemistry textbooks for the upper secondary school: Friend or foe? *Chem. Educ. Res. Pract.* **2010**, *11*, 182–192. [CrossRef]
9. Basheer, A.; Hugerat, M.; Kortam, N.; Hofstein, A. The effectiveness of teachers' use of demonstrations for enhancing students' understanding of and attitudes to learning the oxidation reduction concept. *Eurasia J. Math. Sci. Tech. Educ.* **2017**, *13*, 555–570. [CrossRef]
10. Barke, H.D. Two ideas of the redox reaction: Misconceptions and their challenge in chemistry education. *Afr. J. Chem. Educ.* **2012**, *2*, 32–50.
11. Finley, F.N.; Stewart, J.; Yarroch, W.L. Teachers' perceptions of important and difficult science content. *Sci. Educ.* **1982**, *66*, 531–538. [CrossRef]
12. Obomanu, B.; Onuoha, C. Students conceptual difficulties in electrochemistry in senior secondary schools. *J. Emerg. Trends Educ. Res. Pol. Stud.* **2012**, *3*, 99.
13. Paik, S.H.; Kim, S.; Kim, K. Suggestion of a viewpoint change for the classification criteria of redox reactions. *J. Chem. Educ.* **2017**, *94*, 563–568. [CrossRef]
14. Schmidt, H.J.; Volke, D. Shift of meaning and students' alternative concepts. *Int. J. Sci. Educ.* **2003**, *25*, 1409–1424. [CrossRef]
15. De Jong, O.; Treagust, D.F. The teaching and learning of electrochemistry. In *Chemical Education: Towards Research-Based Practice*; Gilbert, J.K., De Jong, O., Justi, R., Treagust, D.F., Van Driel, J.H., Eds.; Springer: Dordrecht, The Netherlands, 2002; pp. 317–337.
16. Shibley, I.A., Jr.; Amaral, K.E.; Aurentz, D.J.; McCaully, R.J. Oxidation and reduction reactions in organic chemistry. *J. Chem. Educ.* **2010**, *87*, 1351–1354. [CrossRef]
17. Osman, K.; Lee, T.T. Impact of interactive multimedia module with pedagogical agents on students' understanding and motivation in the learning of electrochemistry. *Int. J. Sci. Math. Educ.* **2014**, *12*, 395–421. [CrossRef]
18. Eilks, I.; Witteck, T.; Pietzner, V. The role and potential dangers of visualisation when learning about sub-microscopic explanations in chemistry education. *Cent. Educ. Policy Stud. J.* **2012**, *2*, 125–145.
19. Ramnarain, U.; Joseph, A. Learning difficulties experienced by grade 12 South African students in the chemical representation of phenomena. *Chem. Educ. Res. Pract.* **2012**, *13*, 462–470. [CrossRef]
20. Valanides, N.; Nicolaidou, A.; Eilks, I. Twelfth grade students' understanding of oxidation and combustion: Using action research to improve teachers' practical knowledge and teaching practice. *Res. Sci. Tech. Educ.* **2003**, *21*, 159–175. [CrossRef]
21. Gilbert, J.K. On the nature of "context" in chemical education. *Int. J. Sci. Educ.* **2006**, *28*, 957–976. [CrossRef]
22. Pintó, R.; Ametller, J. Students' difficulties in reading images. Comparing results from four national research groups. *Int. J. Sci. Educ.* **2002**, *24*, 333–341. [CrossRef]
23. Dimopoulos, K.; Koulaidis, V.; Sklaveniti, S. Towards an analysis of visual images in school science textbooks and press articles about science and technology. *Res. Sci. Educ.* **2003**, *33*, 189–216. [CrossRef]
24. Eilks, I. Experiences and reflections about teaching atomic structure in a jigsaw classroom in lower secondary school chemistry lesson. *J. Chem. Educ.* **2005**, *82*, 313. [CrossRef]
25. Gkitzia, V.; Salta, K.; Tzougraki, C. Development and application of suitable criteria for the evaluation of chemical representations in school textbooks. *Chem. Educ. Res. Pract.* **2011**, *12*, 5–14. [CrossRef]
26. Stylianidou, F. Analysis of science textbook pictures about energy and pupils' readings of them. *Int. J. Sci. Educ.* **2002**, *24*, 257–283. [CrossRef]
27. Eilks, I. Teacher pathways through the particulate nature of matter in lower secondary school chemistry: Continuous switching between different models or a coherent conceptual structure? In *Concepts of Matter in Science Education*; Tsaparlis, G., Sevian, H., Eds.; Springer: Dordrecht, The Netherlands, 2013; pp. 213–230.

28. Stuckey, M.; Hofstein, A.; Mamlok-Naaman, R.; Eilks, I. The meaning of 'relevance' in science education and its implications for the science curriculum. *Stud. Sci. Educ.* **2013**, *49*, 1–34. [CrossRef]
29. Holman, J. Resources or courses? Contrasting approaches to the introduction of industry and technology to the secondary curriculum. *Sch. Sci. Rev.* **1987**, *68*, 432–438.
30. Raved, L.; Assarafs, O.B.Z. Attitudes towards science learning among 10th-Grade students: A qualitative look. *Int. J. Sci. Educ.* **2011**, *33*, 1219–1243. [CrossRef]
31. Wu, S.P.W.; Rau, M.A. Effectiveness and efficiency of adding drawing prompts to an interactive educational technology when learning with visual representations. *Learn. Instr.* **2018**, *55*, 93–104. [CrossRef]
32. Ainsworth, S. DeFT: A conceptual framework for considering learning with multiple representations. *Learn. Instr.* **2006**, *16*, 183–198. [CrossRef]
33. Rau, M.A.; Bowman, H.E.; Moore, J.W. An adaptive collaboration script for learning with multiple visual representations in chemistry. *Comput. Educ.* **2017**, *109*, 38–55. [CrossRef]
34. Eilks, I.; Rauch, F.; Ralle, B.; Hofstein, A. How to allocate the chemistry curriculum between science and society. In *Teaching Chemistry—A Studybook*; Eilks, I., Hofstein, A., Eds.; Sense Publisher: Rotterdam, The Netherlands, 2013; pp. 1–36.
35. Martinez-Gracia, M.V.; Gil-Quylez, M.J.; Osada, J. Genetic engineering: A matter that requires further refinement in Spanish secondary school textbooks. *Int. J. Sci. Educ.* **2003**, *25*, 1147–1168. [CrossRef]
36. Devetak, I.; Vogrinc, J. The criteria for evaluating the quality of the science textbooks. In *Critical Analysis of Science Textbooks: Evaluating Instructional Effectiveness*; Khine, M.S., Ed.; Springer: Dordrecht, The Netherlands, 2013; pp. 3–15.
37. Souza, K.A.F.D.; Porto, P.A. Chemistry and chemical education through text and image: Analysis of twentieth century textbooks used in Brazilian context. *Sci. Educ.* **2012**, *21*, 705–727. [CrossRef]
38. Cheng, K.L.; Wong, S.L. Nature of science as portrayed in the physics official curricula and textbooks in Hong Kong and on the mainland of the People's Republic of China. In *Topics and Trends in Current Science Education*; Bruguière, C., Tiberghien, A., Clément, P., Eds.; Springer: Dordrecht, The Netherlands, 2014; pp. 519–534.
39. Wang, L.; Tang, J.J.; Zhang, R.H.; Hu, J.H.; Zhi, Y.; Wei, R. Investigation of the use of new chemistry textbooks of senior high school and the influential factors. *J. Educ. Stud.* **2015**, *11*, 77–86.
40. Dagher, Z.R.; Erduran, S. Reconceptualizing the nature of science for science education. *Sci. Educ.* **2016**, *25*, 147–164. [CrossRef]
41. Van Den Akker, J. The science curriculum: Between ideals and outcomes. In *International Handbook of Science Education*; Fraser, B.J., Tobin, K.G., Eds.; Springer: Dordrecht, The Netherlands, 1998; pp. 421–447.
42. Lee, V.R. Adaptations and continuities in the use and design of visual representations in US middle school science textbooks. *Int. J. Sci. Educ.* **2010**, *32*, 1099–1126. [CrossRef]
43. Khaddoor, R.; Al-Amoush, S.; Eilks, I. A comparative analysis of the intended curriculum and its presentation in 10th grade chemistry textbooks from seven Arabic countries. *Chem. Educ. Res. Pract.* **2017**, *18*, 375–385. [CrossRef]
44. Calado, F.M.; Scharfenberg, F.-J.; Bogner, F.X. To what extent do biology textbooks contribute to scientific literacy? Criteria for analysing science-technology-society-environment issues. *Educ. Sci.* **2015**, *5*, 255–280. [CrossRef]
45. Livni-Alcasid, G.; Haskel-Ittah, M.; Yarden, A. As symbol as that: Inconsistencies in symbol systems of alleles in textbooks, and students' justifications for them. *Educ. Sci.* **2018**, *8*, 110. [CrossRef]
46. Department of Statistics Malaysia. Current Population Estimates, Malaysia, 2016–2017. Available online: www.dosm.gov.my/v1/index.php?r=column/cthemeByCat&cat=155&bul_id=a1d1UTFZazd5ajJiRWFHNDduOXFFQT09&menu_id=L0pheU43NWJwRWVSZklWdzQ4TlhUUT09 (accessed on 5 January 2018).
47. Liu, H. Retrospect and prospect of university entrance examination. *Educ. Res.* **2007**, *11*, 19–24.
48. Hong Kong Education Bureau, Recommended Textbook List. Available online: https://cd.edb.gov.hk/rtl/search.asp (accessed on 3 January 2019).
49. National Academy for Educational Research, Project of the Implementation of 12-Year Basic Education. Available online: www.naer.edu.tw/files/15-1000-7944,c639-1.php?Lang=zh-tw (accessed on 5 December 2017).

50. Dong Zong, The background of Dong Zong's Establishment. Available online: www.dongzong.my/aboutus.php (accessed on 5 January 2018).
51. Carney, R.N.; Levin, J.R. Pictorial illustrations still improve students' learning from text. *Educ. Psych. Rev.* **2002**, *14*, 5–26. [CrossRef]
52. Nyachwaya, J.M.; Gillaspie, M. Features of representations in general chemistry textbooks: A peek through the lens of the cognitive load theory. *Chem. Educ. Res. Pract.* **2015**, *17*, 58–71. [CrossRef]
53. Roseman, J.E.; Stern, L.; Koppal, M. A method for analyzing the coherence of high school biology textbooks. *J. Res. Sci. Teach.* **2010**, *47*, 47–70. [CrossRef]
54. Treagust, D.F.; Chittleborough, G.; Mamiala, T. The role of submicroscopic and symbolic representations in chemical explanations. *Int. J. Sci. Educ.* **2003**, *25*, 1353–1368. [CrossRef]
55. Berliner, D.C. The development of expertise in pedagogy. Charles W. Hunt Memorial Lecture presented at the annual meeting of the American Association of Colleges for Teacher Education, New Orleans, LA, USA, 17–20 February 1988.
56. Kozma, R.; Russell, J. Multimedia and understanding: Expert and novice responses to different representations of chemical phenomena. *J. Res. Sci. Teach.* **1997**, *34*, 949–968. [CrossRef]
57. Mahaffy, P. The human element: Chemistry education's contribution to our global future. In *Chemistry Education*; García-Martínez, J., Serrano-Torregrosas, E., Eds.; Wiley-VCH: Darmstadt, Germany, 2011; pp. 131–157.
58. Cuban, L. The lure of curricular reform and its pitiful history. *Phi Delta Kappan* **1993**, *75*, 182–185.
59. Russell, J.W.; Kozma, R.B.; Jones, T.; Wykof, J.; Marx, N.; Davis, J. Use of simultaneous-synchronised macroscopic, microscopic and symbolic representations to enhance the teaching and learning of chemical concepts. *J. Chem. Educ.* **1997**, *74*, 330–334. [CrossRef]
60. Eilks, I.; Hofstein, A. *Teaching Chemistry—A Studybook*; Sense Publisher: Rotterdam, The Netherlands, 2013.
61. Chiappetta, E.L.; Fillman, D.A. Analysis of five high school biology textbooks used in the United States for inclusion of the nature of science. *Int. J. Sci. Educ.* **2007**, *29*, 1847–1868. [CrossRef]
62. Lavonen, J. Commentary: What we can learn from science education in Asian countries? In *Science Education Research and Practice in Asia*; Chiu, M.-H., Ed.; Springer: Singapore, 2016; pp. 215–221.
63. Yore, L.D.; Shymansky, J.A.; Treagust, D.F. An international perspective on the people and events shaping science education in Taiwan—past, present, and future. In *Science Education Research and Practices in Taiwan*; Chiu, M.-H., Ed.; Springer: Singapore, 2016; pp. 397–419.
64. De Jong, O. Comments on section 4: Thoughts on science curriculum reform and teacher learning in western countries and Taiwan. In *Science Education Research and Practices in Taiwan*; Chiu, M.-H., Ed.; Springer: Singapore, 2016; pp. 387–394.
65. Nurul-Awanis, A.; Hazlina, A.; Yoke-Ma, L.; Zariyawati, M. Malaysian education system reform: Educationists' perspectives. In Proceedings of the International Conference on Social Science, Economics and Art 2011, Kuala Lumpur, Malaysia, 14–15 January 2011.

PAPER 3

An Analysis of the Representation of Practical Work in Secondary Chemistry Textbooks from Different Chinese Communities

Submitted to

Science Education International

22 May 2019

Author Contributions: The conceptualization of this paper was made by Xiaoge Chen and Ingo Eilks. The methodology was evaluated by Ingo Eilks. The data were evaluated by Xiaoge Chen and Ingo Eilks. The first version of the manuscript was written by Xiaoge Chen and then finalized and reviewed by all authors.

An Analysis of the Representation of Practical Work in Secondary Chemistry Textbooks from Different Chinese Communities

Xiaoge Chen[1] and Ingo Eilks[1]

[1]Department of Biology and Chemistry, Institute for Science Education, University of Bremen, Leobener Str. NW2, 28359 Bremen, Germany; chen@uni-bremen.de; ingo.eilks@uni-bremen.de

This study analyzes representations of practical work in 10th-grade chemistry textbooks and associated experimental workbooks from different Chinese communities, namely from the People's Republic of China, Taiwan and the Chinese sector in Malaysia. This paper contributes to the current body of knowledge of how practical work in secondary chemistry education is suggested to be applied in Chinese educational contexts. A total of 508 representations related to practical work was identified in seven sets of textbooks. The goal was to gain basic insights into the features associated with suggested approaches to practical work in the textbooks. Our focus was on the suggested type of learning, intended learning outcomes, inquiry level, and aspects of students' engagement with practical work. The results indicate a prevalence of prescribed experiments. This preference is then followed by illustrations of facts and laboratory operation processes. However, only a limited amount of scientific inquiries with at least some amount of openness belongs to the list of preferred items. The intended learning outcomes mainly aim at learning facts. Most textbooks suggest using a structured learning approach. Some suggestions of inquiry-based learning using either guided or open inquiry approaches do occur, but they are relatively limited in the textbooks and do not appear as frequently.

Keywords: Chemistry education, Textbook analysis, Practical work/laboratory

1. Introduction

Performing science is about gathering evidence from nature (Watson, Swain & McRobbie, 2004), or, more specifically as described by Millar (2004), science is an endeavor to gain an evidence-based body of knowledge about the natural world. Ways to generate evidence from nature include observations of natural phenomena, both in nature or in a laboratory context. That is why observations in nature and practical work have achieved their distinctive role in science education, since the time when schools began to teach science in the nineteenth century. They have maintained this central role until today (Hofstein, 2017).

Most educational standards and traditions in science education state the importance of practical work for the teaching and learning of science (Hofstein, 2017). We use the term practical work in a broader sense, which includes many other notions such as laboratory work, laboratory activity, investigation, inquiry, and experimentation. In this paper, it refers to any kind of teacher or student interaction either with equipment or materials to produce or observe phenomena, from which students achieve a better understanding of the natural world (Hofstein & Lunetta, 2004).

As stated by Millar, Le Maréchal and Tiberghien (1999), practical work can help in communicating information and ideas about the natural world to students. In the classroom there are basically two sources which lead students into practical work, namely teachers and textbooks. The focus of this paper is on textbooks. Scientific textbooks play an important role in science education in general (Aldahmash, Mansour, Alshamrani & Almohi, 2016), and in chemistry education in particular (Rusek & Vojíř, 2019). The importance of quality textbooks is especially high in countries where teaching tends to center around a selected textbook, e.g. in the People's Republic of China (Wang, Tang, Zhang, Hu, Zhi & Wei, 2015). There is a growing body of literature emphasizing the important role of critically analyzing textbooks (Clement, 2008). It is suggested that textbooks aim at defining school subjects (Devetak & Vogrinc, 2013), representing the intended curriculum (Aldahmash et al., 2016; Khaddoor, Al-Amoush, & Eilks, 2017; Tamir & Pilar-Garcia, 1992), promoting conceptual learning and helping in achieving scientific literacy (Upahi & Ramnarain, 2019; Wei & Chen, 2017), and presenting proper content for guiding teaching and learning (Abd-El-Khalick, Waters & Le, 2008; Kim & Kim, 2013; Stern & Roseman, 2004). In this study, we focus on how textbooks from different Chinese communities, namely from the People's Republic of China, Taiwan and the Chinese sector in Malaysia, introduce and represent practical work in chemistry education. A careful look was given to the suggested type of learning, the intended learning outcomes, the inquiry level, and students' engagement with practical work.

2. Theoretical framework

Practical work in the laboratory or in nature is widely suggested as a tool to provide students with opportunities to experience the natural world for the sake of learning (Kim & Song, 2006). This is also the case when it comes to helping students develop links between their observations and ideas (Abrahams & Millar, 2008). In the current study, we apply the term "practical work" to all intended or represented hands-on processes which help with better understanding evidence-based science performed inside and outside the laboratory. It covers any activity or associated reference where students can personally see or interact with materials and equipment in order to observe and understand the natural world. More specifically, the term refers to what students do or potentially can do, rather than to the location where the learning may take place. So practical work in our study concerns:

a. any suggested experimental activities in class,

b. all suggested scientific investigations either in or out of the laboratory, and

c. relevant pictures or sketches of experiments which potentially can be performed in the laboratory or beyond.

According to Katchevich, Hofstein, and Mamlok-Naaman (2013), practical work builds a bridge between science and the learner by actively performing science. It is widely accepted that practical work is an integral part of science education in schools, since it supports learning and is popular among students (Jones, Gott & Jarman, 2000). Such work has the potential to promote higher-order cognitive skills, if it is structured properly. It also provides chances for collaboration, deliberation and communication with peers (Katchevich et al., 2013). Hofstein and Lunetta (1982) have suggested, based on their review of former research, that practical work can also be considered as an effective teaching medium for achieving many of the stated goals of science education. They point out that practical work can facilitate students' learning and development and that it should play an important role in the achievement of the goals of science education. Practical work enables science teachers to facilitate both student learning and development to gain an understanding of what science really is.

Practical work can encompass purposeful observations or scientific inquiries by manipulating equipment and materials (Lederman & Lederman, 2012). Such work is driven by questions, predictions, observations, analyses and interpretations. The positive role of practical work for science learning is, however, not self-evident (Hofstein, 2017). Watson et al. (2004) suggested that students' discussions and decision-making processes in scientific inquiry often lag behind, if no clear emphasis is placed on a procedural understanding of scientific inquiry, instead of merely assessing individual practical skills and processes. Kim and Song (2006) promoted the use of more effective ways to organize practical work in order to promote students' thinking and to develop their argumentation abilities, such as the critical "peer review" of reports and arguments. The "thinking" part, for example the negotiation of meaning in practical work, should therefore be emphasized more than the "doing" part. This resonates with work published by Newton, Driver and Osborne (1999).

In 2008, Abrahams and Millar described that teachers put greater emphasis on the interpretation of scientific content, instead of student inquiry, and practical tasks were seen to be deficient in helping students to make these links. Hofstein (2017) also recently pleaded for a deeper reflection on practical work, since the implementation of practical work seems not to have changed much over the past years. His arguments call for paying more attention to higher-order thinking skills and for starting new developments in laboratory teaching strategies and in teacher professional development. This call includes a rethinking of the goals of learning in and from practical work, including how it is presented to students.

Today, the most popular strategy suggested for practical work in science education is inquiry. Inquiry-based practical work asks students to think of problems, formulate hypotheses, design experiments, gather data, and draw conclusions from scientific phenomena (Hofstein, 2017). There are, however, different levels of inquiry with respect to learners' mind-on involvement. A common typology of inquiry-based science education is related to the degree that students can influence scientific investigation. Banchi and Bell (2008) discussed four levels of inquiry-based learning in science education: confirmatory, structured, guided, and open inquiry. The higher levels are believed to challenge students' thinking more and allow them to better construct meaning from a scientific investigation (Table 1).

Table 1. Categorization of inquiry-based level (Banchi & Bell, 2008)

Category	Inquiry level	Question	Method	Answer
1	Confirmatory learning	Given	Given	Given
2	Structured inquiry	Given	Given	Open
3	Guided inquiry	Given	Open	Open
4	Open inquiry	Open	Open	Open

In the practice of science teaching factors such as time, equipment and goals come into play, aside the textbook, when practical work is introduced. They determine whether teachers will choose guided or open inquiry, or whether they will simply demonstrate an experiment to illustrate a scientific fact for their learners. Although there is a growing body of literature emphasizing the important role of textbooks in science teaching (Devetak & Vogrinc, 2013) and various facets of learning were analyzed with reference to textbooks (Aldahmash et al., 2016; Khaddoor et al., 2017; Tamir et al., 1992; Upahi & Ramnarain, 2019; Wei & Chen, 2017; Abd-El-Khalick et al., 2008; or Stern & Roseman, 2004), not much is known about how practical work is presented in secondary chemistry textbooks, especially in the context of secondary chemistry education in Chinese communities. This is why the current study focuses on how textbooks from different Chinese communities present practical work in chemistry education.

3. Sample

The sample consists of seven sets of 10^{th}-grade secondary chemistry textbooks and the accompanying experimental workbooks from the People's Republic of China, Taiwan and the Chinese sector in Malaysia.

In the People's Republic of China there have been two major rounds of curriculum reforms over the past

20 years. In 2003 new national Upper Secondary School Chemistry Curriculum Standards were released by the Ministry of Education (Ministry of Education, 2003) and corresponding textbooks were reviewed and published (Wang, 2010). The latest round of standards were released in 2017 and were meant to be implemented officially in the fall semester of 2018 (Ministry of Education, 2017). Since the textbooks corresponding to the newest 2017 standards are still under revision, the Ministry of Education has asked upper secondary schools to continue using the textbooks based in the 2003 standards (Ministry of Education, 2018). For this study, we chose three widely-used 10th-grade chemistry textbooks and their workbooks, which were suggested by the Ministry of Education. These textbooks are published by People's Education Press (further named CN1), Shandong Science and Technology Press (CN2), and Jiangsu Education Press (CN3) (see Appendix 1). As one of the most developed cities in China, Shanghai is allowed to operate education under its own standards and choose its own textbooks. Textbooks for Shanghai are edited under the review of the Shanghai Primary and Secondary Curriculum and Teaching Materials Reform Commission (Sun, Xu, Zhang & Zhao, 2016). In this study, we chose the chemistry textbooks from Shanghai Scientific and Technical Publishers (CN4, see Appendix 1), as suggested by the Shanghai Municipal Education Commission (2018). In the case of Taiwan, we chose two sets of 10th-grade chemistry textbooks and experimental workbooks (TW1 and TW2, see Appendix 1) which are widely used in Taiwan and were recommended by the National Academy for Educational Research (National Academy for Educational Research, 2018). In addition to Mainland China and Taiwan, Malaysia is a country that operates a complete Chinese educational system from primary school all the way through to college. The country has about 23% ethnic Chinese out of a total of 32.4 million citizens (Xu & Xu, 2016; Xia, Yang & Lee, 2018). Independent Chinese Secondary Schools (ICSSs) are segregated into a disparate branch using Mandarin Chinese as the main instructional language (Vivien, 2018). Official bodies supporting the Chinese educational system in Malaysia are the United Chinese School Committees' Association (UCSCA or Dong Zong), together with the United Chinese School Teachers' Association (UCSTA or Jiao Zong) (Dong Zong, 2018). In this study, we chose the Malaysian upper secondary chemistry textbook and the associated experimental workbook which is published by the United Chinese School Committees' Association of Malaysia (MY, see Appendix 1).

4. Method

All of the textbooks were screened page by page. Each representation of practical work was carefully collected and listed. The collection considered suggestions for practical work, descriptions of laboratory procedures, and sketches or pictures showing examples of practical work. This led to an overall total sample of 508 representations from the seven sets of textbooks and experimental workbooks we selected.

Analysis of the data was performed using qualitative analysis inspired by Mayring (2014) in a combination of inductive and deductive formation of categories. For the general rating grid, four categories (C1-C4) were identified, namely: type of learning, intended learning outcomes, inquiry level and students' engagement. Each category was also subdivided into 3-5 sub-categories (Table 2). Table 2 was modified several times. Pilot trial analysis was performed until the final version sufficiently matched the data. Detailed rating schemes were developed that finally led to an inter-rater agreement of above 85% for the initial coding and above 95% with a second round of joint coding and negotiating the cases of disagreement.

Table 2. Basic overview of features of practical work (adapted from Millar et al., 1999)

Practical work concerns	
C1	Type of learning

	C1.1 Operating a given experiment
	C1.2 Picture/sketch for illustrations
	C1.3 Picture/sketch for illustration of a laboratory technique
	C1.4 Scientific investigation with an open approach
C2	Intended learning outcomes
	C2.1 Identify objects and phenomena and learning a laboratory technique
	C2.2 Learn fact (s)
	C2.3 Learn concept
	C2.4 Learn a relationship
	C2.5 Learn a theory/model with reference to the sub-microscopic level
C3	Inquiry level of practical work
	C3.1 Confirmatory learning without hypothesis
	C3.2 Confirmatory inquiry learning
	C3.3 Structured inquiry learning
	C3.4 Guided inquiry learning
	C3.5 Open inquiry learning
C4	Students' engagement
	C4.1 Context
	C4.2 Performance
	C4.3 Application

The final analyzing instrument was inspired by Millar, Le Maréchal and Tiberghien. (1998), who looked at practical work involving learning activities to prepare students for specific learning outcomes (Table 3). Later, Millar et al. (1999) explored the variety of practical work and came up with different intended leaning outcomes which were used as the basis for developing the coding grid found in Table 4. Concerning the inquiry level, we selected the model by Banchi and Bell (2008). Then we extended it by adding a category called "confirmatory learning without hypothesis," based on findings that the former four levels did not cover all of the cases in our sample (Table 5). To compare levels of students' engagement presented by practical work, we refer to Tiberghien, Veillard, Le Maréchal, Buty and Millar (2001) to explore how given tasks engage students in practical work (Table 6).

Table 3. Types of learning (inspired by Millar et al., 1998)

Type of learning	**Illustration**
Performing a given experiment	Tasks ask either the student or teacher to perform a given experiment
Picture/sketch illustration	Picture or sketches showing any experiment or practical activity to illustrate fact(s)

Picture/sketch illustration on a laboratory technique	Picture or sketches to illustrate a laboratory technique or the proper use of an apparatus
Scientific investigation with an open approach	Tasks that ask students to conduct (potential) experiments with an (at least partially) open approach

Table 4. Intended learning outcomes/objectives of practical work (inspired by Millar et al., 1999)

Intended learning outcomes	**Explanation**	**Examples**
Identifying objects and learning a laboratory technique	Support students in identifying chemical objects and understanding a laboratory technique.	- filtration - distillation - decanting - the proper use of a burette/separating funnel/ centrifuge
Learn fact(s)	Support students in learning fact(s) at the phenomenological level so that they are able using them later for understanding.	-pure water boils at 100°C at standard atmospheric pressure - color change during chemical reactions - flame color test
Learn a concept	Support students in relating two or more observable facts in order to understand a certain scientific idea leading to a concept inferred from observations.	- redox reactions, chemical bonds - molar mass - forces - electrolysis - oxidation and reduction of iron and its compounds
Learn a relationship	Support students in learning how to link a set of observations with properties or substances in order to understand a correlation dependent on variables.	- collecting data and drawing a diagram showing the relationship between potassium nitrate solutions and temperature - the reaction speed of the alkali metals increasing with increasing period in the periodic table of elements - substances in distillations evaporating dependent upon their evaporation temperatures - solubility varying with temperature
Learn a theory/model with reference to the sub-microscopic level	Support students' data collection and interpretation skills by using a specific theory based on unobservable entities, and hence help students to develop their understanding of the theory and how it can be applied.	- law of definite proportions - law of conservation of mass - the model of chemical reactions as a rearrangement of atoms to form new groups

Table 5. Levels of scientific inquiry (inspired by Banchi & Bell, 2008)

Inquiry level	Explanation
Confirmatory learning without hypothesis	Learner given information or procedure without hypothesis, e.g., laboratory technique operation manual
Confirmatory inquiry learning	Verification/confirmatory activities providing a question and detailed instructions to get a result explained in the text
Structured inquiry learning	Activities that provide a question and detailed instructions, but students have to find the answer
Guided inquiry learning	Activities that provide a question and the students have to design their own method to find the answer
Open inquiry learning	Activities that start from a fact or claim and students have to come up with a question, then design the method to find the answer

Table 6. Students' engagement in practical activities (inspired by Tiberghien et al., 2001)

	detailed operation process
	picture or sketch aiding learning
Context	chemical equation writing
	safety operation tips
	chemical recycle and waste disposal
	sub-micro level explanation
Performance	hands-on
	hands-free
Application	apply finding in a new context

5. Findings

5.1 Overall references to practical work

A total number of 508 representations related to practical work was collected from the seven sets of textbooks and associated experimental workbooks in different Chinese communities. The numerical breakdown of the representations was as follows: 98 from CN1, 75 from CN2, 70 from CN3, 61 from CN4, 43 from TW1, 45 from TW2 and 116 from MY.

5.2 Type of learning

In the category labeled type of learning, we can observe wide variety (Figure 1). Figure 1 indicates that most of the practical work representations used in Mainland China and Malaysia focus on conducting a given experiment. The Taiwanese textbooks have the lowest number of references to practical work. These are primarily pictures or sketches of experiments, either for illustration purposes or for introducing laboratory techniques. Scientific investigation employing at least a partially open approach could only be found in the textbooks from China and Malaysia to a varying degree. There were a total of 5 from CN4 and 23 in CN1. This was out of 61 to 98 representations of practical work in total, with having the highest numbers in CN1 and CN2 (23 and 17), correspondingly. Most of these were, however, taken from the associated experimental workbooks, not from the textbooks themselves.

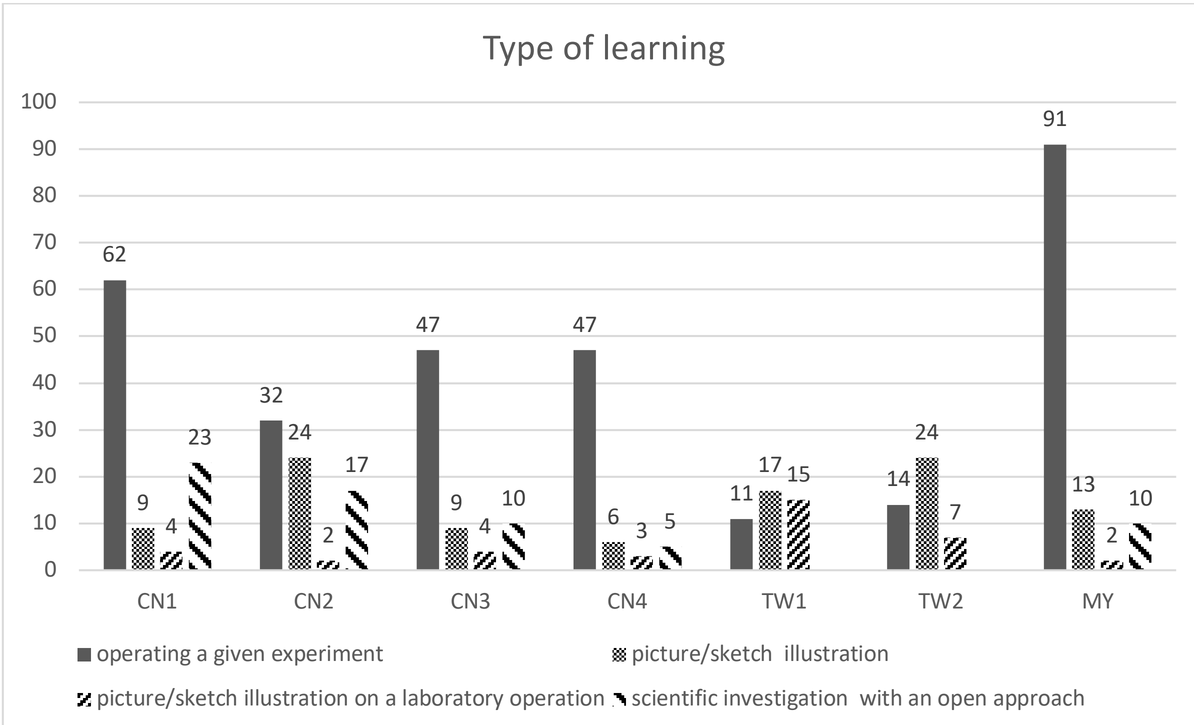


Figure 1. Type of learning suggested in presentations of practical work

5.3 Intended learning outcomes

In terms of intended learning outcomes related to representations of practical work, we find a trend of “learning fact(s)” (Figure 2), which is quite pronounced in the textbooks taken from Mainland China and Malaysia (CN1, CN2, CN3, CN4, & MY). In the textbooks from Taiwan, which had the lower numbers of figures in total, this category is not so predominant. The identification of chemical objects and learning laboratory techniques are more coming up with the identification of facts. The learning of a concept category makes up roughly 20-30% of the representations of practical work found in all the books. The use of practical work for learning relationships between factors or concepts tends to be 10% or less in all the textbooks. Learning about theories or models was only connected to practical work in 7 out of the 508 representations identified in the whole sample, thereby only hovering around the 1% mark.

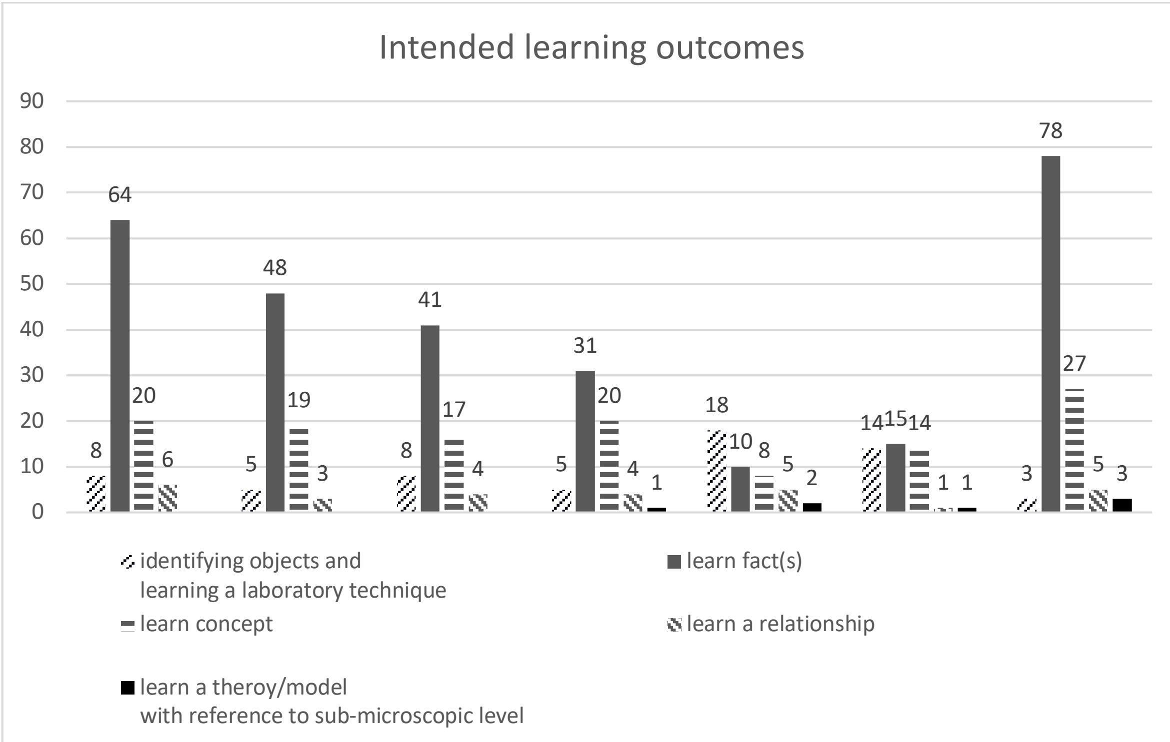


Figure 2. Intended learning outcomes suggested in presentations of practical work

5.4 Inquiry level of practical work

Looking more closely at the data concerning levels of inquiry, we can see that textbooks from Mainland China and Malaysia tend to suggest more inquiry-based activities. Most examples consisted of structured inquiry learning, although a certain proportion also suggested guided inquiry learning approaches (Figure 3). Confirmatory inquiry learning appears in all of the above-mentioned textbooks, with the Shanghai textbook (CN4) containing the smallest number (7) of examples. In the textbooks from Taiwan, confirmatory inquiry learning dominates suggestions for structured or guided inquiry learning, making up about 75% of the references to practical work. This proportion is much smaller in the textbooks taken from Mainland China and Taiwan, which had roughly 15-30% as many references, correspondingly. The Taiwanese textbooks refer more often to practical work with the use of pictures and sketches to illustrate the observation level. Confirmatory learning without a hypothesis tends to refer to the proper use of apparatus and essential operational processes such as filtration, distillation and so on. There are, however, two suggested activities related to an open approach in one of the Mainland China textbooks (CN1). These are presented in an optional module in the experimental workbook.

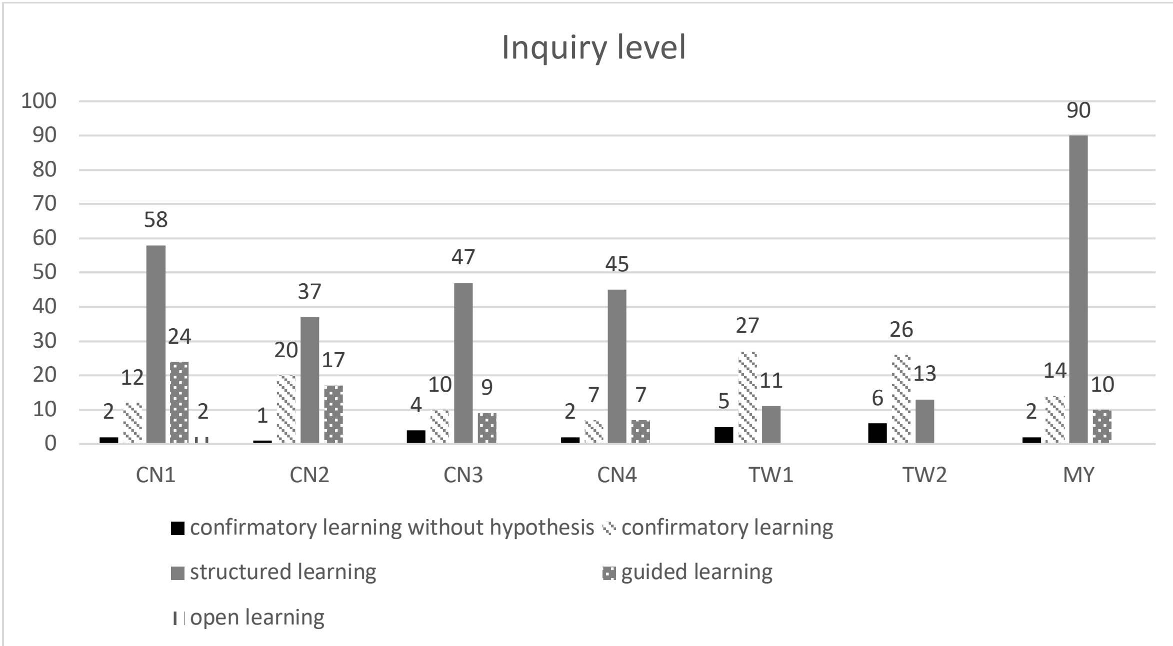


Figure 3. Inquiry level suggested in presentations of practical work

5.5 Students' engagement with practical work

The level of students' engagement with practical work varies widely in the different textbooks, as was the case in the other focuses of this study (Figure 4). In the textbooks from Mainland China and Malaysia, most references to practical work start with detailed instructions or by using pictures or sketches to support learning. The highest number of detailed instructions can be found in the textbook from Malaysia. In Taiwan, there are much fewer detailed instructions; pictures and sketches to support learning dominate. All of the other categories play only a minor role. A focus on chemical recycling and waste disposal plays a prominent role in the textbooks selected for Taiwan, making up roughly 25% of the references to practical work in both of the textbooks. It is also notable that hands-on activities are more often explicitly suggested in the textbooks from Mainland China and Malaysia than in the textbooks from Taiwan (Figure 5). Figure 6 shows that all of the textbooks provide references to practical work, asking students in certain situations to apply their finding in a new context. One example is that after students learn about the zinc-copper galvanic cell, extra tasks are given to them, which demand that they build a fruit battery with a tomato or a lemon. This is the case to a varying degree in only two or three up to ten tasks total (Figure 6).

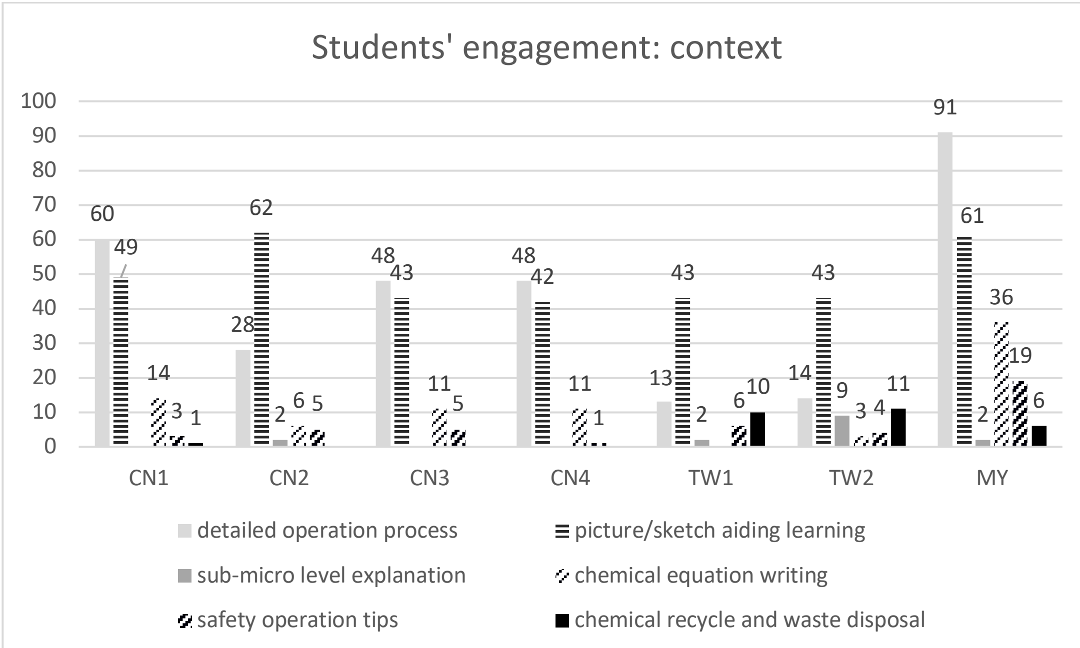


Figure 4. Students' engagement: context related to presentations of practical work

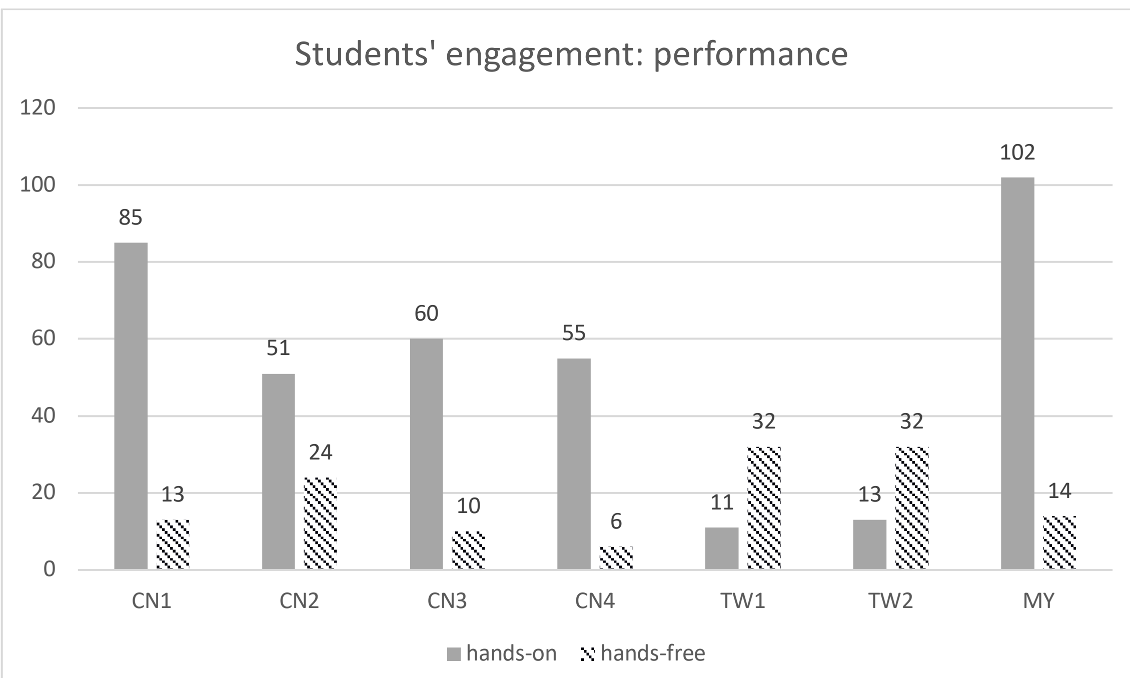


Figure 5. Students' engagement: performance related to presentations of practical work

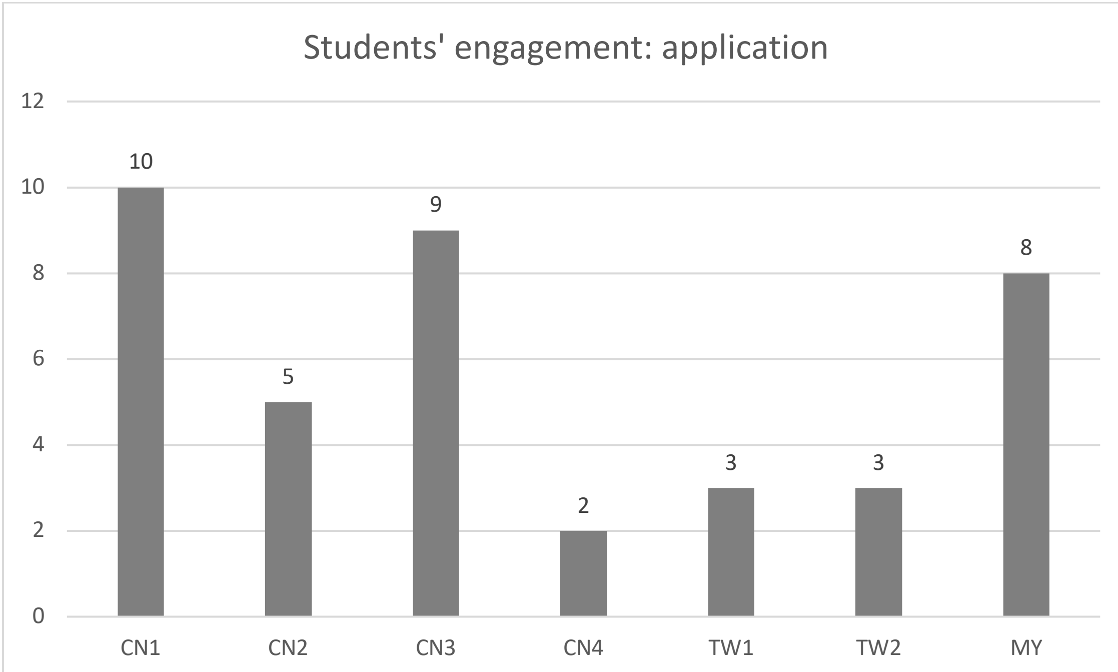


Figure 6. Students' engagement: application of practical work to a new task

6. Discussion and conclusion

The purpose of this study was to examine Chinese 10th-grade chemistry textbooks and their associated experimental workbooks. We examined representations of practical work taken from different Chinese communities, namely the People's Republic of China, Taiwan and the Chinese sector in Malaysia. The study concentrated the textbook analysis in four domains: type of learning, intended learning outcomes, inquiry level, and aspects of students' engagement. There are similarities and differences in the chemistry textbooks of this sample. There are larger differences occurring in textbooks between different Chinese communities than within them. This could also be seen when we compared the use of visual representations in Chinese communities in the specific case of redox reaction content (Chen, Goes, Treagust & Eilks, 2019). The textbooks from Malaysia show similar characteristics to those selected from Mainland China. This is in no way astonishing, since educators from Mainland China take part in Malaysian ICSS chemistry textbook editing. The textbooks from Taiwan look different in terms of the lower overall number of references to practical work, less representations of higher levels of inquiry learning, and in the number of references giving detailed instructions on how to carry out practical work.

Generally, practical work in the textbooks from this sample refers to performing given experiments in all textbooks, except for Taiwan. In Taiwanese textbooks more picture/sketch illustrations are used at the observational level. Confirmatory inquiry learning is quite dominant in Taiwanese textbooks, since they contain the highest proportion of picture/sketch resources that refer to corresponding tasks. This means that students observe pictures, instead of carrying out the whole experimental process for themselves. The other textbooks we examined tended direct teachers and students more thoroughly towards a structured learning approach, which leads to an open answer for students to find by themselves. Guided learning can be found in all of the textbooks, except for Taiwan, but open learning only appears as an optional module in one of the textbooks (CN1).

It is widely believed that textbooks represent publishers' and authors' choices on reflecting the nature of science (Chiappetta & Fillman, 2007). It has been suggested that if laboratory activities in textbooks are properly developed, they have the potential to develop both students' meaningful learning and their conceptual understanding. There is a gap in research in many countries to know exactly how teachers are using textbooks, both in terms of intensity and their pedagogical approach. It is suggest, however, that in many centralized educational systems, such as in Mainland China, curricula and textbooks are officially reviewed and published in order to serve as a main educational resources for the teachers (Zhang & Gao, 2013). In these countries, teachers rely heavily on the official curriculum, the associated textbooks, and any available teacher guidebooks when conducting their lessons. This was reported by Aldahmash et al. (2016) in the Saudi-Arabian context, where 100% of the teachers uniformly follow the same textbook in school step by step. Their data showed that this close adherence to the textbook led to a quite teacher-centered pedagogy. Similar claims that teachers are closely following the curriculum and textbook have also been made in the case of Mainland China (Wang, 2010). Reasons for this include the fact that a given educational system is a combination of physical settings (e.g., class size, class resource) and social settings (e.g., learners' background, local community, school principle, nation policy, local education authority) (Watson et al., 2004). Another factor is the dominant role of centralized national college entrance exams in China, which focus more on rote learning of knowledge than on inquiry skills (Davey, Lian & Higgins, 2007). This clear focus on final exams has already been described as a hindrance to educational reform towards more open teaching approaches (Chai & Cheng, 2011). Similar claims might also be assumed for the Chinese sector in Malaysia. Peen and Arshad (2014) stated that in Malaysian secondary schools, students get used to relying on their teachers for all information and instructions. They mostly listen passively to the teachers with occasionally limited questions being asked. If the teacher follows the textbooks step by step, there is a clear line for how practical work is introduced by the textbook to how it therefore effects students.

In other countries, it might be possible to find more openness for teachers to combine textbooks use with other media, for example, worksheets or Internet resources, if such media are available. Countries with higher average levels of socio-economic development might expect their teachers to possess more resources than just the textbook, e.g., digital media. Internet access should be available more broadly to enrich the learning experience in schools. Evidence has already shown that technology-aided learning in science education has become a popular trend in Taiwan (Lin & Tsai, 2016) and was also introduced in secondary chemistry education (Chen, 2018). This might be one reason for the lower number of representations of hands-on practical work suggestions in the textbooks from Taiwan, if the textbook is being combined with other resources. To answer whether this is the reason, however, further research would be needed on how teachers in Taiwan rely on the textbook for lesson planning. It also need to research in which manner textbooks are being combined with other resources.

This study is limited to chemistry education in three Chinese communities and only looks at one certain grade level. It also only deals with one aspect of textbooks and cannot say how these textbooks are being used, either as stand-alone tools or in combination with other resources. Answering these questions opens up further possibilities for research in the future. It also can stimulate further research into how textbooks develop over time. Malaysia recently implemented new chemistry textbooks and Mainland China will do so in the near future. Thus, the analysis of textbooks presented here can only be a snapshot in time, which needs to be revisited and deepened after the next round of curriculum reform and its implementation take place.

Acknowledgment

We would like to thank the China Scholarship Council (CSC) and the program STIBET Deodorant at the University of Bremen for funding this research. We appreciate cooperation in this research with Robin Millar (UK), Chua Kah Heng (Malaysia) and Hongseok Jeong (Korea).

References

Abd-El-Khalick, F., Waters, M., & Le, A. P. (2008). Representations of nature of science in high school chemistry textbooks over the past four decades. *Journal of Research in Science Teaching*, *45*(7), 835-855.

Abrahams, I., & Millar, R. (2008). Does practical work really work? A study of the effectiveness of practical work as a teaching and learning method in school science. *International Journal of Science Education. 30*(14), 1945-1969.

Aldahmash, A. H., Mansour, N. S., Alshamrani, S. M., & Almohi, S. (2016). An analysis of activities in Saudi Arabian middle school science textbooks and workbooks for the inclusion of essential features of inquiry. *Research in Science Education*, *46*(6), 879-900.

Banchi, H., & Bell, R. (2008). The many levels of inquiry. *Science and Children*, 46(2), 26.

Chai, C., & Cheng, G. (2011). Policies on China's basic education over the last thirty years. In X. Zhang (Ed.), *China's Education development and policy*, 1978-2008 (pp. 111-163). Leiden: Brill.

Chen, Z. S. (2018). Application of software and platform in primary and secondary chemistry teaching-promote the acid-base conceptual learning by creating an educational platform. *Chemistry Education in Taiwan*, 2018 (24), 1-7.

Chen, X., Goes, L. F., Treagust, D. F., & Eilks, I. (2019). An analysis of the visual representation of redox reactions in secondary chemistry textbooks from different Chinese communities. *Education Sciences*, *9*(1), 42.

Chiappetta, E. L., & Fillman, D. A. (2007). Analysis of five high school biology textbooks used in the United States for inclusion of the nature of science. *International Journal of Science Education*, *29*(15), 1847-1868.

Clement, P. (Ed.). (2008). Special issue of SEI-relating to critical analysis of school science textbooks. *Science Education International, 19*(2), 98-250.

Davey, G., Lian, C. D., & Higgins, L. (2007). The university entrance examination system in China. *Journal of Further and Higher Education*, *31*(4), 385-396.

Devetak, I., & Vogrinc, J. (2013). The criteria for evaluating the quality of the science textbooks. In M. Khine (Ed.), *Critical Analysis of Science Textbooks* (pp. 3-15). Dordrecht: Springer.

Dong Zong, 2018. The background of Dong Zong's establishment. Available at: www.dongzong.my/eindex.php (accessed on 09 February2019).

Hofstein, A. (2017). The role of laboratory in science teaching and learning. In K.S. Taber & B. Akpan (Eds.), *Science education* (pp. 357-368). Rotterdam: Sense.

Hofstein, A., & Lunetta, V. N. (1982). The role of the laboratory in science teaching: Neglected aspects of research. *Review of Educational Research*, *52*(2), 201-217.

Hofstein, A., & Lunetta, V. N. (2004). The laboratory in science education: Foundations for the twenty-first century. *Science Education*, *88*(1), 28-54.

Jones, M. E., Gott, R., & Jarman, R. (2000). Investigations as part of the key stage 4 science curriculum in Northern Ireland. *Evaluation & Research in Education*, *14*(1), 23-37.

Katchevich, D., Hofstein, A., & Mamlok-Naaman, R. (2013). Argumentation in the chemistry laboratory: Inquiry and confirmatory experiments. *Research in Science Education*, *43*(1), 317-345.

Khaddoor, R., Al-Amoush, S., & Eilks, I. (2017). A comparative analysis of the intended curriculum and its presentation in 10th grade chemistry textbooks from seven Arabic countries. *Chemistry Education Research and Practice, 18*(2), 375-385.

Kim, H. T., & Kim J. G. (2013). How do high school textbooks in Korea, Japan and the U.S. explain bioaccumulation concepts? *Science Education International, 24*(4), 416-436,

Kim, H., & Song, J. (2006). The features of peer argumentation in middle school students' scientific inquiry. *Research in Science Education*, *36*(3), 211-233.

Lederman, N. G., & Lederman, J. S. (2012). Nature of scientific knowledge and scientific inquiry: Building instructional capacity through professional development. In B. Fraser, K. Tobin & C. McRobbie (Eds.), *Second international handbook of science education* (pp. 335-359). Dordrecht: Springer.

Lin, T.-C., & Tsai, C.-C. (2016). Innovative technology-assisted science learning in Taiwan. In M.-H. Chiu (Ed.), *Science education research and practice in Asia* (pp. 189-209). Singapore: Springer.

Mayring, P. (2014). Qualitative content analysis. www.psychopen.eu/fileadmin/user_upload/books/mayring/ssoar-2014-mayring-Qualitative_content_analysis_theoretical_foundation.pdf (accessed on 22 May 2019).

Millar, R. (2004). The role of practical work in the teaching and learning of science. Paper prepared for the meeting *High School Science Laboratories: Role and Vision.* Washington: National Academy of Sciences.

Millar, R., Le Maréchal, J.-F., & Tiberghien, A. (1998). A map of the variety of labwork. Labwork in science education. Available at: www.epitropakisg.gr/grigorise/Labwork-wp1.pdf (accessed on 13 May 2019).

Millar, R., Le Maréchal, J.-F., & Tiberghien, A. (1999). “Mapping” the domain: Varieties of practical work. In J. Leach & A. C. Paulsen (Eds.), *Practical work in science education: Recent research studies* (pp. 33-59). Dordrecht: Kluwer.

Ministry of Education (2003). *National upper secondary school chemistry curriculum standards*. Beijing: People’s Education Press.

Ministry of Education (2017). *National upper secondary school chemistry curriculum standards*. Beijing: People’s Education Press.

Ministry of Education (2018). Notice of the teaching books for primary and secondary schools in 2018. Available at: http://www.moe.gov.cn/srcsite/A26/moe_714/201805/t20180507_335240.html (accessed on 20 May 2019).

National Academy for Educational Research (2018). Textbooks for upper secondary school. Available at: review.naer.edu.tw/Bulletin/PA02.php (accessed on 08 February 2019).

Newton, P., Driver, R., & Osborne, J. (1999). The place of argumentation in the pedagogy of school science. *International Journal of Science Education, 21*(5), 553-576.

Peen, T. Y., & Arshad, M. Y. (2014). Teacher and student questions: a case study in Malaysian secondary school problem-based learning. *Asian Social Science. 10*(4). 174-182.

Rusek, M., & Vojíř, K. (2019). Analysis of text difficulty in lower-secondary chemistry textbooks. *Chemistry Education Research and Practice*, *20*(1), 85-94.

Shanghai Municipal Education Commission (2018). Announcement of recommendation for primary and secondary textbooks for 2019 academic year. Available at: www.shmec.gov.cn/html/xxgk/201811/402052018009.html (accessed on 05 March 2019).

Stern, L., & Roseman, J. E. (2004). Can middle-school science textbooks help students learn important ideas? Findings from Project 2061's curriculum evaluation study: Life science. *Journal of Research in Science Teaching. 41*(6), 538-568.

Sun, Y., Xu, D., Zhang, F., & Zhao, C. (2016). 25 years of curriculum reform in Shanghai (上海课程改革 25 年): Shanghai Educational Publishing House.

Tamir, P., & Pilar-Garcia, M. (1992). Characteristics of laboratory exercises included in science textbooks in Catalonia (Spain). *International Journal of Science Education*, *14*(4), 381-392.

Tiberghien, A., Veillard, L., Le Maréchal, J. F., Buty, C., & Millar, R. (2001). An analysis of labwork tasks used in science teaching at upper secondary school and university levels in several European countries. *Science education, 85*(5), 483-508.

Upahi, J. E., & Ramnarain, U. (2019). Representations of chemical phenomena in secondary school chemistry textbooks. *Chemistry Education Research and Practice*, *20*(1), 146-159.

Vivien, W. (2018). The language medium policies: A study on the development of independent Chinese secondary schools (ICSS) in Malaysia. *KATHA*, *13*(1), 32-53.

Wang, L. (2010). Basic chemistry education curriculum reform progress and reflection in the past years (Volume I). *Chinese Journal of Chemical Education, 31*(4), 15-21.

Wang, L., Tang, J., Zhang, R., Hu, J., Zhi, Y., & Wei, R. (2015). Investigation of the use of new chemistry textbooks of senior high school and the influential factors. *Journal of Educational Studies*, *11*(4), 77-86.

Watson, R. J., Swain, J. R. L., & McRobbie, C. (2004). Students' discussions in practical scientific inquiries. *International Journal of Science Education*, *26*(1), 25-45.

Wei, B., & Chen, B. (2017). Examining the senior secondary school chemistry curriculum in China in view of scientific literacy. In L. Liang X. Liu X & G. Fulmer (Eds.), *Chinese science education in the 21st century: Policy, practice, and research. Contemporary trends and issues in science education* (pp. 133-148). Dordrecht: Springer.

Xia, N., Yang, Y. N., & Lee, Y. E. (2018). Chinese Education in Malaysia under Malaysian Ethnic Politics.

Journal of Politics and Law, 11(2). 23-36.

Xu, L. L., & Xu, P. (2016). The popularization of Chinese language in multilingual environment - Based on the analysis of examples from Malaysia. Paper presented at *The 2nd International Conference on Modern Education and Social Science* (MESS 2016). China: Wuhan.

Zhang, H., & Gao, Z. (2013). Curriculum studies in China: retrospect and prospect. In W. F. Pinar (Ed.), *International handbook of curriculum research* (2nd ed., pp. 118-133). New York: Routledge.

Appendix 1:

Overview about the textbooks

Textbook	Reference
CN1	Song, X. Q. (ed.). (2007). Chemistry 1 (3rd ed.). Beijing: People Education Press.
	Song, X. Q. (ed.). (2007). Chemistry 2 (3rd ed.). Beijing: People Education Press.
	Song, X. Q. (ed.). (2007). Chemistry Experiment (4rd ed.). Beijing: People Education Press.
CN2	Wang, L. (ed.). (2007). Chemistry 1 (3rd ed.). Shandong: Shandong Science and Technology Press.
	Wang, L. (ed.). (2007). Chemistry 2 (3rd ed.). Shandong: Shandong Science and Technology Press.
	Wang, L. (ed.). (2007). Chemistry Experiment (2nd ed.). Shandong: Shandong Science and Technology Press.
CN3	Wang, Z. H. (2014). Chemistry 1 (6th ed.). Nanjing: Jiangsu Education Press.
	Wang, Z. H. (2015). Chemistry 2 (6th ed.). Nanjing: Jiangsu Education Press.
	Wang, Z. H. (2009). Chemistry Experiment (2nd ed.). Nanjing: Jiangsu Education Press.
CN4	Yao, Z. P. (ed.). (2007). Chemistry (Volume 1) (1st ed.). Shanghai: Shanghai Scientific and Technical Publishers.
	Yao, Z. P. (ed.). (2007). Chemistry (Volume 2) (1st ed.). Shanghai: Shanghai Scientific and Technical Publishers.
	Yao, Z. P. (ed.). (2007). Chemistry Workbook (Volume 1) (1st ed.). Shanghai: Shanghai Scientific and Technical Publishers.
	Yao, Z. P. (ed.). (2007). Chemistry Workbook (Volume 2) (1st ed.). Shanghai: Shanghai Scientific and Technical Publishers.
TW1	Huang, D. S. (ed.). (2010). Basic Chemistry 1 (1st ed.). Taiwan: LungTeng Culture.

	Huang, D. S. (ed.). (2010). Basic Chemistry 1-Experimental Manuscript (1st ed.). Taiwan: LungTeng Culture.
TW2	Yeh, M.C. P. (ed.). (2010). Basic Chemistry 1 (1st ed.). Taiwan: Nan I Book Enterprise. Yeh, M.C. P. (ed.). (2011). Basic Chemistry 1- Experimental Manuscript (1st ed.). Taiwan: Nan I Book Enterprise.
MY	Wang, C. K. (2017). Upper secondary school chemistry (volume 1) (1st ed.). Malaysia: United Chinese School Committees' Association of Malaysia. Wang, C. K., Lin, Y. (2018). Chemistry Experiment Manuscript (volume 1) (1st ed.). Malaysia: United Chinese School Committees' Association of Malaysia.

Note. MICSS=Unified Curriculum Committee of Malaysian Independent Chinese Secondary School Working Committee.

PAPER 4

Transformation of chemistry education in the People's Republic of China–A view on the chemistry education standards

Book chapter in

I. Eilks, S. Markic & B. Ralle (Eds.), Building bridges across disciplines for transformative education and a sustainable future

Author Contributions: The conceptualization of this study was made by Xiaoge Chen and Ingo Eilks. The methodology was evaluated by Ingo Eilks. The data were evaluated by Xiaoge Chen. The first version of the manuscript was written by Xiaoge Chen and then finalized and reviewed by all authors.

Transformation of chemistry education in the People's Republic of China – A view on the chemistry education standards

Xiaoge Chen and Ingo Eilks
University of Bremen, Bremen, Germany

For more than the last ten years, upper secondary school curriculum programs in the People's Republic of China were guided by the curriculum standard framework released in 2003 by the Ministry of Education. In 2017, a new standard framework for the upper secondary school curriculum was issued. The new standard framework is suggested leading to a significant improvement in education, especially in science teaching and learning, with the aim to keep students up with global developments in technology, economy and society. In this chapter, both standard frameworks are compared. It is suggested that scientific knowledge was over emphasized in the 2003 chemistry curriculum standards compared to scientific attitudes and values. These standards are now compared with the 2017 standards and reflected based on a model of the relevance of science education. The 2003 upper secondary school chemistry standards focus mainly the individual dimension of relevance of science education but with some indicators of incorporating inquiry learning and science, technology and society views. It is suggested that the 2017 upper secondary school chemistry standards align better with modern curriculum theory and indicate better focusing relevant science education with respect to its societal and vocational relevance.

Introduction and Framework

School education, especially secondary school education, is an essential stage for students' transition toward higher education in many different professions. Science education is, however, not very popular among many students. Many reasons are suggested behind this issue. One is: Science education in many countries is not operated in a way to promote students' understanding of the relevance of science learning for their individual and professional life in society, today and for the future (Hofstein, Eilks, & Bybee, 2011; Stuckey, Hofstein, Mamlok-Naaman, & Eilks, 2013).

Although growing research is devoted to make school science more engaging (Erduran & Dagher, 2014), more relevant (Stuckey et al., 2013) or to implement teaching in science related to relevant topics with the aiding of traditional or unconventional media (Belova & Eilks, 2015) it is not clear for many countries to which extend corresponding ideas are implemented yet.

I. Eilks, S. Markic & B. Ralle (Eds.): Building bridges across disciplines, 295-300

Two rounds of curriculum reform took place in People's Republic of China in the last 20 years. In 1999, a curriculum standard committee was set up and issued new upper secondary school chemistry curriculum standards in 2003 (Wang, 2010). In the end of 2017, a new version of upper secondary school chemistry curriculum standards was released and will be implemented officially in the 2018 fall semester.

In this chapter, we focus the differences of the 2003 and 2017 upper secondary school chemistry curriculum standards based on the theory of relevant science education as suggested by Stuckey et al. (2013). We examine how new chemistry curricula in the People's Republic of China now are suggested to embrace innovative themes and contents related to the individual, societal and vocational relevance of science education.

Method

The sample includes the upper secondary school chemistry curriculum standard frameworks (USSCC) released by the Ministry of Education in the People's Republic of China in 2003 (Ministry of Education, 2003) and 2017 (Ministry of Education, 2017). We analysed the content of the two USSCCs and particular focussed on any innovative topics that reflect modern science curriculum theory. The focus was on the intended curriculum which is set up by the curriculum structure, curriculum goals, academic requirements, and content standards. Suggested activities, inquiry work, teaching/learning contexts, teaching strategies, and suggested lesson plans were not part of the analysis in this chapter since their operation will be much more based on teachers' knowledge and personality, class size, or local environment.

Findings

Both the two USSCCs released in 2003 and 2017 suggest starting chemistry education mainly with a view on its individual relevance as a base and further aligns chemistry learning with its societal and vocational relevance. In terms of the three dimension of relevant science education (Stuckey et al., 2013), both USSCCs conceptualize them in a different way.

Individual relevance

Both the two standard frameworks focus individual relevance mainly by emphasising basic knowledge and skills. The 2003 USSCC approaches individual relevance in the field of "knowledge and skills" together with "process and methods" and relates the emphasis of individual achievement mainly to the acquisition of facts, laws, concepts, and rules. The 2003 USSCC asks students' integrated skills in two ways. One way is focusing chemistry experiments in combining basic experimental operations with general operational skills, for example, laboratory skills in the separation or purification of matter and preparation of solutions. The other way focuses learning-into-application, for example, to know about different metals and their properties important to their application in the alloy material industry. Scientific inquiry mainly focuses on experimental inquiry abilities, generally described as a continuous process of suspect, proposal, hypothesis and design.

The 2017 USSCC suggests to better keep up with the individual relevance of chemistry learning by referring stronger to general intellectual skill development. Corresponding curriculum goals focus “macro identify and micro inquiry”, “critical thinking and balance cognition”, and “evidence deductiving and modelling cognition”. Instead simply focusing basic knowledge and skills (like in the 2003 USSCC), the 2017 USSCC focuses more on knowledge acquisition, development, model construction, and coping related applications as a whole. For example: In the section on atomic structure and properties of the elements, both standards ask for acquisition of fundamental knowledge on electron configuration, ionization energies, electronegativity, hydrogen-bond interaction etc. The 2017 USSCC add academic requirements of becoming able to illustrate the importance of modelling on the process of human understanding of atomic structure. Modelling competence is asked as an academic requirement. The 2017 USSCC also highlights the understanding of existence and effects of hydrogen-bonding in nature besides describing the academic requirement of hydrogen-bonding just as a concept. More places can be found where the 2017 USSCC suggests supporting students various ways of thinking and thus supporting their intellectual skills development.

Societal relevance

Generally, the 2017 USSCC focuses more the societal dimension of relevant science education than 2003 USSCC does. It focuses students’ learning toward the importance of avoiding certain societal problems, like water pollution or energy wasting. It aims at environmental protection instead of later searching for proper ways to solve societal problems after pollution has come into being. For example: the 2003 USSCC requires students to know air/house/water pollutants, being aware of their harmfulness and to exemplify proper ways to solve pollution and waste problems. The 2017 USSCC requires students to know about related national laws and regulations on environment control and pollution prevention first, then to build sense and responsibility of compliance with laws and regulations to avoid causing environmental problems, and finally, to know proper control measures and being aware of the importance of a harmonious coexistence between humans and nature. Basically, the 2017 USSCC tries to make students aware of the importance of protecting the environment, rather than paying attention to remedial action after any kind of pollution. By suggesting a multi knowledge-skills-values level, the 2017 USSCC conveys a richer focus on the societal dimension of relevant science education than the 2003 USSCC does. The 2017 USSCC better suits the idea that chemistry education involving the societal relevance of science education contributes to forming responsible citizens.

Related to the skills described above, the 2017 USSCC adds further academic requirements by asking students to become able to analyse societal issues and to participate, discuss, judge, evaluate, make own decisions on socio-scientific issues. The intended innovations imply that the new curriculum regards learners as individual units within society and suggests to promote their influence to issues in their environment, both for the present and future.

Vocational relevance

Vocational issues are quite limited in both USSCCs. The 2017 USSCC, however, provides wider vocational orientation than the 2003 USSCC does. The 2017 USSCC does not only demonstrate that new technology and materials do have chemistry behind, the importance of developing chemicals to promote societal and economic growth are also connected to career awareness and vocational orientation. For example, the 2017 USSCC asks students to list potential careers related to chemistry and to illustrate the connection of these professions to chemistry. This is suggested to show the learners the vocational relevance of chemistry learning, relevant not only to get well marks or coping with personal life, but also to connect chemistry learning with potential careers at present or getting a job in the future. Such kind of future careers discussions is absent in the 2003 USSCC.

Discussion

The two USSCCs are outcomes of a corresponding development of education with time. We can see a variety of approaches taken towards changing the chemistry curriculum (Table 1).

Table 1. General characteristics of USSCC

	2003 USSCC	2017 USSCC
Individual relevance	Fundamental knowledge Scientific inquiry Skills for life application	Fundamental knowledge Scientific inquiry Skills for life application Modeling cognition Critical thinking Evidence deductiving
Societal relevance	Citizen responsibility STS	Citizen responsibility STSE Balance cognition
Vocational relevance	Interdisciplay application Contributing to society	Interdisciplay application Contributing to society Orientation about potential careers
Degree of suggested relevance dimension coverage	Individual relevance - high Societal relevance - medium Vocational relevance - low	Individual relevance - high Societal relevance - high Vocational relevance - medium

Both the two curriculum standards emphasis more the individual dimension of relevant science education including knowledge and skills related to fundamental chemistry, rather than focusing both the societal and vocational dimensions. One reason might be that the People's Republic of China is still one of the Asian countries where paper and pencil examinations dominate and provide the only way for the Chinese youth to aspire to higher college/university education. These exams mainly focus knowledge and content rather skills and contexts. To get good marks at the end of the year external examination or college entrance examination usually are used as a measure for accounting school performances. The centralised system may be hindering to students' achieving more advanced levels of scientific literacy as suggested by Sjöström and Eilks (2018).

We can see from the two USSCCs that they can be considered as developments in the intended curriculum toward relevant chemistry education. The 2017 USSCC includes more aspects of relevant science education. It tends to promote knowledge and skills to a richer and wider academic level by involving modelling cognition, critical thinking in society, the awareness for environment protection, responsibility that each individual should bear in mind to be a responsible citizen in society etc. The vocational dimension is also highlighted not only referring to interdisciplinary applications but also related to potential careers.

However, there might be a gap between the curriculum standards, the intended curriculum transferred by textbooks, and the operated curriculum taught by the school teachers (Van Den Akker, 1998). As far as we can see, chemistry textbooks from the People's Republic of China do not yet support the corresponding USSCC in a sufficient way. It might also happen that teachers are supportive of the new USSCC but struggle to imply it because of a miss of proper implementation and professional development programs. Teachers, being trained in traditional approaches, might struggle with new directions in teaching. Without proper preparation and professional development they might fall back into their previous practices (Van Berkel, 2005). Thus, besides the development of an updated curriculum, a strong focus is needed to enhance the delivery and implementation of the new USSCC. This has to be done in a collaborative effort by policy makers, educators, and practitioners with a focus on developing corresponding curriculum materials and teaching strategies based on teachers' prior experiences and knowledge (Eilks & Hofstein, 2017). The main issue, however, will be to align the central examinations with the suggested changes in the intended curriculum. Otherwise, no change and development will occur (Osborne & Dillon, 2008).

Acknowledgement

We are grateful for the support afforded to the research by the China Scholarship Council.

References

Belova, N., & Eilks, I. (2015). Research and innovation on learning with and about advertising in science education. In N. L. Yates (ed.). *New developments in science education research* (pp. 29-50). Hauppauge: Nova.

Eilks, I., & Hofstein, A. (2017). Curriculum development in science education. In B. Akpan & K. S. Taber (eds.), *Science education: An international comprehensive course companion* (pp. 169-181). Rotterdam: Sense.

Erduran, S., & Dagher, Z. R. (2014). Regaining focus in Irish Junior Cycle Science: potential new directions for curriculum and assessment on Nature of Science. *Irish Educational Studies*, *33*, 335-350.

Hofstein, A., Eilks, I., & Bybee, R. (2011). Societal issues and their importance for contemporary science education—a pedagogical justification and the state-of-the-art in Israel, Germany, and the USA. *International Journal of Science and Mathematics Education*, *9*, 1459-1483.

Ministry of Education (2003). *National standards of the general senior secondary school chemistry curriculum*. Beijing: People's Education Press (in Chinese).

Ministry of Education (2017). *National standards of the general senior secondary school chemistry curriculum*. Beijing: People's Education Press (in Chinese).

Osborne, J., & Dillon, J. (2008). Science education in Europe: Critical reflections. A Report to the Nuffield Foundation. Retrieved October 01, 2012, from www.nuffieldfoundation.org/fileLibrary/pdf/Sci_Ed_in_Europe_Report_Final.pdf.

Sjöström, J., & Eilks, I. (2018). Reconsidering different visions of scientific literacy and science education based on the concept of Bildung. In J. Dori, Z. Mevarech & D. Baker (eds.), *Cognition, metacognition, and culture in STEM education* (pp. 65-88). Dordrecht: Springer.

Stuckey, M., Hofstein, A., Mamlok-Naaman, R., & Eilks, I. (2013). The meaning of 'relevance' in science education and its implications for the science curriculum. *Studies in Science Education*, *49*, 1-34.

Van Berkel, B. (2005). *The structure of current school chemistry*. Utrecht cdβ.

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: Kluwer.

Wang, L. (2010). Basic chemistry education curriculum reform progress and reflection in the past years (Volume I). *Chinese Journal of Chemistry Education*, *31(4)*, 15-21 (in Chinese).

Universität Bremen

Ort, Datum: Bremen, 28.05.2019

Versicherung an Eides Statt

Ich, Xiaoge Chen, Spittaler Str. 1E, 28359 Bremen, 3063299 (Vorname, Name, Anschrift, Matr.-Nr.)

versichere an Eides Statt durch meine Unterschrift, dass ich die vorstehende Arbeit selbständig und ohne fremde Hilfe angefertigt und alle Stellen, die ich wörtlich dem Sinne nach aus Veröffentlichungen entnommen habe, als solche kenntlich gemacht habe, mich auch keiner anderen als der angegebenen Literatur oder sonstiger Hilfsmittel bedient habe. Ich versichere an Eides Statt, dass ich die vorgenannten Angaben nach bestem Wissen und Gewissen gemacht habe und dass die Angaben der Wahrheit entsprechen und ich nichts verschwiegen habe.
Die Strafbarkeit einer falschen eidesstattlichen Versicherung ist mir bekannt, namentlich die Strafandrohung gemäß § 156 StGB bis zu drei Jahren Freiheitsstrafe oder Geldstrafe bei vorsätzlicher Begehung der Tat bzw. gemäß § 161 Abs. 1 StGB bis zu einem Jahr Freiheitsstrafe oder Geldstrafe bei fahrlässiger Begehung.

Bremen, 28.05.2019
Ort, Datum Unterschrift