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Education for Sustainability Meets Confucianism in Science Education

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Abstract

Confucianism provides a specific view on the world held by many people living in several Asian societies. It offers views on humans and nature that generally differ from other traditional or Western modern views. The paper presents a systematic analysis of the literature in education with a focus on science education about the connection of Confucianism with education for sustainability. It suggests a framework for how education for sustainability can be operated in the foreground of Confucian societies taking concepts from the international literature into consideration. This critical review provides justification for a stronger reflection about how to include ideas from Confucianism into education for sustainability in the teaching and learning of science. It suggests that Confucian thinking offers a rich and authentic context for science learning in Confucian societies and also provides a chance to reflect on views of humans, nature, and science in science education in other societies, potentially contributing to the development of more balanced and holistic worldviews.

1 Introduction

As technological development brings modern societies to the global community, global development is accompanied by many human made challenges, such as climate change, global pollution problems, gradually decreasing natural resources, or biodiversity loss (United Nations Environment Program [UNEP], 2012). Because humans became the most influential factor to the world, geologists suggested calling our epoch now as the Anthropocene (Caro et al., 2012). The Anthropocene concept suggests that humankind needs to take responsibility for the world; change in behaviors is suggested to reduce negative human impacts on the Earth (Jeong et al., 2021; Ogden et al., 2013). To fend these challenges, the United Nations (UN, 1987) made the concept of sustainable development a regulatory idea of international policy: "Sustainable development is development that meets the needs of the present generation without compromising the ability of future generations to meet their

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own needs" (UN, 1987, para.1). In other words, the current generation is asked to re-think their lifestyles for the sake of the rights and needs of future generations. Sustainability, or sustainable development, emphasizes maintaining sustainable living conditions. Although the concept of sustainability has been under constant debate for many years (Hopwood et al., 2005), most of them refer to a balanced development under ecological, economic, and societal sustainability (Burmeister et al., 2012; UN, 1987).

To further promote sustainable development around the world, the United Nations (UN) coined the term Education for Sustainable Development (ESD) in the Agenda 21. ESD means to educate people to be able to make informed decisions and take responsible action in line with the sustainability ideas of ecological integrity, economic feasibility, and societal justice (United Nations Conference on Environment and Development [UNCED], 1992). ESD proposes a continuously updated education for sustainability to promote current and future generations having abilities to live sustainable lives. ESD suggests learning and acquiring related skills about sustainability in schooling and higher education and also in informal, nonformal, and lifelong learning (UN, 2015; UNCED, 1992; United Nations Educational, Scientific and Cultural Organization [UNESCO], 2005a, 2016). The political vision of ESD, and related concepts with slightly differing visions (Öhman & Östman, 2019), led to an exponential growth of related scientific research articles in the last 30 years in general and in science or chemistry education in particular (e.g., Burmeister et al., 2012; Herranen et al., 2021; Jegstad & Sinnes, 2015; Juntunen & Aksela, 2014).

Education for sustainability (or ESD, sustainability education, etc.) is more than environmental or moral education. It is the fruit of evolution of environmental education and the leading approach for environmental protection now, for its stressing social contribution to deal with major contemporary ecological issues, rather than mainly relying on the study of science for environmental protection (Castellanos & Queiruga-Dios, 2021; McBeath et al., 2014). It concerns the ethical values of individuals concerning individual life, society, economy, and environment in a systems thinking approach (Mahaffy et al., 2018). Its implementation should consider students' and society's ethical and cultural values about local and global sustainability and promote appraisal of the rights and chances of others (e.g., Feng & Newton, 2012; Li et al., 2016b; UNESCO, 2005b).

In school education, science education plays an important role for ESD. Science education is teaching and learning of and about science, including scientific knowledge itself, and the development and utilization of it (Herron, 1969). Scientific theories and knowledge highly relate to and directly reflect the development of industry and technology and their impacts on the natural environment, society, and the economy. Science knowledge is essential for modern citizens' lives, and science is part of the culture in any society, being in Western or Eastern industrialized societies, countries of the Global South, or indigenous living peoples (Zidny et al., 2020). Science education also plays an important role in preparing future scientific literate citizens, scientists, and related experts. Science education is traditionally implemented as one core field of school education in most educational systems, and both teaching science knowledge and teaching about science are highly recommended, such as about the nature of science and its societal ramifications (e.g., Hansson & Yacoubian, 2020; Hofstein et al., 2011; Holbrook & Rannikmae, 2007; Park et al., 2020; Taber, 2017).

Science education for sustainability (or science education in ESD, science education for ESD, etc.) is used here as a term with the understanding of education to promote sustainability knowledge and skills through or in science education. It can be defined in different ways. One way is to see it as the research field where science education meets environmental/sustainability education (e.g., Dillon, 2014; Herranen et al. 2021).

Another related way is to see it as science education driven by a sustainability vision (e.g., Colucci-Gray et al., 2013; Sjöström, 2018; Zidny et al., 2020). The latter is based on a view of science that goes beyond reductionist Western modernization. It is characterized by, e.g., complexity, uncertainty, epistemological reflections, and transdisciplinarity. Such an approach emphasizes "the interplay between facts and values and the way in which we build and make use of new knowledge" (Colucci-Gray et al., 2013, p. 138).

The above-mentioned, negative side effects of Western modern societies' development are particularly also shown in present mainland China caused by its rapid economic growth during the past few decades in connection with its big territory and the world's largest population. Education for sustainability is urgently needed in mainland China. Moreover, mainland Chinese students have drawn lots of attention from international education scholars, due to their frequently excellent science performance in the international science assessments, such as the *Trends in International Mathematics and Science Study* (TIMSS) and the *Programme for International Student Assessment* (PISA) during these years (Cheng & Wan, 2016; Grosseck et al., 2019). However, literature about how ESD is implemented in school science education in mainland China is still limited (Li & Eilks, 2021).

Culture deeply influences not only individuals' ways of living and thinking, but also learning or teachers' teaching approaches. It forms certain patterns of education in a society, due to the differences of history, values, philosophy, beliefs, and behaviors (e.g., Chuang, 2012; Gorry, 2011; Gündüz & Özcan, 2010). Culture is also a direct factor for how people are thinking and knowing about the physical world (e.g., Cobern, 1993; Gao, 1998). This is of importance if a new paradigm of education, like ESD, is to be implemented in general and in science education in particular. Mainland China has one large people of Han with the largest population in the world and 55 ethnic minorities. Han Chinese also take the largest part of Chinese communities in Asia and other parts of the world. They have highly been influenced and maintained by Confucianism, generation by generation (Cheng & Wan, 2016). According to Ogawa (1989), Western modern science, as part of the imported culture from Western civilization, should be taught by concerning local traditional and scientific ways of understanding and observing nature in non-Western countries.

As Chinese scholars look back to Chinese traditional culture, they find that Confucian wisdom about friendly living in nature has potential value to deal with modern ecological problems by leading action towards a sustainable future (Chen, 2019; Chen & Bu, 2019; Cheng, 2013). Confucian ecological ethics, as a cosmological metaphysics, emphasizes that humans and nature are one dynamic, holistic, and organic body, where humans harmoniously and sustainably live together with all the things in nature (Chen & Bu, 2019; Li et al., 2012; Tu, 1998, 2001, Tucker, 1991). Confucianism suggests that humans should love all things in nature and carefully, mildly, and prudently use natural resources (Chen & Bu, 2019; Li et al., 2012; McBeath et al., 2014). This can be understood as a contribution to sustainability. Confucianism is a moral code with the core Confucian spirit of benevolence, highlighting self-cultivation of moral ethics, which is also related to the intended outcomes of modern ESD (Tu, 2001). Even though China has adopted environmental education and ESD since 1992, Confucian ecological ethics is still not paid enough attention to in ESD in China until now in general and science education in particular (Li & Eilks, 2021; McBeath et al., 2014). Therefore, based on a systematic analysis of the literature, this paper tries to identify the features of and explore a potential model for ESD in science education in the context of Confucianism.

2 Confucianism, Education, and Science

2.1 Confucianism, Neo-Confucianism, and New Confucianism

Confucianism is the dominant ethical and philosophical thought in Chinese communities established by the Chinese philosopher, politician, and educator Confucius (551–479 BC) about 2500 years ago (Fung, 1948; Huang & Asghar, 2018; Li et al., 2016a; Sun et al., 2016). Confucianism is the predominant philosophy that is deeply rooted in every Chinese person (Chiu, 2002). It covers educational, social, ethical, governmental, and economic aspects of all levels of society (Li et al., 2016a; Sun et al., 2016) and provides norms and paradigms of different hierarchies of people's daily lives (Feng & Newton, 2012). It continuously influences life in Chinese societies nowadays and is deeply embedded in Chinese culture (Kwek & Lee, 2010; Li et al., 2016b; Sun et al., 2016), with culture being understood as the mental pattern of feeling, thinking, and acting for a group of people, nationally, regionally, or globally (Hofstede, et al., 2010). In the same culture, people share common customs, beliefs, values, attitudes, and behaviors about certain issues (Guy, 1999). Culture leads individuals to have corresponding behaviors, values, and perceptions advocated and admitted by society (Chuang, 2012; Yorks & Sauquet, 2003). As such, Confucianism profoundly shaped the cultures and histories of many East Asian countries or regions, such as mainland China, Hong Kong, Macao, Taiwan, Korea, Japan, and Vietnam (Li et al., 2016a), including countries containing large minorities of Chinese, for example, Malaysia (Foong & Daniel, 2013) and Singapore (Cheng & Wan, 2016).

Confucius dedicated his life to the teaching for individuals' self-cultivation of virtues. Confucianism aims to build a stable and harmonious society with ethics and morality by the hierarchy of gender, age, and social status-based relationships in the society and family (Chinn, 2002; Huang & Asghar, 2018; Lai, 2008; Schirokauer, 1991). Confucianism stipulates that people should have proper and good behaviors according to the situations and their different hierarchical statuses and roles. People should obey and respect their leaders, in consideration of the kindness and fairness given from the leaders (Chinn, 2002; Feng & Newton, 2012; Lee & Kim, 2019). Similarly, in a family, the older persons foster the young, and the young give them "filial piety" in return (Liu, 2013). In Confucianism, education is underscored as the most important power and tool for guiding individuals' moral practices to sustain a stable and prosperous society. On the other hand, Confucianism emphasizes that education plays a pivotal role in nation building by instructing the people (Guo, 2006). It follows that a teacher is widely respected and is the authority in the teacher-student relationship (Lee & Kim, 2019) but also has full responsibility for students' learning.

Confucius's thoughts about human ethics and morality were recorded in the Chinese ancient book of *the Analects* by his students (Liu, 2013). This book reveals that Confucius highlighted the practice of ethical virtues of benevolence (*ren*) and propriety (*li*) to build order for society. Confucius depicted a certain type of person as "a noble person" (*junzi*), who takes the role of the moral authority and responsibility for bettering society. Confucius advocated an individual to become a *junzi* with moral awareness and autonomy (Brindley, 2011). His teaching thoughts in *the Analects* still influence Chinese pedagogy today. Confucian scholars later further developed the thoughts of Confucius, which gradually formed Neo-Confucianism, especially in the Song (960–1276) and Ming (1368–1643) dynasties.

Neo-Confucianists absorbed significant ideas of Taoism and Buddhism about environmentally friendly practices (Chen & Bu, 2019; Fung, 1948; Wang, 2012), added

philosophical views of Confucian ethics and put ethical virtues broadly into cosmology, and subsequently shaped a more rational and dialectical Confucian thought system. Neo-Confucianism mainly focuses on naturalistic cosmology and the ethics of self-cultivation in the anthropocosmic views with ecological concerns. The anthropocosmic Confucianism vision asserts that humans should harmonize with the universe and gain knowledge by self-cultivation (Savelyeva, 2017). Neo-Confucianism also was brought into Japan, Korea, and Vietnam and influenced their cultures and education (Tucker, 1991). Neo-Confucianism of Yulgok from Korea is cosmoanthropic. It means the unity of human and nature is controlled by the universe (Savelyeva, 2017). In Neo-Confucianism, the universe is understood as a vital and dynamic holism where everything interacts with each other and has its own force to change and transform. Humans should rationally use the environment to maintain a fundamental living and harmonize with their natural environment through cosmological concerns and human ethics of self-cultivation (Tucker, 1991).

New Confucianism began in the last century and inherited Neo-Confucianism in mainland China, Hong Kong, and Taiwan, due to the influence of Western civilization. New Confucianists, also called Modern Confucianists, rethought Confucian ideas and infused Western thinking into Chinese traditional thoughts for highlighting the positive role of Chinese traditional culture (Tu, 2001). According to Zagonari (2020), Confucianism has great potential to achieve local and global sustainability. Due to the influence of Western countries with much more developed science and technology to China in the nineteenth century, the last Dynasty of Qing collapsed in the early twentieth century, and the new culture movement (1915–1919) tried to completely adopt Western science for recovering the country and criticized and abandoned Confucianism. It caused Confucianism to become peripheral. Moreover, anti-Confucianism was one theme in the Cultural Revolution (1966–1976) in mainland China (Liu, 2013; Park, 2011). However, the "Reform and Opening Up" policy in mainland China since 1978 brings a new era of Confucianism enlightenment for the international communication of new Confucianists, and it also provides the condition for people to revisit traditional culture treasures (Liu, 2013).

2.2 Confucianism and Education

Education has a high position in Chinese culture. The rapid development of the economy in mainland China in the last 40 years has brought huge progress in the quality of most people's lives. It has also brought high expectations of Chinese parents and society about the quality of education for children. Mainland China with its large population also has a corresponding vast number of school students (Liu et al., 2015). In 2019, the promotion ratios of primary school graduates and lower secondary school graduates reached 99.5% and 95.5%, respectively (Ministry of Education [MOE], 2021).

Growing industrialization and urbanization raised the value of education in people's view from mainland China. During the last few decades, the enormous investment in education was put into schools and higher education, including infrastructure (e.g., improvement of school science laboratories), implementation of reforms (e.g., new school science education standards), and raising human resources (e.g., enhancement of science teacher education) (Liu et al., 2015). Scientific literacy and scientific competence were introduced in the new educational reforms, which tried to blend the knowledge-centered instruction from the past with international trends and the developments of skill-based science education (Li & Eilks, 2021). ESD in school science education becomes highlighted in the

current round of science education reform in mainland China (Li & Eilks, 2021), but it is still a field to be developed (Chen et al., 2019).

Confucianism still plays a dominant role in influencing Chinese education (Wan et al., 2018). Although the strict hierarchies of people from the past vastly disappeared in modern Chinese societies, individuals' obedience and respect to authorities or leaders in family and society are still embedded in Chinese moral ethics (Feng & Newton, 2012). Harmonism is considered the highest value of Confucianism to avoid conflicts and reconcile problems. It brings people to actively collaborate with excellent results. Some researchers (Chan, 1999; Feng & Newton, 2012) argue that it might hinder students' development in critical thinking if they are raised to obey their teachers and parents without objection. In fact, interactive discussion and questioning are encouraged in accordance with *the Analects*. It can be achieved as long as the teacher provides the right atmosphere (Tweed & Lehman, 2002). Chinese traditional culture, however, has a strong ability to infuse imported cultures, such as Buddhism. The integration of Confucian and Western education is seen as positively supporting Chinese education reforms in times of globalization and can provide potential ways to deal with certain problems if arising in Chinese education (Yang, 2019).

Confucianism determines the contents and methods of learning as one of the most important activities and highlights ethical knowledge rather than practical or technological knowledge (Hung, 2016). Confucius was considered the model teacher for generations and made East Asian students extremely respectful to teachers as their mentors and role models. Confucius highlighted that all individuals should equally have the chance for education regardless of their backgrounds (*you jiao wu lei*), and teachers' instructions should fit students' abilities and individual needs (*yin cai shi jiao*) (Huang & Asghar, 2018).

Confucianism advocates individuals' efforts to learn by intrinsic and extrinsic motivation with reflection and investigation (Lee, 1996) and teachers' competent capabilities for tirelessly teaching all kinds of students with heuristic instruction. This can be shown in many phrases of Confucian classics. For example,

> [Confucius] said, "I do not open up the truth to one who is not eager to get knowledge, nor help out any one who is not anxious to explain himself. When I have presented one corner of a subject to any one, and he can not from it learn the other three, I do not repeat my lesson." (*bu fen bu qi, bu fei bu fa. Ju yi yu bu yi san yu fan, ze bu fu ye*.) (*the Analects*, 7:8, translated by Legge, 1861a, p.61)

Confucian education suggests that teaching and learning can facilitate each other, and teachers also are considered learners (Hung, 2016; Meyer et al., 2017; Zhao, 2013). In addition, Confucianism advocates that instruction should be implemented step by step at a suitable time, and students are encouraged to learn from each other, including group discussions. It is in line with the effective teaching strategies shown in *Liji:Xue Ji*. They are,

> [t]he rules aimed at […] were the prevention of evil before it was manifested; the timeliness of instruction just when it was required; the suitability of the lessons in adaptation to circumstances; and the good in fluence of example to parties observing one another. (*da xue zhi fa: zhi yu wei fa zhi wei yu, dang qi ke zhi wei, bu ling jie er shi zhi wei xun, xiang guan er shan zhi wei mo*.) (16:3, translated by Legge, 1885, p.86)

Confucian learning is seen as a process of studying, questioning, thinking, and practicing by investigation, reflection, inner motivation, and surrounding influence (Cheng, 2016). Confucian education is moral education for a person advocated to be a noble person (*junzi*) based on ideas of Confucianism and the learning of Confucian classics without

the knowledge of formal logic and mathematics and science (Liu, 2013). Confucius, as one versatile teacher, dialogically led to all kinds of students' active and effortful learning based on their abilities and life experiences, guided them to explore answers to their ethical questions, and reflected their teaching and learning for evaluating students' progress and behaviors, under the educational goal of becoming a *junzi*. As formal education with national examination systems was established over time, active learning was replaced by a focus on students' memorization without questioning ethical issues (Guthrie, 2011; Ho, 2018; Hung, 2016; Wu, 2011; Zhao, 2013).

Compared with the acquisition of knowledge, it is more important to fulfill one's self-cultivation as a *junzi* in Confucian education (Chen, 2005). The learning, to *junzi*, should be to "extensively study what is good, accurately inquire about it, carefully reflect on it, clearly discriminate it, and earnestly practice it."(*bo xue zhi, shen wen zhi, shen si zhi, ming bian zhi, shen si zhi*) (*Doctrine of the Mean*, 20, modified from Legge's translation, 1861a, p.227). (Neo-)Confucian education emphasizes dealing with knowledge and action, especially in moral education, justice and self-interest, and the relationship between human beings and nature. Its key ideas are kindness, benevolence, and harmonism. As we will describe more in depth later in the text, the harmony among oneself, others, society, and nature, including other nations and cultures, is the goal of Confucian education (Jin & Dan, 2004). The fundamental Confucian education is to develop an individual's character by self-cultivation and the implementation of Confucian virtues of property and benevolence (Ozoliņš, 2017).

2.3 Confucianism and Science Education

Due to the societal and political interest in "Westernization" or "Modernization" in mainland China since the early 1900s, Western modern science knowledge systematically has taken the place of Chinese traditional knowledge at the school level. It has been widely accepted by educational authorities in China as a base to become an industrialized country (Ding, 2015a; Isozaki & Pan, 2016; Ma, 2009).

This adoption of Western modern science for school science education underwent a series of collisions and reconstruction processes between Western modern science and Chinese culture (Ding, 2015a, 2015b; Kennedy & Lee, 2017; Ma, 2009, 2011). For instance, in the New Culture Movement, one of its two slogans was "science," which was expected to completely substitute Chinese traditional culture. Science was seen as the opposite of Chinese traditional culture (Ding, 2015a; Ma, 2009).

The copying of Western science education still exists with its limitations and problems due to the cultural tradition and societal development in mainland China (Cheng, 2018). Accompanying with the political movement of "reviewing Legalism and criticizing Confucianism" at the last stage of the Cultural Revolution, it reached the climax of criticizing Confucianism since the early 1900s in China. In this movement, Legalism, one of Chinese traditional philosophies, was raised and considered the most influential Chinese philosophy for condemning Confucianism. However, it also brought the booming reprint of Chinese classics including Confucian classics shown as critical books and changed the state of burning Chinese classics at the beginning of the Cultural Revolution. Confucian classics, with its strong vitality, were reopened into Chinese people with their views (Zhou, 2006). Furthermore, it was the end of the cultural revolution that brought reinvigorating of traditional culture in education, Confucian education in particular. Chinese educators suggested gradually integrating imported educational theories into local contexts (Jin & Dan, 2004).

This is in line with Taylor and Cobern (1998), who highlighted that science education in non-Western societies should adapt meaningful science content from Western modern science and absorb it into their own local cultures.

Environmental issues became gradually serious with the rapid development of modern industrial China. They addressed new Confucianists' attention to revisiting traditional Confucian ecological ethics and wisdom. They widely thought that the Confucian idea of the unity of heaven and humans (*tian ren he yi*, for more explanations, see below), could remedy ecological crisis caused by Western science built upon the dualism of humans and nature (Meng, 2001; Tu, 2001; Tucker, 2017). The new Confucianist Weiming Tu (2001) suggested *tian ren he yi* as an ecology turn to modern China, to sustain the harmonious relationship among self, others, community, society, and the universe by individual self-cultivation from inside to outside. *Tian ren he yi* implies that human ethics are analogized and extended into environmental ethics, with hierarchy, for caring all living things, including the respect and appreciation of the natural world in Confucianism. An economic system produced from science and moral ethics of humanism is complementary for a sustainable society (Tu et al., 2003). Meng (2001) stressed that Confucianism is value rationality, rather than science with its instrumental rationality. Only the integration of these two kinds of rationality can bring a peaceful society for modern China. However, during the modernization process of China, the argument of the relationship between humanism and science is still existing, especially at the most recent, hot debate on the benchmark for scientific literary for Chinese citizens in Chinese society in 2016–2017. It was discussed whether traditional Chinese knowledge should be included in that benchmark or not. According to Zhang and Liu (2021)'s analysis of the societal viewpoints of the debate, it implies that locality of science, linking between humanism and science, and understanding of nature of science are urgently needed to enhance science education in China. Some researchers suggest for Chinese science education looking backward to the Chinese traditional culture and philosophy and to discuss science education through the Chinese cultural lens (Cheng, 2018; Ding, 2015b; Isozaki & Pan, 2016; Ma, 2009, 2012). Modern Chinese science education is suggested to nurture students with both Confucian humanistic spirits and scientific knowledge (Bai, 2013). A recent analysis of textbooks from mainland China, however, indicates that Western modern science views are still the dominant lens science is approached in education in mainland China (Chen et al., 2019).

3 Confucianism, Education for Sustainability, and Science Education

3.1 Method of the Literature Review

The following discussion is based on a systematic review of the existing international and local research literature in the field. Three databases were analyzed, namely the Web of Science Core Collection, ERIC, and the China National Knowledge Infrastructure (CNKI). The Web of Science Core Collection was chosen as one of the standard databases for the international research literature; ERIC was chosen because of its broader capture of the field of education and CNKI as one of the most popular Chinese academic databases. CNKI was concerned to also explore publications from the Chinese context that are not captured in international databases because of local reasons or language barriers.

In the Web of Science Core Collection, screening "confucian*" by topic (the asterisk allows a search of both Confucianism and Confucian) gained 8814 hits retrieved on 24

August 2021. They are distributed over many disciplines, mainly Asian studies (2164), philosophy (2146), religion (874), education research (805), area studies (617), history (567), management (403), social sciences interdisciplinary (386), and others, including environmental studies (69) and education scientific disciplines (38). In total, 215,506 hits were found for the topic "sustainability" (531,460 hits of sustainab*). Most of them are about environmental science or green and sustainable technologies. The search terms were chosen for gaining a broad picture as the background of research in the international communities. Combined searching for confucian* and sustainab* by topic in the Web of Science Core Collection produced 108 hits (78 articles, 3 book chapters, and some proceedings papers), retrieved on 24 August 2021. To analyze the relationship of Confucianism and sustainability in the context of the international literature on education, all these papers were read and extracted by hand to exclude unrelated papers without relevant content. Forty-two target papers were identified. Twelve of them are about ecological, moral, or environmental education.

In ERIC, there were 760 hits (peer-reviewed only) by searching the topic "Confucianism OR Confucian" (retrieved on 24 August 2021). Most of them are about cultural influences or differences in education. The combined terms "(confucianism OR confucian) and (sustainability OR sustainable)" by topic produced 12 hits. Seven papers were identified by hand, and three were already found from Web of Science search. Finally, 46 papers were identified on Confucian philosophy views about sustainability based on international databases. Some references from the target papers were also included.

A combined search for "(confucianism OR confucian) and science education" by topic resulted in 51 hits in ERIC (retrieved on 24 August 2021). Some obviously unrelated papers from the title and abstract were excluded, such as health or mathematics education. Others were further read and refined by hand, whether relevant or not. Twenty-two articles were identified, dealing with school or college education from mainland China (9), Hong Kong (1), Taiwan (4), and other East Asian countries or regions (8), such as Korea, Vietnam, and Malaysia. Although Confucian culture in a certain country may have slightly or big different explanations as to the societal, political, and historical changes compared to mainland China, articles from these other countries or regions were nevertheless used carefully as references for respecting general and common ideas. A combined search for "confucian* and science education" in the Web of Science Core Collection also was searched by topic, and resulted in 74 hints, in which 16 papers were refined by hand. Most of them overlapped with the target papers from ERIC, except two papers. Hence, 24 identified papers about science education in the context of Confucianism would be analyzed. To gain more data for this research, the theme of "environmental education" also was concerned. Searching the combined term "(confucianism OR confucian) AND environmental education" in ERIC produced 16 hints. Seven target papers were identified by hand, mainly about theoretical discussions, however, and one of them was gained by the search above as well. Searching the combined term "confucian* AND environmental education" in the Web of Science Core Collection produced 14 hints, and four target papers were identified by hand which were included in the above refining. Therefore, 30 identified papers about science education or environmental education in Confucianism totally were gained, based on the international databases.

To gain a comprehensive picture for this review, a similar search was carried out in CNKI on 30 August 2021. The method of identifying papers was similar to the above-mentioned strategy. Searching "Confucianism" by topic resulted in 58,383

hits of Chinese academic articles in CNKI, mainly about Confucian ideas, culture, and ethics, *the Analects*, modern values, and so on. Searching "sustainability" got 292,205 hits, mostly referring to strategies for sustainable development. Combining these two terms, "Confucianism and sustainability" by topic produced 171 hints, mainly about *tian ren he yi* (the unity of heaven and the humans) (23), Confucian culture or ideas (21), and ecological ethics (21). Seventy-nine papers were refined by hand. Combining search terms "Confucianism and Science education" by topic gained 14 hints. Six papers were identified about the integration of science and humanistic education or any historical analysis of science education in China. Furthermore, eleven hints were obtained by searching combined topics "Confucianism and environmental education," and four target papers were identified by hand. They are about environmental education concerning Confucianism.

All in all, the above-mentioned searching results with representative papers are shown in Table 1. The first round of analysis focused on Confucianism and sustainability in a philosophical view, and the second analysis then tried to map current features of science education and environmental education in Confucian culture and then combining the first round analysis to portray science education for sustainability in a Confucian view. There are huge differences in students' abilities, learning environments, contents, education goals, etc. from pre-primary to tertiary education. The following literature analysis has its focus on secondary education since it is suggested that secondary students have already developed an understanding of science and culture, and at the same time, a lot of basic knowledge and skills for promoting sustainability must be promoted at this level. Nevertheless, research papers concerning other educational levels were also concerned as references for gaining general and common ideas.

Table 1 Research publications about sustainability and science/environmental education in the Confucian culture based on Web of Science, ERIC, and CNKI

Related topics	Databases and the number of hints (refined papers in the parentheses)	Representative papers
Confucianism AND sustainability	Web of Science: 108 (42) ERIC: 12 (7) CNKI:171 (79)	◇ Confucianism and sustainability: Cheng, 2012, 2013; Feng & Newton, 2012; Hsu, 2015; Tu, 1998, 2001; Li et al., 2016b; Mok, 2020; Tucker, 2017; Tucker, 1991; Wu, 2019; Xu et al., 2014; Yu, 2007; Zeng & Liu, 2002; Zhao, 2019; Zhuang, 2015
Confucianism AND science education	Web of Science: 74 (16) ERIC: 51 (22) CNKI:14 (6)	◇ Science education: Foong & Daniel, 2013; Ho, 2018; Huang & Asghar, 2018; Meng, 2004; Liu et al., 2015; Sjöström, 2018; Thomas, 2006
Confucianism AND environmental education	Web of Science: 14 (4) ERIC: 16 (7) CNKI:11 (4)	◇ Environmental education: Chen, 2007; Kim & Roth, 2008; Luan et al., 2020; Yang & Weber, 2019; Zhang et al., 2020

3.2 Confucianism and Sustainability in a Philosophical View

Confucianism suggests ethical standards and values for individuals' attitudes and behaviors in Chinese societies (Chiu, 2002; Kwek & Lee, 2010; Zhang et al., 2020). In more detail, Zhang et al. (2020) presented some characteristics of Confucianism to improve people's eco-friendly awareness, namely behavior-identity matching, self-esteem and reputation, and listening to others (Wang et al., 2017). Individuals' behaviors influence family and social identities and their reputation (Contrada et al., 2001), and they tend to obey the authority and depend on others' opinions for showing their respect to others. It is suggested that core ethical norms and ideas of Confucianism profoundly present environmental friendliness for the modern world.

The core Confucian ethical norms are called five constant virtues (*wu chang*). They include benevolence (*ren*), righteousness (*yi*), propriety (*li*), wisdom (*zhi*), and trustworthiness (*xin*) (Chen, 2015; Kwek & Lee, 2010; Meyer et al., 2017; Sun et al., 2016).

–　Benevolence is considered the most essential concept in Confucianism (Kwek & Lee, 2010; Meyer et al., 2017). It means "to love others" and contains generousness, respect, kindness, caring, sympathy, empathy, and tolerance to others (Low, 2011; Sun et al., 2016). Its root or starting point is "filial piety," which means being filial or respectful to one's parents (Tan & Tan, 2014). The Confucianist Mencius (372–289 BC) stressed that "[a noble person] is affectionate to his parents, and lovingly disposed to people generally. He is lovingly disposed to people generally, and kind to creatures." (*qin qin er ren min, ren min er ai wu*) (*Works of Mencius*, 13: 45, translated by Legge, 1861b, p.352). Benevolence is also shown in the remark: "[Confucius] angled, –but did not use a net. He shot, – but not at birds perching" (*zi diao er bu gang, yi bu she su*) (*the Analects*, 7:27, translated by Legge, 1861a, p.67), including Confucian frugality virtue, connecting modern "green consumption." Benevolence is the intrinsic power for the suitable and enduring implementation of external propriety (Christensen, 2017). This is related to a core value of sustainability as benevolence and love to all creatures. This value advocates individuals to treat all things kindheartedly to nurture environmentally friendly awareness (Li et al., 2012; Zhang et al., 2020).

–　Righteousness is the standard for appropriate behavior (Yu, 2007). It pursues a just distribution of rights and benefits, duties, and responsibilities to achieve a harmonious society (Cheng, 2012). Confucius depicted that "[t]he mind of the [noble person] is conversant with righteousness; the mind of the mean man is conversant with gain" (*jun zi yu yu yi, xiao ren yu yu li*) (*the Analects*, 4:16, translated by Legge, 1861a, p.34). Righteousness is the right attitude nurtured by benevolence, and righteous actions are the imperative presentation of fulfilling benevolence, rather than by the short-term benefits (Cheng, 2012). In terms of sustainability, righteousness can be related, e.g., to respect norms for resources protection and societal sustainability.

–　Propriety guides humans to have proper actions or interactions with others and the environment for avoiding conflicts based on social rituals and manners (Meyer et al., 2017; Wu, 2019). It is "the ritualized body language of benevolence" (Bockover, 2012, p. 180), and its most significant mission is to attain harmony (Cheng, 2012). In terms of sustainability, propriety can be related, e.g., to put individual interest last to come up with sustainability challenges.

–　Wisdom is a quality in an individual who has intelligence knowledge for self-cultivation to deal with certain problems and then take proper moral actions to gain good

results by following social rituals (Cheng, 2012; Kwek & Lee, 2010), and it is the foundation for the implementation of morality (Cheng, 2012). People with wisdom can learn how to live harmoniously in order to understand the world with benevolence. For instance, Confucius said, "The wise find pleasure in water; the [benevolent] find pleasure in hills." (*zhi zhe yue shui, ren zhe yue shan*) (*the Analects*, 4:16, translated by Legge, 1861a, p. 56). It also shows that Confucianism innately enjoys the natural world. In terms of sustainability, wisdom can be related, e.g., to knowledge about sustainability issues, the underlying values, and potential consequences.

– Trustworthiness is the trust of others and knowledge based on one's understanding and observation of the world. Trustworthiness is the inevitable part to sustain a harmonious world, for it promotes the common good virtues or spirits in society through effective and dependable communication (Cheng, 2012). In terms of sustainability, trustworthiness can be related, e.g., to acknowledge that sustainability is a challenge that societies can only achieve together.

The Confucian five virtues are similar to the German philosopher Herbart's five moral ideas, namely, benevolence, right, equity, perfection, and internal freedom (Meyer et al., 2017). According to Sjöström (2018), Confucian education also has similarities with the Central and Northern European educational tradition called *Bildung*. Many parallels can be found to connect Confucian education with *Bildung*, a German word that, among other things, understands education as the formation of a person to become able to live a self-determined and solitary life in society (e.g., Hofstein et al., 2011; Horlacher, 2016; Sjöström et al., 2017; Sjöström & Eilks, 2020).

Bildung in the Central and Northern European tradition is a word for both the process of formation of a person and the final aim to be achieved. A similar concept can be found in Confucianism. The concept of sincerity (*cheng*) is understood as the starting and the return point of one's ethical self-cultivation and the highest virtue of Confucianism (Yu, 2007). Sincerity is not only a process but also a state (Wu, 2019; Yu, 2007). Sincerity contains one's self-actualization and the completion of all things; it can support humans to gain the self-understanding of environmental concerns in the ideal and real life (Wu, 2019). In other words, Confucianism suggests that people follow environmentally friendly ethics and carry out relevant activities or behaviors to accomplish their autonomous self-formation (Christensen, 2017; Li et al., 2016b). Sincerity also encompasses the sustainability idea of inter-generational justice. The Neo-Confucianist, Zhang Zai, said his self-aspiration is "to ordain conscience for Heaven and Earth, to build the Way for people, to continue lost teachings for the past sages, and to bring about peace for all future generations" (*wei tian di li xin, wei sheng min li dao, wei qu sheng ji jue xue, wei wan shi kai tai ping*) (Zhu & Lv, 1998, p. 68).

Finally, the light should be shed on the Confucian concept of harmonism (*he*). A Western modern science view suggests looking at physical things separated from each other. Humans consider other things in nature as objects (Pak & Kim, 2016). The Western modern science view can be considered anthropocentric. In contrast, Confucianism highlights the idea of the unity of heaven and humans (*tian ren he yi*), which is anthropocosmic (Christensen, 2017; Tu, 1998, 2001). It suggests that humans and nature together form a holistic and organic body (Li, 2018; Mok, 2020; Tucker, 1991).

In the Chinese traditional culture, the principal idea of *zi ran* (translated as "nature") is *tian ren he yi* (translated as "nature and humans form one body" or "the unity of heaven and humans") which means "Nature and humans have the same origin and belong to the same unity; Nature and humans follow the same law; and, Nature and humans are

interconnected" (Ma, 2012, p. 13). *Tian ren he yi* sees nature and humans as an integrated whole with a holistic thought and indicates that human activities can lead to the change of nature, and everything that exists should be in harmony with each other (Chen & Bu, 2019; Ma, 2012). This idea is highly matching ideas of sustainability and holistic thinking and as such related to recent suggestions better recognize systems thinking approaches when it comes to science education for sustainability (Mahaffy et al., 2018).

In Confucian cosmology, heaven and earth are two core Confucian trigrams, as the universe, and the third one is human (Fung, 1948). Humans, as spiritual beings, have capacity of internal echoing among themselves and between all things in the nature to reach *tian ren he yi* (Tu, 1998). *Tian ren he yi* also shows the appreciation of the natural environment, in line with the following description of the natural world from Confucian classics *Doctrine of the Mean*:

> The [H]eaven now before us is only this bright shining spot; but viewed in its inexhaustible extent, the sun, moon, stars, and constellations of the zodiac, are suspended in it, and all things are overspread by it, The earth before us is but a handful of soil; but when regarded in its breadth and thickness, it sustains mountains like the [Hua] and the [Yue], without feeling their weight, and contains the rivers and seas, without their leaking away. The mountain now before us appears only a stone; but when contemplated in all the vastness of its size, we see how grass and trees are produced on it, and birds and beasts dwell on it, and precious things with men treasure up are found on it, The water now before us appears but ladleful; yet extending our view to its unfathomable depths, the largest tortoises, iguanas, iguanodons, dragons, fishes, and turtles, are produced in them, articles of value and sources of wealth abound in them. (*Jin fu tian, si zhao zhao zhi duo, ji qi wu qiong ye, ri yue xing chen xi yan, wan wu fu yan. Jin fu di, yi cuo tu zhi duo, qi ji guang hou, zai hua yue er bu zhong, zhen he hai er bu xie, wan wu zai yan. Jin fu shan, yi juan shi zhi duo, qi ji guang hou, cao mu sheng zhi, qin shou ju zhi, bao zang xing yan. Jin fu shui, yi piao zhi duo, ji qi bu ce, yuan tuo jiao long yu bie sheng yan, cai huo zhi yan*) (*Doctrine of the Mean*, 26, modified from Legge's translation, 1861a, p.284-285)

This holistic eco-ethical view also is represented in the idea of benevolently utilizing natural resources depending on time, guided by the patterns of the natural world (*yi shi jin fa*), e.g., to avoid excess fishing, hunting, and logging, related to sustainable development. It can lead to a sustainable society, for its ecological, economic, and political aspects (Chen & Bu, 2019; McBeath et al., 2014).

Furthermore, *tian ren he yi* also is explained by Neo-Confucianist Zhang Zai in his *Western Inscription*:

> [Heaven] is called the father and [Earth] the mother. We, these tiny beings, are commingled in the midst of them. I, therefore, am the substance that lies within the confines of Heaven and Earth, and my nature is that of the (two) Commanders, Heaven and Earth. (All) people are my blood brothers, and (all) creatures are my companions. (*qian cheng fu, kun cheng mu, yu zi mao yan, nai hun ran zhong chu. gu tian di zhi sai, wu qi ti. tian di zhi shuai, wu qi xing. min, wu tong bao; wu, wu yu ye*.) (Fung, 1948, p. 493)

Based on such an understanding, people should respect the value of nature and learn from nature for humans' ethics and morality (Christensen, 2017; Li et al., 2012; Mok, 2020). According to Confucian filial piety, individuals not only should respect their parents (and other elders), but also need to respect all the things in nature (Tucker, 2017). As

shown above, "harmony between nature and humans" (*tian ren he xie*) becomes the core thought of Confucianism about ecology (natural environment) (Li et al., 2012; Li et al., 2016b), as the modern explanation of "unity of heaven and humans" influenced by western civilization highlighting the relationship to form logic thinking based on the dualism of humans and nature (Liu, 2000). It encourages humans to be friendly with all the creatures and cherish life; to know, respect, and love the law of nature; and sustainably to use natural resources or nature (Li et al., 2012; Li et al., 2016b; Zeng & Liu, 2002).

The word "harmonism" (*he*) in Chinese means "moderate, coordinated, and reconciled" (Li et al., 2016b, p. 683). The idea of Chinese harmonism (*he*) is more complicated and sophisticated than the Western idea of harmony (Wang, 2012). For example, in terms of individual self-cultivation, the idea of *he* in Chinese is that an individual has a peaceful mind and heart with benevolence. Harmony between body and mind can be achieved by satisfying the unity of righteousness and profits and improving the spirit world rather than irrationally chasing materials. It is an important starting point for dealing with the external relationship (Zhan, 2005). In terms of human relationship, *he* in Chinese is meant not only to be respectful and friendly to others, but also not to agree to the wrong ideas of his superiors, as Confucius said in *the Analects*, "[t]he superior man is affable, but not adulatory; the mean is adulatory, but not affable" (*junzi he er bu tong, xiaoren tong er bu he*) (*the Analects*, 13:23, translated by Legge, 1861a, p.137). In Chinese, *he* is meant to be harmony or in harmony, while *tong* is just the opposite; the former is an epistemological way of creative knowing, trying to absorb various elements from different things to create something new and valuable, whereas the latter cannot do so (Wang, 2012). "[Confucian harmonism] is a creative process, amid which things are balanced with one another, but amid which something new also emerges" (Wang, 2012, p. 189). "Harmony without uniformity (*he er bu tong*)" is an important idea for facing conflicts or differences in Confucianism, and it is the most effective means to overcome them (Feng, 2010). In terms of the unity of heaven and humans, the idea of *he* in Chinese is more relevant to sustainability. In the Chinese ancient book *Guoyu*, Shi Bo thought that "Mixing one factor with others means harmonism" (*Yi ta ping ta wei he*) (*Guoyu:zhengyu*, 16:5, Zuo et al., 2015, p. 347), and he further pointed out that "Harmonism will create new things, but sameness will not." (*he shi sheng wu, tong ze bu ji*) (*Guoyu:zhengyu*, 16:5, Zuo et al., 2015, p. 347). This indicates that only by integrating different things or factors, new things can be created and developed—a philosophical insight into the nature of matters indeed (Wang, in press). The concept of Chinese harmonism is one of the most important Confucian ideas in the traditional culture, and it is very relevant to science education for sustainability. So, it would be of great importance to be included as one of the significant features of Confucianism (Ding & Su, 2021; Ding & Wang, 2017).

As *Bildung* in German, the Chinese character *he* can be combined with other characters to form many, many terms (see Table 2). All these terms consist of two Chinese characters, with *he* coming first. There are also many two-Chinese-character terms with *he* coming second, and there are much more four-Chinese-character idioms, such as *he er bu tong* (translated as "seeking harmonism, not the sameness" or "harmony without uniformity"). So, these examples indicate that Chinese harmonism is ingrained in the Chinese people's mind and heart through Mandarin. Although there was radicalistic anti-Confucianism during periods of times in modern Chinese history, especially in the New Cultural Movement and in the Cultural Revolution, Confucianism could not be wiped out completely in the mind of the Chinese society.

Confucian harmonism among people and between people and nature can support to live healthier and more beneficial lives in the West and the East in the current globalization era.

Table 2 Popularly used binary terms of Chinese characters consisting of one Chinese character *he* (harmonism) in modern Chinese language

No	Chinese characters	ping yin	English	No	Chinese characters	ping yin	English
1	和平	he ping	Peace	19	和睦	he mu	(Of relationship) friendly
2	和会	he hui	Peace conference	20	和戎	he rong	Peaceful dealings with minorities
3	和议	he yi	Peace negotiation	21	和乐	he le	Happy and harmonious
4	和约	he yue	Peace treaty	22	和美	he mei	Harmonious and beautiful
5	和谐	he xie	Harmonious (relationship)	23	和答	he da	In response to the other in poems
6	和婉	he wan	Mild in tone	24	和番	he fan	Make peace with other countries
7	和合	he he	In one mind with others	25	和气	he qi	Friendly feelings
8	和心	he xin	Peaceful mind	26	和善	he shan	Genial
9	和洽	he qia	In harmony	27	和泰	he tai	Mild and peaceful
10	和蔼	he ai	Affable	28	和声	he sheng	Harmony
11	和谦	he qian	Modest	29	和弦	he xian	Chord
12	和雅	he ya	Gentle and respected	30	和顺	he shun	(Of character of a person) gentle
13	和畅	he chang	(Of a wind) pleasant or gentle	31	和棋	he qi	A draw in chess or other board games
14	和风	he feng	Soft wind	32	和尚	he shang	A monk
15	和雨	he yu	Small rain	33	和味	he wei	Delectable food
16	和玉	he yu	Precious jade, rare treasure	34	和局	he ju	A draw in a game, a tie in a competition
17	和解	he jie	Become reconciled or settled	35	和诗	he shi	A poem that leads to responses in poems by others
18	和好	he hao	Become reconciled	36	和曲	he qu	In chorus in a song

It is an effective way to deal with cultural differences but also limited natural resources (Wang, 2012). It can also facilitate the implementation of sustainability in Chinese science education, to know the western cultures or values and Chinese cultures about sustainability and grasp the rational contents and ideas. Integrating the local contexts and traditional ethics about ecology can gain many advantages for sustainability (Li et al., 2012). Harmonism in Confucianism endorses the unity of all the creatures with diversities, thrivingly and peacefully living together (Zhu, 2010). Such an understanding is in line with modern concepts of sustainability that re-interpret the balancing of ecological, economic, and societal sustainability in a means that:

> The concept of balancing has failed as it always leads to imbalances. In case of doubt, social as well as ecological needs were pushed aside in favour of a growing economy […]. With the knowledge about the planetary boundaries we have to state that the physical boundaries of the natural resources are not negotiable boundaries. In a nutshell: When the biophysical boundaries are absolute we cannot build a relativistic model on them. […] we must re-conceptualize sustainability where the economy serves the social needs of people today and tomorrow and eliminates poverty and hunger. But, it can only act within the planetary boundaries. (Niebert, 2018, p.62)

In Confucianism, humans and nature are in the same ethical system, and the concept of unity of heaven and humans (*tian ren he yi*) is raised, and individuals' practicing ethical morality in the family and the society is highlighted. In Neo-Confucianism, the concept of unity of heaven and humans is further explained, and ethics are essentially practiced among humans and between humans and all the things or beings in the cosmos (Cui, 2012; Hsu, 2015). New Confucianists emphasize individuals' self-cultivation and the pursuit of the way of heaven or nature to achieve harmony between individuals and communities and between humans and nature (Hsu, 2015; Tu, 2001). Above all, Confucian unity of heaven and humans can be understood as the driver for ecological benignity and human ethics (Li, 2018). Confucian ecology stresses ethical conscience. So it can probably provide another way for achieving sustainable development (Hsu, 2015). A potential organizer of (Neo-)Confucian philosophical views about sustainability is provided in Fig. 1 according to Cheng (2012). Sincerity is the initial stage, and benevolence is the core spirit of harmonism. Vital force (*qi*) is the basic element of all the things of the cosmos and bonds them
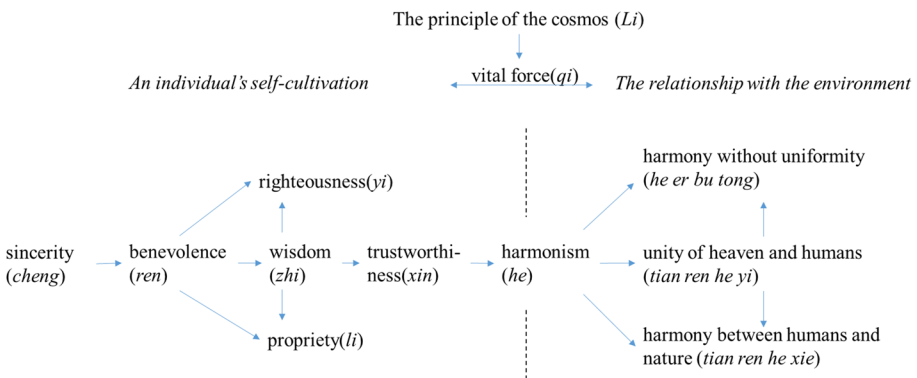

Fig. 1 A framework of philosophical views on sustainability in (Neo-)Confucianism (adapted from Cheng, 2012)

as an entity (Chung, 2012; Mok, 2020; Paton, 2021; Tucker, 2017; Xu et al., 2014). It is very similar to the ideas of matter from Western philosophy, whereas *qi* has accessibility to all things and the intrinsic motility with frequently moving and changing. *Qi* can be considered the unity of matter and energy (Needham, 2004; Zhang, 2002). The left part is the concepts for individuals' self-cultivation which are basic to sustainable development, and the right is the harmony with the environment including living and non-living things. The principle *Li* controls the operation of the universe (Chung, 2012; Mok, 2020; Tucker, 2017).

3.3 Confucianism and Sustainability in Science Education

Huang and Asghar (2018) found that there are cultural restraints and supports as secondary science teachers in Taiwan carried out inquiry-based and student-centered teaching. The equality and equity in Confucian education match with Western modern education, and student-centered instruction is similar to the Confucian education principle of satisfying students' abilities and needs. The science teachers considered Confucian virtues and ethics as an important goal of education for a harmonious and stable society. Teachers should enrich content knowledge and be role models for students. However, Confucian self-discipline and respect for authorities might impede nurturing students' autonomy, critical thinking, inquiry, and creative ability.

Sjöström (2018) suggested that Confucianism has some similarities with Western *Bildung* about ecological friendly views. Neo-Confucian and *Bildung*-oriented science education, or eco-reflexive science education (Sjöström et al., 2016), concerns the awareness of uncertainties, the recognition of benefits and risks of science and technology, and ethical and social factors based on contemporary views of nature of science. Socio-scientific issues (SSI), which are authentic, relevant, present, and controversial, are suggested for improving students' scientific literacy in teaching science (e.g., Bencze et al., 2020; Marks & Eilks, 2009). This teaching approach can develop students' higher-order thinking skills to form rational decisions for involving societal debates and future decisions about related SSIs in becoming responsible citizens (Hofstein et al., 2011; Holbrook & Rannikmae, 2007; Sadler, 2009). Foong and Daniel (2013) implemented two socio-scientific issues in Chinese science classroom and found that this kind of instruction can promote student-oriented learning and relieve the Confucian teacher-centered influence with students' progression in argumentation skills.

Feng and Netwon (2012) implemented a Master's course about sustainability education which is designed based on the harmony principle in Confucianism. They found that the principle of harmony in Confucianism can facilitate the implementation of sustainability education by addressing sustainability issues with respect to others and their different interests. It can help actively collaborative and collective actions. Cheng (2013) suggests that Confucian virtues have potential value for meeting the modern global and local needs of sustainable development. Zhang et al. (2020) mentioned that Confucian values greatly influence Chinese environmental values, attitudes, and behavior. Increasing Chinese recognition of and adherence to Confucian values can positively promote science education (Huang, 2015) and environmentally benign behaviors (Zhang et al., 2020). Modern science education is not only to nurture students with scientific knowledge and motivate their learning, but also to prepare them to be active and responsible citizens (Hansson & Yacoubian, 2020), with a goal of "science education for all and social transformation," expressed as "scientific literacy" on three visions. Vision I focuses on scientific and technical knowledge

and concepts in the epistemological view, Vision II is the contextual or application aspect of scientific knowledge connecting students' daily lives (Roberts, 2007), and Vision III suggests multiple cultural perspectives on scientific worldviews for science education for sustainability (Murray, 2015), such as critical-reflexive *Bildung* (Sjöström & Eilks, 2018). As mentioned above, the rapid development of science, technology, and society leads to the modernization of China during the last few decades, but it also faces serious environmental issues. The Confucian idea of harmony between nature and humans, as a sustainability value, might facilitate modern science education for sustainability, in the light of Vision III of scientific literacy in China.

Meng (2004) advocated merging humanist education with science education by effectively integrating Eastern and Western cultures. Chinese educators should concern both Western modern and traditional views of the natural world. It is suggested to revisit Chinese traditional culture about the relationship between nature and humans, to implement a local version of sustainability education and for developing students' environmental awareness (Chen & Bu, 2019; Li, 2020; Savelyeva, 2017). Chen (2007) proposed to increase the recognition of green civilization, provoke treating beings with benevolence, and develop appropriate consumption behaviors, to reach Confucian *tian ren he yi*. Liu and Constable (2010) underpinned connecting the values and knowledge of Chinese culture with global principles for enhancing education for sustainability. Confucian virtues such as benevolence, commitment to harmony, and filial piety are suggested to have positive implications for environmental education (Nuyen, 2008).

Some programs about sustainability education based on Confucian values have already been carried out. For instance, an ecological education program was implemented for highlighting harmony between nature and humans (Kim & Lim, 2007). Kim and Roth (2008) proposed to combine Confucian values of sincerity (*cheng*), propriety (*li*), and righteousness (*yi*) about ecological ethics into Korean environmental education to confront the gap between students' knowing and acting about environmental issues. In short, ethical views are indispensable for promoting scientific literacy in science education for building a sustainable and responsible society (Zeidler et al., 2005). Moreover, sustainability education needs collective efforts, and Confucian collectivism can actively promote the implementation of sustainability education by combining the fostering of responsible and capable individuals and collective learning with global perspectives (Liu & Constable, 2010). Similarly, the (Neo-)Confucian ideas of the unity of knowing and acting (*zhi xing he yi*) and reflection also can make sure to achieve participatory skill competency of sustainability education (Chen, 2019). The relationship between Confucian education and science education for sustainability is mapped in Fig. 2.

Confucianism has advantages and disadvantages for science education for sustainability, and both have some common parts which perform the moral function as suggested in Fig. 2. The core function of Confucian education is moral education in the sense that it makes human beings human. It is generally in line with different concepts of education for sustainability, although different interpretations of sustainability-oriented education exist (Öhman & Östman, 2019). Individual self-cultivation for a noble person and the idea of harmony between nature and humans in (Neo-)Confucianism match with the social, ecological, and economic aspects of education for sustainability. Science education in Confucian culture should highlight moral education based on Confucian values. According to McBeath et al. (2014) and Li and Eilks (2021), Chinese science education research with a focus on sustainability is still at its initial stage. Main foci are introducing teaching strategies and different approaches to practical work. Most of students' and teachers' pro-environmental awareness and behaviors are quite weak at secondary schools.
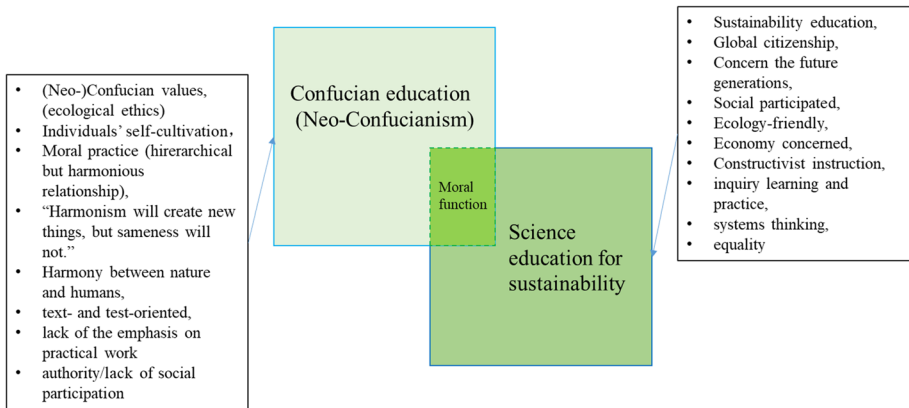
Fig. 2 The relationship between Confucian education and science education for sustainability including significant features

Instruction focusing on socio-scientific issues in science education is just starting. Teachers lack appropriate teaching resources and external support for promoting science education for sustainability, especially in the context of the current national secondary science education standards for use. The persisting emphasis on theoretical knowledge learning is also influenced by the textbooks and the neglect of scientific practices and creativity in modern Chinese science education (Gao, 1998; Huang et al., 2016; Thomas, 2006). Further reasons suggested in the literature are the dominance of teacher-centered instruction (Yeung, 2015), rote learning by just memorizing scientific knowledge, and the strong role and nature of the exams (Chan, 1999) with the paper-and-pencil standard for assessment (Yin & Buck, 2015) that do not match with modern concepts of science education for sustainability. In contemporary educational theory, knowledge is suggested to be constructed by learners' thinking processes and can be constructed by exchange and argumentation (Tweed & Lehman, 2002). This new theory seems to be familiar to many Chinese science educators and teachers alike, but it is very difficult to be thoroughly implemented in the classrooms.

Critical thinking is highlighted in contemporary science education, and one of the core spirits of the nature of science is skepticism (Aikenhead & Ogawa, 2007). Science education for sustainability can lead to student-centered learning and increase students' interest for their more participation by addressing SSIs (McBeath et al., 2014). SSIs provide contexts for students raising questions, and in combination with Confucian education, there is potential for nurturing critical thinking abilities, since questioning is one process of Confucian learning (Hung, 2016; Tweed & Lehman, 2002). Education for sustainability is value-driven and emphasizes environmental ethics (UN, 2015), similar to the behavioral reform of Confucian education including Confucian ecological ethics (Tweed & Lehman, 2002). Confucian collective values could support students' participation in group discussions for contributing their efforts to the collective and developing their thinking skills. Science education for sustainability can promote students' discussion on SSIs so that it will enhance student-centered learning, foster independent thinking and argumentation, and assist in nurturing a Confucian noble person in modern technological society. According to Thomas (2006), science teachers mainly highlight examination and knowledge rather than students' metacognition development in Asian regions in the case of Hong Kong. Students lack self-regulation and accept the authoritative and parental figure of the teacher, due to the filial

piety of Confucianism. Compared to international schools, Chinese teachers are stricter with their students in terms of higher expectations of academic results but lack emotional support to their students (Huang & Asghar, 2018; Thomas, 2006). As efforts are seen as the most important requirement for one's achievement in Confucianism rather than intrinsic abilities in Western culture (Lee, 1996), Chinese teachers concern more with the efforts put by students and ignore students' different learning abilities and needs (Lau & Lam, 2017).

However, the authority of teachers in the classroom can assist the implementation of new teaching methods for students' smooth acceptance of it and respect to their teachers in Confucianism (Yin & Buck, 2015). Yin and Buck (2015) noted that formative assessment helped Chinese science education to shift into learner-centered, constructivist teaching. As it is concerned more with students' learning process, it could get rid of relying on "questions sea tactics" of teaching and learning, which means doing plenty of written exercises for better test results. Writing tasks of formative assessment can effectively encourage students to elaborate their viewpoints on certain issues and suit Chinese classrooms. The leading summative assessment, big class sizes, and the limited class time might impede the implementation of formative assessment and need supports from educational authorities and schools. Luan et al. (2020) found that although scientific teaching approaches in environmental education can improve secondary school students' environmental awareness and holistic thinking abilities, the authorities' supports from schools or the society about environmentally friendly ideas or policies can further promote students' decision-making abilities and pro-environmental behaviors for their respect for the authority in Confucian culture. It is in accordance with Fu et al. (2017), who suggest that it is underscored how university environmental policies nurture students' environmental-friendly behaviors as Chinese social and cultural aspects, such as dignity and collectivism, highly influence one's behaviors (Yang & Weber, 2019). Due to cultural factors, systems thinking instructional approaches, including attitudes, knowledge, emotion, and so on, should be implemented for promoting students' sustainability behaviors (Huang & Yore, 2005).

3.4 A Model for the Implementation of ESD in Science Education for Confucian Culture

As Chinese science education today mostly follows the Anglo-American curriculum tradition, a general teaching model is not defined, and the development of its science teaching model is still at the beginning in mainland China. Even though science education research was launched in China in the 1980s, it mainly focuses on the local reconstruction of educational theories from other countries, e.g., inquiry learning and student-centered pedagogies. It is suggested to add research on the theory of science teaching based on theories, goals, procedures, strategies, and assessments for the Chinese educational context (Ma & Zhao, 2018).

As mentioned above, Chinese Confucian education should not be understood as the opposite of Western education (Huang, 2015; Zhao, 2019). Meyer et al. (2017) analyzed the German Didaktik tradition and Confucian philosophy of education as the core of Chinese school education from perspective. They explored Confucian education with the main goals of "humanism, harmony, and hierarchy with discipline" (Starr, 2012, p. 8), in relation to the German Didaktik by Wolfgang Klafki's conception of "self-determination, cooperation, and solidarity" as main goals. They found strong parallels and possibilities of associating these two kinds of schooling visions. Similarly, Sjöström (2018) pointed out

resemblances for learning between Confucianism and *Bildung* from Western culture for sustainability education.

In the "(*Bildung*-centered) Didaktik analysis" model for lesson planning by Klafki (2000; originally published in German in 1958), key questions are provided to identify content and approaches for learning (see Table 3). These questions are suggested to identify the suitable topics also for ESD in respect of cultural differences and traditions. The model underscores content-related aspects for all the levels of teaching and learning. It can effectively support teachers to identify and transform meaningful knowledge to their students for ESD in the foreground of any given culture (Arnold & Koch-Priewe, 2011).

The "(*Bildung*-centered) Didaktik analysis" model can be considered a reference model for formulating science education for sustainability, related to Confucian culture in mainland China. Based on this approach, a framework in the means of a Didaktik model (e.g., Sjöström et al., 2020) for implementation of science education for sustainability connecting with Confucianism in mainland China is sketched in Fig. 3. It contains the determination of aims and goals, the selection of topics and contents, the design of teaching materials, media and assessment, teaching and learning methods, implementation, and evaluation. It also includes the context of the entire implementation, which are individual, school, and societal dimensions as well as educational goals. In the globalization era, different cultures harmonious living with diversities (*he er bu tong*) is also concerned. The model is supported by theories of science education for sustainability, Confucian values for sustainability education, and pedagogical and psychological theories including adjusted Confucian education for suiting the features of science learning. Additionally, students' preconditions and existing knowledge influence the implementation. Individuals' behavior and conceptions will interact with their communities and bring change to society.

Western modern science produces scientific knowledge and supports the development of technologies based on Western views of nature and humans and Western modern scientific way of thinking. Thus, science education in non-Western modern societies should be compared to them as regards the traditional cultural views on nature and their way of thinking and should be contextualized by students' traditional local culture (Ogawa, 1986). The views of nature and humans in Confucian culture and sustainability in science education are concentrated and shown in Fig. 3 as well. Modern Chinese students nurtured with scientific knowledge or tools for sustainability, such as systems thinking and life cycle assessment, can effectively deal with humans and nature with sincerity (*cheng*) and Confucian virtues to reach *tian ren he yi* of (Neo-)Confucianism by the integration of knowledge and

Table 3 Key questions of Klafki's (2000) Didaktik analysis

(1) What wider or general sense or reality does this content exemplify and open up to the learner? What basic phenomenon or fundamental principle, what law, criterion, problem, method, technique, or attitude can be grasped by dealing with this content as an "example"?

(2) What significance does the content in question, or the experience, knowledge, ability, or skill to be acquired through this topic already possess in the minds of the children in my class? What significance should it have from a pedagogical point of view?

(3) What constitutes the topic's significance for the children's future?

(4) How is the content structured (which has been placed in a specifically pedagogical perspective by Questions 1, 2, and 3)?

(5) What are the special cases, phenomena, situations, experiments, persons, elements of aesthetic experience, and so forth, in terms of which the structure of the content in question can become interesting, stimulating, approachable, conceivable, or vivid for children of the stage of development of this class?
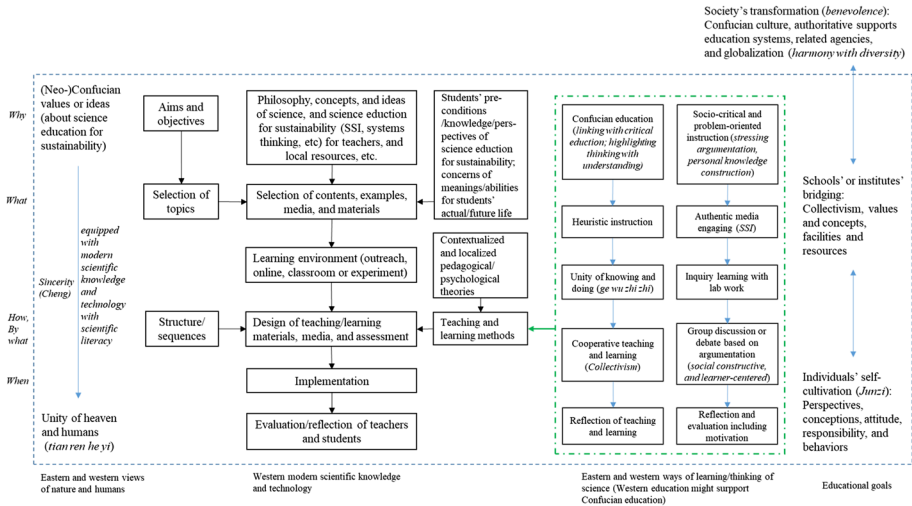
Fig. 3 A framework for the implementation of science education for sustainability connecting Confucianism (based on mainly Du et al. (2013), Heimann et al. (1969), Marks and Eilks (2009), Ogawa (1986), Sjöström et al. (2020), and Zhao (2013))

behaviors. Zhao (2013) drew back to *the Analects* and found the following themes similar to Western critical education: students' and teacher's collaborative learning, the unity of knowing and doing, the reflection on teaching and learning, and the building of societal transformation of humanity. They are also highly related to Marks and Eilks' (2009) socio-critical and problem-oriented instructional model for science education. Obtaining knowledge by investigating things (*ge wu zhi zhi*) is an important concept of (Neo-)Confucianism connected with ideas of scientific spirits and inquiry (Zheng & Wang, 2021) and a way of sincerity (*cheng*). Individuals finish their inter transformation by self-cultivation and character-building and then take responsibility to reach societal harmonism and transformation as the finial education goal in a moral way under Confucian culture (Zhao, 2013), while Western critical education encourages individuals to directly question and change the social environment to reach democracy (Giroux, 1985). So authorities' supports might facilitate students' pro-environmental behaviors and motivate students' engagement in the discussion about SSIs.

4 Conclusion

The United Nations (UN) suggest by 2030

> [ensuring] all learners acquire knowledge and skills needed to promote sustainable development, including among others through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship, and appreciation of cultural diversity and of culture's contribution to sustainable development. (see Goal 4.7: UN, 2015, p. 17)

This overarching political goal should influence educational practices in all countries, among them those having a background in Confucian culture and tradition. It is, however,

necessary to note that the international discourse on education for sustainability in science education is basically dominated by Western modern views, at least when it comes to questions of science, technology, and the environment. More recent discussions nevertheless emphasize the importance of respecting non-Western worldviews on science more thoroughly in science education (Zidny et al., 2020).

Science education in China has been localized with disadvantages and/or advantages of Confucianism accompanying the development of Chinese industrialization in recent decades. As the awareness of the side effects is increased, the traditional anthropocosmic view of nature and humans (*tian ren he yi*) including Confucian values is being withdrawn. *Tian ren he yi* might be considered an important contribution for the global education community to enrich education for sustainability (Tu, 2001). Many (Neo-)Confucian values and ideas are in line with the philosophies of education for sustainability or ESD. Since most industrialized societies are built upon scientific knowledge and technology based on a Western modern scientific way of thinking, comparison, tensions, and connections of Western and Eastern cultures should be concerned in science education, including the fissions that potentially exist (Ogawa, 1986, 1989).

This paper provides an analysis of the research literature on science education for sustainability in Confucian culture with reference to the international discourse on education for sustainability. The discussion in this paper shows many parallels between Confucian thoughts and values and Western educational theories, e.g., in the concept of *Bildung*, when it comes to sustainability issues. Many connections were identified between Confucianism, education for sustainability, and selected concepts from Western education. Respect for nature and more holistic thinking in systems are essential components of both Confucianism and contemporary concepts of sustainability. These parallels provide a chance to enrich science education in Confucian societies by reflecting on developments in science and technology from both the political agenda for sustainable development and the values of Confucianism. From this comparison, the view of nature and humans can be considered a good link for Chinese science education to foster skills by education for sustainability. It is, however, important that curriculum development and research are needed in science education on how to better operate the combination of learning science with ESD in mainland China and other Asian societies, and Confucian views are related to both of them. To support this endeavor, a framework is suggested that aims to guide this process.

Declarations

Competing Interest The authors declare that they have no conflict of interest.

References

Aikenhead, G. S., & Ogawa, M. (2007). Indigenous knowledge and science revisited. *Cultural Studies of Science Education, 2*(3), 539–620.

Arnold, K. H., & Koch-Priewe, B. (2011). The merging and the future of the classical German traditions in general didactics: A comprehensive framework for lesson planning. In B. Hudson & M. A. Meyer (Eds), *Beyond fragmentation: Didactics, learning and teaching in Europe* (pp. 252–264). Barbara Budrich.

Bai, L. (2013). Practicality in curriculum building: A historical perspective on the mission of Chinese education. *Frontiers of Education in China, 8*(4), 518–539.

Bencze, L., Pouliot, C., Pedretti, E., Simonneaux, L., Simonneaux, J., & Zeidler, D. (2020). SAQ, SSI and STSE education: defending and extending "science-in-context". *Cultural Studies of Science Education, 15*, 825–851.

Bockover, M. I. (2012). Confucian ritual as body language of self, society, and spirit. *Sophia, 51*(2), 177–194.

Brindley, E. (2011). Moral autonomy and individual sources of authority in The Analects. *Journal of Chinese Philosophy, 38*(2), 257–273.

Burmeister, M., Rauch, F., & Eilks, I. (2012). Education for Sustainable Development (ESD) and chemistry education. *Chemistry Education Research and Practice, 13*(2), 59–68.

Caro, T., Darwin, J., Forrester, T., & Ledoux-Bloom, C. (2012). Conservation in the Anthropocene. *Conservation Biology, 26*, 185–188.

Castellanos, P. M. A., & Queiruga-Dios, A. (2021). From environmental education to education for sustainable development in higher education: A systematic review. *International Journal of Sustainability in Higher Education. Advance online publication.* https://doi.org/10.1108/IJSHE-04-2021-0167

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

Chen, L. (2005). Lun rujia jiaoyu sixiang de jiben linian [On the basic of ideas of Confucian thought of education]. *Journal of Peking University (Philosophy and Social Sciences), 42*(5), 198–205.

Chen, W. (2007). Rujia huanjing lunli: Gaoxiao huanjing daode jiaoyu de yingyong he qishi [Confucian environmental ethics: The application and enlightenment of tertiary environmental moral education]. *Journal of Jianzuo University, 2007*(1), 109–110, 127.

Chen, X. (2015). The value of authenticity: Another dimension of Confucian ethics. *Asian Philosophy, 25*(2), 172–187.

Chen, X. (2019). Harmonizing ecological sustainability and higher education development: Wisdom from Chinese ancient education philosophy. *Educational Philosophy and Theory, 51*(11), 1080–1090.

Chen, H., & Bu, Y. (2019). Anthropocosmic vision, time, and nature: Reconnecting humanity and nature. *Educational Philosophy and Theory, 51*(11), 1130–1140.

Chen, X., 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.

Cheng, C. Y. (2012). A transformative conception of Confucian ethics: The Yijing, utility and rights. *Journal of Chinese Philosophy, 38*(Supplement), 7–28.

Cheng, C. Y. (2013). Confucian ethics in modernity: Ontologically rooted, internationally responsive, and integratively systematic. *Journal of Chinese Philosophy, 40*, 76–98.

Cheng, C. Y. (2016). A theory of learning (學) in Confucian perspective. *Educational Philosophy and Theory, 48*(1), 52–63.

Cheng, F. P. (2018). Confucian educational thought: Enlightenment and value for contemporary education in China. In X.F. Liu & W. Ma (Eds.), *Confucianism reconsidered: Insights for American and Chinese education in the twenty-first century* (pp. 47–63). : SUNY Press.

Cheng, M. H. M., & Wan, Z. H. (2016). Unpacking the paradox of Chinese science learners: Insights from research into Asian Chinese school students' attitudes towards learning science, science learning strategies, and scientific epistemological views. *Studies in Science Education, 52*(1), 29–62.

Chinn, P. W. U. (2002). Asian and pacific islander women scientists and engineers: A narrative exploration of model minority, gender, and racial stereotypes. *Journal of Research in Science Teaching, 39*(4), 302–323.

Chiu, R. K. (2002). Ethical judgement, locus of control, and whistleblowing intention: A case study of mainland Chinese MBA students. *Managerial Auditing Journal, 17*(9), 581–587.

Christensen, J. E. (2017). Confucianism, food, and sustainability. *Asian Philosophy, 27*(1), 16–29.

Chuang, S. F. (2012). Different instructional preferences between Western and Far East Asian adult learners: A case study of graduate students in the USA. *Instructional Science, 40*(3), 477–492.

Chung, E. Y. J. (2012). Yi T'oegye on reverence for nature: A modern Neo-Confucian ecological vision. *Acta Koreana, 14*(2), 93–111.

Cobern, W. W. (1993). Contextual constructivism: The impact of culture on the learning and teaching of science. In K. G. Tobin (Ed.), *The practice of constructivism in science education* (pp. 51–69). Lawrence Erlbaum.

Colucci-Gray, L., Perazzone, A., Dodman, M., & Camino, E. (2013). Science education for sustainability, epistemological reflections and educational practices: From natural sciences to trans-disciplinarity. *Cultural Studies of Science Education, 8*(1), 127–183.

Contrada, R. J., Ashmore, R. D., Gary, M. L., Coups, E., Egeth, J. D., Sewell, A., Ewell, K., Goyal, T. M., & Chasse, V. (2001). Measures of ethnicity-related stress: Psychometric properties, ethnic group differences, and associations with well-being. *Journal of Applied Social Psychology, 31*(9), 1775–1820.

Cui, D. (2012). Ren yu ziran guanxi de ruxue xuanze [Ruist selections regarding the relationship between humanity and nature]. *Journal of Early Chinese Philosophers, 6*, 1–14.

Dillon, J. (2014). Environmental education. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education* (2nd ed., pp. 497–514). Routledge.

Ding, B. (2015a). Science education in Mainland China. In R. Gunstone (Ed.), *Encyclopedia of Science Education* (pp. 882–889). Springer.

Ding, B. (2015b). Science teacher education in Mainland China. In R. Gunstone (Ed.), *Encyclopedia of science education* (pp. 917–924). Springer.

Ding, B., & Su, X. (2021). The dialogue between Didaktik and curriculum studies within mainland China. In E. Krogh, A. Qvortrup, & S. T. Graf (Eds.), *Didaktik and curriculum in ongoing dialogue* (pp. 207–221). Routledge.

Ding, B., & Wang, F. (2017). Didactics meets curriculum studies in the context of teacher education in mainland China: A historical and comparative perspective. In J. C. Lee & K. J. Kennedy (Eds.), *Theorizing teaching and learning in Asia and Europe: A conversation between Chinese curriculum and European didactics* (pp. 123–139). : Routledge.

Du, X., Su, L., & Liu, J. (2013). Developing sustainability curricula using the PBL method in a Chinese context. *Journal of Cleaner Production, 61*, 80–88.

Feng, Y. (2010). Legal culture in China: A comparison to Western law. *Exchange, 16*, 115–123.

Feng, L., & Newton, D. (2012). Some implications for moral education of the Confucian principle of harmony: Learning from sustainability education practice in China. *Journal of Moral Education, 41*(3), 341–351.

Foong, C. C., & Daniel, E. G. S. (2013). Students' argumentation skills across two socio-scientific issues in a Confucian classroom: Is transfer possible? *International Journal of Science Education, 35*(14), 2331–2355.

Fu, L., Zhang, Y., & Bai, Y. (2017). Pro-environmental awareness and behaviors on campus: Evidence from Tianjin, China. *Eurasia Journal of Mathematics, Science and Technology Education, 14*(1), 427–445.

Fung, Y. (1948). *A short history of Chinese philosophy*. The Free Press.

Gao, L. (1998). Cultural context of school science teaching and learning in the People's Republic of China. *Science Education, 82*(1), 1–13.

Giroux, H. A. (1985). Critical pedagogy, cultural politics, and the discourse of experience. *Journal of Education, 167*(2), 22–41.

Gorry, J. (2011). Cultures of learning and learning culture: Socratic and Confucian approaches to teaching and learning. *Learning and Teaching, 4*(3), 4–18.

Grosseck, G., Ţîru, L. G., & Bran, R. A. (2019). Education for sustainable development: Evolution and perspectives: A bibliometric review of research, 1992–2018. *Sustainability, 11*(21), 6136.

Gündüz, N., & Özcan, D. (2010). Learning styles of students from different cultures and studying in Near East University. *Procedia-Social and Behavioral Sciences, 9*, 5–10.

Guo, Q. (2006). *A history of Chinese educational thought*. Foreign Language Press.

Guthrie, G. (2011). Formalistic traditions in China. In G. Guthrie (Ed.), *The progressive education fallacy in developing countries: In favour of formalism* (pp. 173–193). Springer

Guy, T. C. (1999). Culture as context for adult education: The need for culturally relevant adult education. In T. C. Guy (Ed.), *New directions for adult and continuing education: Providing culturally relevant adult education* (pp. 5–18). Jossey-Bass.

Hansson, L., & Yacoubian, H. A. (2020). Nature of science for social justice: Why, what and how? In H. A. Yacoubian & L. Hansson (Eds.), *Nature of science for social justice* (pp. 1–21). Springer.

Heimann, P., Otto, G., & Schulz, W. (1969). Unterricht, Analyse und Planung [*Instruction - analysis and planning*] (4th ed). : Schroedel.

Herranen, J., Yavuzkaya, M., & Sjöström, J. (2021). Embedding chemistry education into environmental and sustainability education: Development of a Didaktik model based on an eco-reflexive approach. *Sustainability, 13*(4), 1746.

Herron, M. D. (1969). Nature of science: Panacea or Pandora's box. *Journal of Research in Science Teaching, 6*, 105–107.

Ho, F. M. (2018). Reforms in pedagogy and the Confucian tradition: Looking below the surface. *Cultural Studies of Science Education, 13*(1), 133–145.

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

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.

Holbrook, J., & Rannikmae, M. (2007). The nature of science education for enhancing scientific literacy. *International Journal of Science Education, 29*(11), 1347–1362.

Hopwood, B., Mellor, M., & O'Brien, G. (2005). Sustainable development: Mapping different approaches. *Sustainable Development, 13*(1), 38–52.

Horlacher, R. (2016). *The educated subject and the German concept of Bildung: A comparative cultural history*. Routledge.

Hsu, H.-C. (2015). Ruxue siwei yu yongxufazhan linian:guonei huanjingjiaoyu zhengce neihan zhi shenshi [Confucianism and the Idea of Sustainable Development: An Examination of Domestic Environmental Education Policy]. *Universitas-Monthly Review of Philosophy and Culture, 42*(9), 107–127.

Huang, Y. (2015). Integrating reflexivity: Negotiating researcher identity through autoethnography. *Educational Research for Social Change, 4*(2), 89–103.

Huang, Y. S., & Asghar, A. (2018). Science education reform in Confucian learning cultures: Teachers' perspectives on policy and practice in Taiwan. *Cultural Studies of Science Education, 13*(1), 101–131.

Huang, H. P., & Yore, L. D. (2005). A comparative study of Canadian and Taiwanese grade 5 children's environmental behaviors, attitudes, concerns, emotional dispositions, and knowledge. *International Journal of Science and Mathematics Education, 1*(4), 419–448.

Huang, N. T. N., Chiu, L. J., & Hong, J. C. (2016). Relationship among students' problem-solving attitude, perceived value, behavioral attitude, and intention to participate in a science and technology contest. *International Journal of Science and Mathematics Education, 14*(8), 1419–1435.

Hung, R. (2016). A critique of Confucian learning: On learners and knowledge. *Educational Philosophy and Theory, 48*(1), 85–96.

Isozaki, T., & Pan, S. D. (2016). Why we study the history if science education in East Asia: A comparison of the emergence of science education in China and Japan. In H. S. Lin, J. K. Gilbert, & C. J. Lien (Eds.), *Science education research and practice in East Asia: Trends and perspectives* (pp. 1–26). Higher Education Publishing.

Jegstad, K. M., & Sinnes, A. T. (2015). Chemistry teaching for the future: A model for secondary chemistry education for sustainable development. *International Journal of Science Education, 37*(4), 655–683.

Jeong, S., Sherman, B., & Tippins, D. J. (2021). The Anthropocene as we know it: Posthumanism, science education and scientific literacy as a path to sustainability. *Cultural Studies of Science Education, 16*, 805–820.

Jin, S., & Dan, J. (2004). The contemporary development of philosophy of education in mainland China and Taiwan. *Comparative Education, 40*(4), 571–581.

Juntunen, M. K., & Aksela, M. K. (2014). Education for sustainable development in chemistry–challenges, possibilities and pedagogical models in Finland and elsewhere. *Chemistry Education Research and Practice, 15*(4), 488–500.

Kennedy, K. J., & Lee, J. C. (2017). Conclusion: Lessons learned from theorising curriculum, teaching and learning in an Asia-Europe dialogue. In J. C. Lee & K. J. Kennedy (Eds.), *Theorizing teaching and learning in Asia and Europe: A conversation between Chinese curriculum and European didactics* (pp. 311–322). Routledge

Kim, E., & Lim, J. (2007). Eco-early childhood education: A new paradigm of early childhood education in South Korea. *Young Children, 62*(6), 42-45.

Kim, M., & Roth, W.-M. (2008). Rethinking the ethics of scientific knowledge: A case study of teaching the environment in science classrooms. *Asia Pacific Education Review, 9*(4), 516–528.

Klafki, W. (2000). Didaktik analysis as the core of preparation of instruction. In I. Westbury, S. Hopmann, & K. Riquarts (Eds.), *Teaching as a reflective practice: The German Didaktik tradition* (pp. 245–282). Erlbaum.

Kwek, A., & Lee, Y. S. (2010). Chinese tourists and Confucianism. *Asia Pacific Journal of Tourism Research, 15*(2), 129–141.

Lai, K. (2008). *An introduction to Chinese philosophy*. Cambridge University Press.

Lau, K. C., & Lam, T. Y. P. (2017). Instructional practices and science performance of 10 top-performing regions in PISA 2015. *International Journal of Science Education, 39*(15), 2128–2149.

Lee, W. O. (1996). The cultural context for Chinese learners: Conceptions of learning in the Confucian tradition. In D. A. Watkins & J. Biggs (Eds.), *The Chinese learner: Cultural, psychological and contextual influences* (pp. 25–41). CERC/ACER.

Lee, J. A., & Kim, C. J. (2019). Teaching and learning science in authoritative classrooms: Teachers' power and students' approval in Korean elementary classrooms. *Research in Science Education, 49*(5), 1367–1393.

Legge, J. (1861a). *The Chinese classics: Vol. 1: Confucian analects, the great learning, and the doctrine of the mean (Vol. 1)*. At the author's.

Legge, J. (1861b). *The Chinese Classics: Vol. 2: The works of Mencius (Vol. 2)*. At the author's.

Legge, J. (1885). *The Sacred books of China: The texts of Confucianism (Part IV)*. Clarendon Press.

Li, H. L. (2018). Rethinking Confucian values in a global age. In X. Liu & W. Ma (Eds.), *Confucianism reconsidered: Insights for American and Chinese education in the twenty-first century* (pp. 221–235). SUNY.

Li, H. L. (2020). Toward weaving a "common faith" in the age of climate change. *ECNU Review of Education, 3*(1), 88–106.

Li, B., & Eilks, I. (2021). A systematic review of the green and sustainable chemistry education research literature in mainland China. *Sustainable Chemistry and Pharmacy, 21*, 100446.

Li, M., Jin, X., & Tang, Q. (2012). Policies, regulations, and eco-ethical wisdom relating to ancient Chinese fisheries. *Journal of Agricultural and Environmental Ethics, 25*(1), 33–54.

Li, J., Liu, C., Lam, K. C. K., Xu, J.-Y., Zhang, Y., & Yang, X. (2016a). The symbol of Yin/Yang and sustainable tourism in China. In J. Khatib (Ed.), *2nd Annual International Conference on Energy, Environmental & Sustainable Ecosystem Development (EESED 2016)* (pp. 633–639). Atlantis Press.

Li, Y., Cheng, H., Beeton, R. J. S., Sigler, T., & Halog, A. (2016b). Sustainability from a Chinese cultural perspective: The implications of harmonious development in environmental management. *Environment, Development and Sustainability, 18*(3), 679–696.

Liu, X. Z. (2000). "Tian ren he yi" ji "tian ren hexie"?:Jiedu rujia "tian ren he yi" guannian deyi ge wuqu [Is "Heaven and Man combine into an integral whole"(tian ren he yi) the same as "Harmony of Heaven and Man"(tian ren he xie)]. *Journal of Shaanxi Normal University, 29*(2), 7–12.

Liu, S. H. (2013). A reinterpretation and reconstruction of Confucian philosophy. *Journal of Chinese Philosophy, 40*, 239–250.

Liu, Y., & Constable, A. (2010). Earth charter, ESD and Chinese philosophies. *Journal of Education for Sustainable Development, 4*(2), 193–202.

Liu, E., Liu, C., & Wang, J. (2015). Pre-service science teacher preparation in China: Challenges and promises. *Journal of Science Teacher Education, 26*(1), 29–44.

Low, K. C. P. (2011). Confucius, the value of benevolence and what's in it for humanity? *Conflict Resolution & Negotiation Journal, 2011*(1), 32–43.

Luan, H., Li, T. L., & Lee, M. H. (2020). High school students' environmental education in Taiwan: Scientific epistemic views, decision-making style, and recycling Intention. *International Journal of Science and Mathematics Education, 20*, 25–44.

Ma, H. (2009). Chinese secondary school science teachers' understanding of the nature of science - Emerging from their views of nature. *Research in Science Education, 39*(5), 701–724.

Ma, H. (2011). Chinese teachers' views of teaching culturally related knowledge in school science. In D. Corrigan, J. Dillon, & R. Gunstone (Eds.), *The professional knowledge base of science teaching* (pp. 153–171). Springer.

Ma, H. (2012). *The images of science through cultural lenses: A Chinese study on the nature of science*. Sense.

Ma, F., & Zhao, H. J. (2018). *Lv se huaxue jiaoyu yanjiu [Green chemistry education research]*. Northeast Normal University Press.

Mahaffy, P. G., Krief, A., Hopf, H., Mehta, G., & Matlin, S. A. (2018). Reorienting chemistry education through systems thinking. *Nature Reviews Chemistry, 2*, 1–3.

Marks, R., & Eilks, I. (2009). Promoting scientific literacy using a socio-critical and problem-oriented approach to chemistry teaching: Concept, examples, experiences. *International Journal of Environmental and Science Education, 4*, 131–145.

McBeath, G. A., McBeath, J. H., Tian, Q., & Huang, Y. (2014). *Environmental education in China*. Edward Elgar Publishing.

Meng, P. (2001). Rujia de dexing lunli yu xiandai shehui [The Confucian Ethics of virtue and Modern China]. *Qilu Journal, 2001*(4), 49–52.

Meng, J. (2004). Shixi kexue jiaoyu yu renwen jiaoyu fenli de genyuan: Cong kexueguan yu renwenguan de jiaodu kan [An analysis of reasons for the separation of science education from humanist education]. *Educational Research, 2004*(1), 26–32.

Meyer, M. A., Meyer, H., & Ren, P. (2017). The German Didaktik tradition revisited. In J. C. K. Lee & K. J. Kennedy (Eds.), *Theorizing teaching and learning in Asia and Europe: A conversation between Chinese curriculum and European didactics* (pp. 179–216). Routledge.

MOE. (2021). *Promotion ratio of graduates of regular school by level*. Retrieved May 23, 2021, from http://www.moe.gov.cn/s78/A03/moe_560/jytjsj_2019/qg/202006/t20200611_464791.html

Mok, B. K. M. (2020). Reconsidering ecological civilization from a Chinese Christian perspective. *Religions, 11*(5), 261.

Murray, J. J. (2015). Re-visioning science education in Canada: A new polar identity and purpose. *Education Canada, 55*(4). Retrieved February 20, 2022, from https://www.edcan.ca/articles/re-visioning-science-education-in-canada/

Needham, J. (2004). *Science and civilisation in China: Volume 4, Physics and physical technology, Part 1, Physics*. Cambridge University Press.

Niebert, K. (2018). Science education in the anthropocene. In I. Eilks, S. Markic, & B. Ralle (Eds.), *Building bridges across disciplines for transformative education and a sustainable future* (pp. 61–72). Shaker.

Nuyen, A. T. (2008). Ecological education: What resources are there in Confucian ethics? *Environmental Education Research, 14*(2), 187–197.

Ogawa, M. (1986). Toward a new rationale of science education in a non-western society. *European Journal of Science Education, 8*(2), 113–119.

Ogawa, M. (1989). Beyond the tacit framework of 'science' and 'science education' among science educators. *International Journal of Science Education, 11*(3), 247–250.

Ogden, L., Heynen, N., Oslender, U., West, P., Kassam, K.-A., & Robbins, P. (2013). Global assemblages, resilience, and earth stewardship in the Anthropocene. *Frontiers in Ecology and the Environment, 11*(7), 341–347.

Öhman, J., & Östman, L. (2019). Different teaching traditions in environmental and sustainability education. In K. Van Poeck, L. Östman, & J. Öhman (Eds.), *Sustainable development teaching - Ethical and political challenges* (pp. 70–82). Routledge.

Ozoliņš, J. T. (2017). Creating the civil society East and West: Relationality, responsibility and the education of the humane person. *Educational Philosophy and Theory, 49*(4), 362–378.

Pak, M. S., & Kim, J. (2016). Ecophilosophy in modern East Asia: The case of Hansalim in South Korea. *Problemy Ekorozwoju – Problems of sustainable development, 11*(1), 15–22.

Park, J. (2011). Metamorphosis of Confucian heritage culture and the possibility of an Asian education research methodology. *Comparative Education, 47*(3), 381–393.

Park, W., Wu, J. Y., & Erduran, S. (2020). The nature of STEM disciplines in the science education standards documents from the USA, Korea and Taiwan. *Science & Education, 29*(4), 899–927.

Paton, M. J. (2021). Science and Fengshui: The concept *shi* 勢, rationality and emotion, and the ritualisation of knowledge. *Science & Education, 30*, 1371–1386.

Roberts, D. A. (2007). Scientific literacy/science literacy. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 729–780). Lawrence Erlbaum.

Sadler, T. D. (2009). Situated learning in science education: Socio-scientific issues as contexts for practice. *Studies in Science Education, 45*(1), 1–42.

Savelyeva, T. (2017). Vernadsky meets Yulgok: A non-Western dialog on sustainability. *Educational Philosophy and Theory, 49*(5), 501–520.

Schirokauer, C. (1991). *A brief history of Chinese civilization*. Harcourt Brace Jovanovitch.

Sjöström, J. (2018). Science teacher identity and eco-transformation of science education: Comparing Western modernism with Confucianism and reflexive Bildung. *Cultural Studies of Science Education, 13*(1), 147–161.

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

Sjöström, J., & Eilks, I. (2020). The Bildung theory – from von Humboldt to Klafki and beyond. In B. Akpan & T. J. Kennedy (Eds.), *Science education in theory and practice* (pp. 55–67). Springer.

Sjöström, J., Eilks, I., & Zuin, V. G. (2016). Towards eco-reflexive science education: A critical reflection about educational implications of green chemistry. *Science & Education, 25*, 321–341.

Sjöström, J., Frerichs, N., Zuin, V. G., & Eilks, I. (2017). The use of the concept of Bildung in the international literature in science education and its implications for the teaching and learning of science. *Studies in Science Education, 53*, 165–192.

Sjöström, J., Eilks, I., & Talanquer, V. (2020). Didaktik models in chemistry education. *Journal of Chemical Education, 97*(4), 910–915.

Starr, D. (2012). *China and the Confucian education model*. Universitas, 21. Retrieved May 12, 2022, from https://silo.tips/download/china-and-the-confucian-education-model

Sun, Y., Garrett, T. C., & Kim, K. H. (2016). Do Confucian principles enhance sustainable marketing and customer equity? *Journal of Business Research, 69*(9), 3772–3779.

Taber, K. S. (2017). Reflecting the nature of science in science education. In K. S. Taber & B. Akpan (Eds.), *Science education: An international course companion* (pp. 21–37). Sense.

Tan, C., & Tan, C. S. (2014). Fostering social cohesion and cultural sustainability: Character and citizenship education in Singapore. *Diaspora, Indigenous, and Minority Education, 8*(4), 191–206.

Taylor, P. C., & Cobern, W. W. (1998). Towards a critical science education. In W. W. Cobern (Ed.), *Sociocultural perspectives on science education: An international dialogue* (pp. 203–207). Springer.

Thomas, G. P. (2006). An investigation of the metacognitive orientation of Confucian-heritage culture and non-Confucian-heritage culture science classroom learning environments in Hong Kong. *Research in Science Education, 36*(1), 85–109.

Tu, W. (1998). Beyond the enlightenment mentality. In M. E. Tucker & J. Berthrong (Eds.), *Confucianism and ecology: The interrelation of Heaven, Earth, and Humans* (pp. 3–23). Harvard University Press.

Tu, W. (2001). The ecological turn in new Confucian humanism: Implications for China and the world. *Daedalus, 130*(4), 243–264.

Tu, W., Meng, P., Zheng, J., Li, C., Lu, F., & Lei, Y. (2003). Rujia yu shengtai [Confucianism and ecology]. *History of Chinese Philosophy, 2003*(1), 5–18.

Tucker, M. E. (1991). The relevance of Chinese Neo-Confucianism for the reverence. *Environmental History Review, 15*(2), 55–69.

Tucker, J. A. (2017). Japanese philosophy after Fukushima: Generative force, nationalism, and the global environmental imperative. *Journal of Japanese Philosophy, 5*(1), 11–42.

Tweed, R., & Lehman, D. R. (2002). Learning considered within a cultural context: Confucian and Socratic approaches. *American Psychologist, 57*, 89–99.

UN (1987). *Our common future: Report of the world commission on environment and development*. Retrieved September 8, 2021, from http://www.un-documents.net/ocf-02.htm

UN (2015). *Transforming our world: The 2030 Agenda for sustainable development*. Retrieved September 8, 2021, from http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E

UNCED (1992). *Agenda 21*. Retrieved September 8, 2021, from http://www.un-documents.net/a21-36.htm

UNEP (2012). *Global environment outlook 5: Environment for the future we want*. United Nations.

UNESCO (2005a). *United Nations Decade of Education for Sustainable Development (2005-2014): International implementation scheme*. Retrieved September 8, 2021, from https://unesdoc.unesco.org/ark:/48223/pf0000148654?posInSet=1&queryId=785d7330-62cb-4a41-a9c0-314f7ee5fe78

UNESCO. (2005b). *Guidelines and recommendations for reorienting teacher education to address sustainability*. UNESCO.

UNESCO (2016). *Education 2030: Incheon Declaration and Framework for Action for the implementation of sustainable development Goal 4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all*. Retrieved September 8, 2021, from https://unesdoc.unesco.org/ark:/48223/pf0000245656

Wan, D., Zhang, H., & Wei, B. (2018). Impact of Chinese culture on pre-service science teachers' views of the nature of science. *Science & Education, 27*(3), 321–355.

Wang, Z. (2012). *Process and pluralism: Chinese thought on the harmony of diversity*. Ontos.

Wang, C. (in press). *Guoji jiaoshi jiaoyu sixiangshi yanjiulugang [The research framework of history of international teacher education thoughts]*. Northeast Normal University Press.

Wang, J., Bao, J., Wang, C., & Wu, L. (2017). The impact of different emotional appeals on the purchase intention for green products: The moderating effects of green involvement and Confucian cultures. *Sustainable Cities and Society, 34*, 32–42.

Wu, Z. (2011). Interpretation, autonomy, and transformation: Chinese pedagogic discourse in a cross-cultural perspective. *Journal of Curriculum Studies, 43*, 569–590.

Wu, B. (2019). Cheng (誠) as ecological self-understanding: Realistic or impossible? *Educational Philosophy and Theory, 51*(11), 1152–1163.

Xu, H., Cui, Q., Sofield, T., & Li, F. M. S. (2014). Attaining harmony: Understanding the relationship between ecotourism and protected areas in China. *Journal of Sustainable Tourism, 22*(8), 1131–1150.

Yang, R. (2019). Turning Scars into Stars: A reconceptualized view of modern university development in Beijing, Hong Kong, Taipei, and Singapore. *Frontiers of Education in China, 14*(1), 1–32.

Yang, X., & Weber, A. (2019). Who can improve the environment—Me or the powerful others? An integrative approach to locus of control and pro-environmental behavior in China. *Resources, Conservation and Recycling, 146*, 55–67.

Yeung, Y. Y. (2015). Characteristics of Chinese learners as revealed from their affective domain and choices of science learning in China. In M. S. Khine (Ed.), *Science education in East Asia: Pedagogical innovations and research-informed practices* (pp. 123–145). Springer.

Yin, X., & Buck, G. A. (2015). There is another choice: An exploration of integrating formative assessment in a Chinese high school chemistry classroom through collaborative action research. *Cultural Studies of Science Education, 10*(3), 719–752.

Yorks, L., & Sauquet, A. (2003). Team learning and national culture: Framing the issues. *Advances in Developing Human Resources, 5*(1), 7–25.

Yu, J. (2007). *The ethics of Confucius and Aristotle: Mirrors of virtue*. Routledge.

Zagonari, F. (2020). Comparing religious environmental ethics to support efforts to achieve local and global sustainability: Empirical insights based on a theoretical framework. *Sustainability, 12*(7), 2590.

Zeidler, D., Sadler, T., Simmons, M., & Howes, E. (2005). Beyond STS: A research-based framework for socioscientific issues education. *Science Education, 89*(3), 357–377.

Zeng, J., & Liu, X. (2002). Kechixu fazhan yu rujia wenhua [Sustainable development and Confucianism]. *Journal of Hainan Normal University (Humanities and social sciences), 15*(3), 61–64.

Zhan, X. (2005). Rujia hexieguan de xiandai jiedu [Modern explanation of Confucian harmonism]. *Jianghuai Tribune, 2005*(5), 85–89, 143.

Zhang, D. (2002). *Key concepts in Chinese philosophy (translated and edited by Edmund Ryden)*. Foreign Languages Press.

Zhang, M., & Liu, B. (2021). The theoretical foundations of Feng Shui and science education in China: The debate on the benchmark for scientific literacy of Chinese citizens. *Science & Education, 30*(6), 1473–1490.

Zhang, J., Xie, C., Morrison, A. M., & Zhang, K. (2020). Fostering resident pro-environmental behavior: The roles of destination image and Confucian culture. *Sustainability, 12*(2), 597.

Zhao, J. (2013). Confucius as a critical educator: Towards educational thoughts of Confucius. *Frontiers of Education in China, 8*(1), 9–27.

Zhao, W. L. (2019). Historicizing *tianrenheyi* as correlative cosmology for rethinking education in modern China and beyond. *Educational Philosophy and Theory, 51*(11), 1106–1116.

Zheng, T.-X., & Wang, K.-X. (2021). "Gewu Zhizhi" de kexue luoji yiyun [The Logic of Science Implications of Gewu-zhizhi]. *Journal of Hunan University of Science & Technology (Social Science Edition), 24*(1), 41–45.

Zhou, Z. (2006). Naoju beihou: Cong sixiangshi de jiaodu kan"ping fa pi ru"yundong [Behind the farce: The movement of "Reviewing Legalism and Criticizing Confucianism" from the perspective of ideological history]. *Modern Philosophy, 2006*(2), 78–83.

Zhu, T. (2010). Fan chengshi pinkun yu chengshi hexieshehui de goujian [Counter-impoverishment strategy and construction of harmonious society in urban areas]. *Studies on Mao Zedong and Deng Xiaoping Theories, 27*(12), 6–10.

Zhu, X., & Lv, Z. (1998). *Jin Si Lv [Reflections on things at hand]*. Huacheng Press.

Zhuang, Y. (2015). Confucian ecological vision and the Chinese eco-city. *Cities, 45*, 142–147.

Zidny, R., Sjöström, J., & Eilks, I. (2020). A multi-perspective reflection on how indigenous knowledge and related ideas can improve science education for sustainability. *Science & Education, 29*, 145–185.

Zuo, Q., Wei, Z., & Wu, W. (2015). *Guo yu [Discourses of the states]*. Shanghai Classics Publishing House.