A phenomenographic study of Chinese primary school students’ conceptions about technology

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Abstract
Although there are some researches conducted about students’ conceptions of technology, little research has been conducted to reveal the primary school students’ conceptions concerning technology in China. This research investigated Chinese primary school students’ (aged 9–12) conceptions of technology as regards their understanding of (a) the concept of technology, (b) the impact of technology on human life and nature, and (c) the relationship between technology and science. Phenomenography as the methodological framework was adopted for this study. A total of 63 primary school students were chosen as participants in the study to probe their conceptions about technology through picture/photo eliciting activities, and semi-structured, personal interviews in a website video format. It is found that the primary school students defined technology from diverse perspectives, including the dimensions of its attributes, production, operation and use, function, with most of them regarding technology as a double-edged sword. It is also found that they lack a comprehensive and rational understanding of the concept of technology and cannot understand the relationship between science and technology properly. This study contributes better to understanding primary school students’ conceptions about technology in mainland China and beyond, thus providing an empirical basis for improving technology education policy, curriculum, instruction, and assessment in the future for China and other countries.

Keywords Conceptions about technology · The concept of technology · Primary school students · Mainland China · Science-technology relationship · The impact of technology · Phenomenography
Introduction

The present research reveals mainland China’s primary school students’ conceptions about technology which can help to provide an empirical basis for improving technology curriculum and instruction for China and beyond. Specifically, this study investigated Chinese primary school students’ (aged 9–12) conceptions of technology as regards their understanding of (a) the concept of technology, (b) the impact of technology on human life and nature, and (c) the relationship between technology and science.

Helping students acquire a comprehensive and proper understanding of technology is one of the significant purposes of technology education. Studies have placed great emphasis on the significance of individuals’ understanding of technology from various aspects (Ankiewicz, 2018; de Klerk Wolters, 1989; DiGironimo, 2011; Jones, 1997; Olson, 2013; Rohaan et al., 2010). One’s concept of technology can affect what knowledge and skills he/she operates in a technological task and therefore it influences their technological competencies. The broader concepts of technology students own, the more likely they could holistically perform their technological activities, i.e., showing links between the various stages (such as analyzing technological situations, making technological decisions, or evaluating technological activities) in the process. One’s narrow concepts of technology will constrain his/her technological practice and potential for learning concepts and processes regarding technology (Jones, 1997). Rather than becoming ignorant consumers of technology, students with a comprehensive and proper concept of technology are more possibly to become liberally educated individuals who can understand the world around them and the consequences of modern technologies, and make informed and conscious decisions on technology (Olson, 2013). Also closely connected to their attitude towards technology is students’ concept of technology. Although the Pupils’ Attitude Towards Technology (PATT) studies revealed that students generally have a positive attitude toward technology but with a limited concept of technology (Ankiewicz, 2018), researchers have reached a consensus that one’s comprehensive and rational concept of technology will help promote the formation of a positive attitude toward technology (Ankiewicz, 2018; de Klerk Wolters, 1989; Rohaan et al., 2010). Besides, due to the close relationship between modern technology and science, holding a comprehensive and proper understanding of technology can contribute to students’ better understanding of the relationship between technology and science, to assist them in forming an appropriate conception of science (DiGironimo, 2011) and the distinction between them. Furthermore, the increased focus on the implementation of effective integrated STEM education requires students to own an in-depth and proper understanding of the nature of each distinct component (Blom & Abrie, 2021), so cultivating students’ rational and comprehensive concept of technology calls for attention.

Understanding students’ conceptions of technology is a fundamental and necessary step in any constructivist pedagogy. In the PATT studies, for example, pupils’ conceptions of technology were investigated by answering questions about what they thought technology was, and then students’ answers were compared with the original concept categories derived from a literature study of the concept of technology, as well as through interviews with technology professionals, and the results indicated a lack of correlation between students’ answers and these categories (Bame & Dugger Jr. 1989; Van Rensburg et al., 1999). In other words, the PATT studies indicated that students’ conceptions of technology are much different from those which the author of the textbook or teachers try to make students acquire (or construct). This discrepancy will still exist during the learning process, and it is frequently there too when the class proceeds to the next topic. Therefore, it is badly
needed to investigate students’ concept of technology as well as their conceptions about technology, since students’ prior cognition provides an important cornerstone and implications used to design mini curriculum, teaching, and learning approaches for researchers and teachers.

Studies also revealed that students’ conceptions about science, technology, and their views of scientists generally begin to form in the primary school stage, and persist for many years to come (Buldu, 2006; Newton & Newton 1998). Therefore, investigating and identifying primary school students’ understanding of technology becomes indispensable. It can help researchers and educators better analyze the factors which influence the formation of these conceptions, thus taking actions to reduce their distortions from the early stages.

To reveal mainland China’s primary school students’ conceptions about technology, this paper begins by reviewing the literature concerning the object of this study and proposes the research questions. Next to make an in-depth understanding of mainland China’s technology education currently, the context of primary school technology education in mainland China will be introduced. Under the guidance of phenomenography, sixty-three primary school students aged 9–12 years old from rural, urban–rural, and urban schools separately have been interviewed to reveal their conceptions about technology, and then the results will be presented and discussed.

**Literature review**

To investigate primary school students’ conceptions about technology in mainland China, three areas of literature are to be reviewed, i.e., the concept of technology, previous studies on students’ conceptions about technology, and a brief history of technology evolvement in mainland China.

**The concept of technology**

Different concepts of technology have been proposed by philosophers of technology, experts of technology, researchers of technology education, and some organizations of technology education. Some of them consider, for example, that technology includes artifacts that can extend human capacities (Feenberg, 1999; McGinn, 1991; Mitcham, 1994) and a process of creation or design (McGinn, 1991), and it involves values, ethics, rules and politics (Durbin, 2006). Mitcham (1994) put forward a framework describing the nature of technology, i.e., technology as activity, technology as objects, technology as knowledge, and technology as volition. This framework bridges the gap between engineering philosophy and humanities philosophy of technology, which serves as two separate traditional branches of technology philosophy. Alternatively, Arthur (2009) identified principles of the nature of technology, arguing that technology is (a) an approach to fulfill the human purpose, (b) an assemblage of practices and components, and (c) the entire collection of devices and engineering practices available to a culture. From the perspective of the role that science plays in the development of technology, de Vries (1996), an expert philosopher of technology and technology education, identified three different types of technology: experience-based technologies, macrotechnologies, and microtechnologies. The experience-based technologies are not driven by fundamental theories of science but by knowledge of natural phenomena which is gained by experimentation. And the macro-technologies are driven by classical theories of science (mechanics, thermodynamics, and
electromagnetics) with macroscopic structures, while the fundamental theories of science with microstructures play a vital role in microtechnologies. De Vries’s identification can be seen as a further classification of technology as objects and as activities that were proposed by Mitcham (1994). Raat and de Vries (1986; 1987) defined technology from five scales:

(a) Technology is an activity that is indispensable to mankind. Its creation is one of the features of human beings; (b) There are three ‘pillars’ connected with technology: matter, energy, and information; (c) Technology and science are interconnected. This concerns both knowledge and procedure. Technology and science exert a mutual influence on one another; (d) Important technological skills are designing, working in a practical-technical way, and handling technical products; and (e) Technology has a large impact on society and in turn, is influenced by society. (Raat & de Vries, 1987, pp. 163–164).

The International Technology and Engineering Educators Association (ITEEA) defines technology as the modification of the natural environment through human-designed products, systems, and processes, to satisfy human needs and wants (ITEEA & CTETE, 2020). Similarly, the National Assessment of Educational Progress (NAEP) defines technology as any modification of the natural world done to fulfill human needs or desires (NAEP, 2018). The national document of technology education in New Zealand argues that technology uses intellectual and practical resources to create technological outcomes, and it is intervened by design (New Zealand Government, 2017).

Although a consensus has not been made on a unified concept of technology, the concepts proposed by specialists, professional organizations, and national documents (a) identify technology as human’s behavior to modify the natural world, and its purpose or function is to serve people, (b) distinguish technology in different forms, (c) include the relationship between technology and science and classify technology from this dimension, (d) involve the relationship between technology and society, (e) identify three prominent ‘pillars’ of technology, i.e., matter, information, and energy (Raat & de Vries, 1987, pp. 163–164), and (f) strengthen the importance of ‘design’. All of these definitions provide us not only with angles to investigate primary students’ concepts of technology but also with references and standards to judge the pupils’ concepts of technology.

**Previous research on students’ conceptions about technology**

Before the 1980s, little research investigated students’ conceptions and attitudes toward technology (Ankiewicz, 2018, 2019). From the middle of the 1980s, the PATT studies made a pioneering effort to investigate students’ attitudes and concepts of technology. Since then, more than 22 countries and areas have taken part in the PATT studies (Bame et al., 1993; Jones, 1997; Mawson, 2010; Rennie & Jarvis, 1995a; Van Rensburg et al., 1999; Volk & Yip, 1999). All of these studies provide empirical bases for the issue of many countries’ (such as the United States, the United Kingdom, New Zealand, and Australia) national document standards of technology education, which facilitated the process of a transition from craft/technical education to technology education in primary and secondary schools (de Vries, 2018).

Ankiewicz (2019) studied the mainstream, unconventional and non-related instruments used in the PATT studies that investigate students’ concepts of technology. The classical PATT studies used a Likert-type scale or modified concept questionnaire developed by Raat and de Vries (1986) with a three-point response format to collect data on students’ concepts of technology. Questionnaires can provide structured information on the selected topics (Rennie & Jarvis, 1995a) and help collect a large deal of data, scores effectively and
be easy to make comparisons between groups (Rennie & Jarvis, 1995b). But questionnaires can merely measure students’ readiness for action while not the action itself (Ankiewicz, 2019), and much attention should be paid to interpreting scores when large numbers of participants choose the neutral category (Grant & Harding, 1987). In the PATT studies, students were asked to answer the open-ended question of ‘what comes to your mind when you think about technology’, and students aged between 13–15 answered the question by writing an essay, while those aged between 10–12 answered the question by drawing a picture (Raat & de Vries, 1986). Open-ended questions allow respondents to express their own thoughts and ideas freely, and they can reveal insights into students’ thinking that could not be obtained from the measurement using questionnaires (Rennie & Jarvis, 1995a), it can either be used together with drawings or with essays or in interviews. Writing an essay or drawing a picture can make students express their own opinions about technology, rather than making choices from a prepared questionnaire, and it also can be seen that the adopted research method is directly related to the age of students. But writing essays depends on the students’ verbal ability (Rennie & Jarvis, 1995b). Drawing has relied on the given actual instruction, and it is inappropriate to make comparisons among different students’ drawings if instructions were given differently (Hill & Wheeler, 1991; Rennie & Jarvis, 1995b).

Other instruments used to measure primary pupils’ conceptions about technology include semi-structured interviews and picture/photo eliciting activities (Ankiewicz, 2019). Researchers usually lead a personal and face-to-face conversation with one interviewee and ask him/her to answer questions such as ‘what is technology in your opinion?’. Compared with writing an essay and drawings, conducting semi-structured interviews is more flexible and can obtain students’ conceptions about technology more deeply and effectively. The major shortcoming of the interview is that it requires a large amount of time (Rennie & Jarvis, 1995b). Considering better eliciting primary pupils’ conceptions about technology, the semi-structured interviews are often combined with picture/photo eliciting activities. Solomonidou and Tassios (2007) investigated sixty Greece pupils’ conceptions about technology by combining photo eliciting activities with semi-structured personal interviews. They asked pupils to select the pictures that they considered related to technology and those that were not, and then a semi-structured interview was conducted with each participant to discuss their selection. The study revealed two major categories of students’ conceptions about technology, i.e., technology-oriented conceptions which focused on technological developments with no connection to human activities, and human-oriented conceptions which concentrated on the close relationship between technology and human activity. The above methods enlighten the way of data collection for this research.

Svenningsson (2019) pointed out two approaches to analyzing students’ conceptions about technology. One is a deductive approach by which themes gained are created before the data collection and the collected descriptions are placed within them. This approach is helpful to make a comparison with other studies that use the same predefined themes, but using this approach can hardly include all students’ conceptions. For example, DiGironimo (2011) identified a conceptual framework of the nature of technology (technology as artifacts, technology as a creation process, technology as a human practice, the history of technology, and the current role of technology in society), then a sample of 20 middle school students’ answers to the question “in your opinion, what is technology?” was compared with this framework to evaluate students’ conceptions about technology, and the results indicated that (a) half of the students considered technology as artifacts, (b) newer technologies have been identified much more compared to older technological artifacts, and (c) students did not regard the creative process as part of technology, and humans were not considered as being involved in the use and development of technology. Liou (2015)
designed a set of questionnaires on the nature of technology based on the investigation of a large group of 455 senior school students in Taiwan, and the questionnaire identified 6 subthemes of technology, i.e., technology as artifacts, technology as an innovative change, the current role of technology in society, technology as a double-edged sword, history of technology, and technology as a science-based form. The study revealed that students usually linked technology with ‘convenience’, ‘artifacts and tools’, and ‘improvement of life’. Svenningsson (2019) used Mitcham’s philosophical framework of technology to analyze 164 middle school students’ conceptions of technology, and the results revealed that these students could describe technologies in a broad way that involved the four aspects of Mitcham’s framework. Specifically, 79.9% of the students described technology as objects, 49.4% as activity, 44.5% as something that has to do with or requires knowledge, and only 4.9% as volition.

The other approach to studying students’ conceptions about technology is an inductive one, which means that themes gained are created based on students’ descriptions. This approach can include almost all participants’ descriptions and can help to explore the misconceptions. Burns (1992) used a modified PATT questionnaire and open-ended questions to investigate students’ conceptions about technology, and the grounded theory was used to encode students’ answers to the open-ended questions. The results revealed that students tended to consider technology as a recent phenomenon as well as artifacts, and they also connected technology to improving the quality of human life. Collier-Reed (2006) investigated South African pupils’ conceptions about technology and analyzed the data using the methodology of phenomenography as well, and the research revealed that students conceived of technology as artifacts, as an application of artifacts, as the process of artifacts progression, as using knowledge and skills to develop artifacts, and as a solution to a problem. The above research illuminates the approach to data analysis for this study.

A brief history of technological development in China

China has been an agricultural country since ancient times and has gradually developed an economy based on agricultural production and supplemented by animal husbandry. As an atheistic nation, the ancient Chinese valued the real world and life experience, and as a result, they attached importance to practicality (Wu, 2002). Ancient China (2070 B.C.–1840 A.D.) had many remarkable technological achievements, such as bronze smelting, iron technology, silk weaving, water engineering, pottery technology, printing technology, gunpowder, compass, paper making, etc. The level of its technological development was at the forefront of the world for a long time (McClellan & Dorn, 2007). The development of technology enjoyed a golden age for hundreds of years in the Song Dynasty (960 A.D.–1279 A.D.). Plenty of prominent technological inventions were generated during the Song Dynasty, such as the compass, gunpowder production technology, iron artillery, fire gun, movable type printing, well-salt production techniques, and rice cultivation techniques that greatly increased productivity, etc. In ancient China, science and technology were separated; there were all kinds of ‘sciences’, such as astronomy, astrology, mathematics, meteorology, cartography, seismology, Chinese medicine, etc. Scholars engaged in their scattered studies, but these scattered explorations have not unified into a kind of natural philosophy in the Greek sense (McClellan & Dorn, 2007). Besides, craftsmen and artisans who engaged in technical activities were generally illiterate and of low social status. Their technical activities did not need scientific theories but required their skills gained from experience, apprenticeship, and repeated practice. Therefore, the technological
A phenomenographic study of Chinese primary school students’ conceptions about technology in mainland China is considered ‘experiential technology’ (Jiang, 2009) or experience-based technologies (de Vries, 1996). However, the development of technology in ancient China emphasized practicality and was dependent on the feudal society, at the same time, the imperial competitive examinations (Ke Ju Kao Shi) and the bureaucratic system separated learned scholars from craftsmen and artisans, which aggravated the separation of science and technology. In addition, in the Ming (1368 A.D.–1644 A.D.) and Qing Dynasties (1636 A.D.–1912 A.D.), China implemented policies of secluding the country from the outside world, which further exacerbated the stagnation of technological development (McClellan & Dorn, 2007).

Ancient China’s domestic door was forced to open after the Opium War (1840 A.D.), and successive failures of wars compelled China to learn modern science and technology from western countries. Since then, the ‘experiential technology’ has gradually given way to ‘scientific technology’ which is guided by principles of science and dominated by machine production (Jiang, 2009, p.79).

The Westernization Movement (the 1860s–1900s) and the One-Hundred-Day Reform (1898 A.D.) in the late Qing Dynasty (1636 A.D.–1912 A.D.), the New Culture Movement (1915 A.D.–1923 A.D.), the May 4th Movement (1919 A.D.), a series of policies issued by the government of the Republic of China (1912–1949 A.D.), and the founding of the People’s Republic of China (1949 A.D.) all contributed to promoting the development of modern science and technology. All of these historical events made the Chinese people more and more realize that the western countries’ military and economic power and the backwardness of China are mainly due to China’s inferior technology, and in the eyes of Chinese people, the so-called ‘technology’ here refers to the western science. Therefore, owning to specific historical conditions and experiences, science in the majority of Chinese people’s minds is often equivalent to technology (Wu, 2012). Besides, the words ‘science’ and ‘technology’ are always used together as one combined word Keji (科技) in Chinese, which made this confusion deeply ingrained. Since 1978, China has started and continued to implement the reform and opening-up policy, which regards science and technology as productivity. Meanwhile, China advocates that ‘science and technology must be oriented towards economic construction, and economic construction must rely on science and technology (Documents Research Office of the CPC Central Committee, 1986, p.661). A series of plans to stimulate the development of science and technology has been carried out, including the National High-tech Research and Development Plan, the Torch Plan which aims at promoting the development and commercialization of high-tech and new technology research achievements (Documents Research Office of the CPC Central Committee, 1986), and so on. Thus far, China has made considerable achievements in the development of science and technology.

The above literature review shows that, in the past thirty years, by using different research methods, primary school students’ conceptions about technology have been researched in many different countries and regions, but little research has yet to be done on the pupils’ conceptions about technology in mainland China. And from the above literature review discussed and analyzed, it can be seen that the methods of data collection and data analysis of students’ conceptions should depend on the purpose of research. The purpose of this research is to investigate primary school students’ conceptions about technology in mainland China, including their understandings of the concepts of technology, the impact of technology on nature and human life, and the relationship between technology and science. We are neither concerned with the correctness of students’ conceptions, nor do we predefine any sub-themes before conducting the survey. Therefore, adopting phenomenography as the research methodology for this study—an inductive approach to analyzing the
collected data—is suitable for our purpose. The overarching research question for this research is: What conceptions about technology do pupils in mainland China hold? And this question is further divided into three sub-questions:

a. How do mainland China pupils define technology?
b. What are mainland China pupils’ conceptions of the impact of technology?
c. How do mainland China pupils view the relationship between science and technology?

**Contexts of primary school technology education in mainland China**

In primary schools (students aged 6–12) in mainland China, the national required curriculum for technology education (Grade 1-6) are information technology (IT) and labor-technical education. In practice, compared with labor-technical education, IT generally is given higher priority by schools, governments, and society at large since its perceived significance in national and international economic competitiveness is much more recognized (Ding, 2009). The labor-technical education derives from the demand for strengthening labor education and technical education beginning from the 1950s onwards, and there is no national curriculum standard yet for the subject (except for Shanghai, where there is such a standard for the subject) (Ding, 2009; Xu, 2004). So, schools enjoy the freedom to design their own school-based labor-technical courses. And since the late 1980s and early 1990s, many metropolitan cities such as Beijing and Shanghai have established labor-technical education centers which take on the tasks of labor-technical instruction (Ding, 2009). Taking the labor-technical education center in the Haidian district in Beijing as an example, the overall objective of its courses focuses on the development of students’ preliminary technological literacy, hands-on skills, use of tools, and simple mechanical skills (Su, 2013). Besides, the recent primary science curricular standard has included some content on technology and engineering education, which accounts for one-fourth of the entire course content, for the purpose of helping students acquire three main concepts: the human-made world, technological invention, and engineering design (Ministry of Education [MoE], 2017).

**Methodology and research methods**

The purpose of this research is to reveal pupils’ conceptions about technology in mainland China. Enlightened by the approach to data collection in the aforementioned literature review and considering the age of the research objects, conducting semi-structured interviews combined with photo/picture eliciting activities is chosen as the method to collect data for this research. Besides, for this study, any sub-themes was not predefined before conducting the research, so an inductive approach to analyzing the collected data was applied. And some research (e.g. Ankiewicz, 2019; Luckay & Collier-Reed, 2014) pointed out that phenomenography as a research approach should be adopted first to explore students’ conceptions about technology. For this reason, phenomenography as a research methodology was selected for this study.
Phenomenography is a research orientation designed to map and systematize the qualitatively different ways in which people experience, conceptualize, perceive, and understand various aspects of the world around them (Marton, 1981, 1986). Phenomenography adopts a ‘second-order’ perspective, that is, it makes a statement about peoples’ conceptions of reality, rather than a first-order perspective which makes a statement about reality (Marton, 1986). The research outcome of phenomenography is called ‘outcome space’ which consists of a set of hierarchical ‘categories of descriptions (conceptions)’ (Marton, 1981, p. 181). The categories of descriptions are relational, experiential, content-oriented, and descriptive (Marton, 1981).

Participants

Sixty-three primary school students aged 9–12 years old (from the 3rd, 4th, 5th, and 6th grades) from 11 primary schools participated in this research. Considering the differences in regional economic development may have an impact on students’ conceptions about technology, the participants were selected according to the socio-economic characteristics of the districts in which they resided, and they were sampled from rural, urban–rural, and urban areas separately. Accordingly, this research identified three groups of participants, namely the rural group, the urban-rural group, and the urban group. According to Trigwell (2000), a sample consisting of 15 to 20 participants in a phenomenographic research is typically considered to be large enough to reveal the possible conceptions of the researched group and allows a reasonable interpretation. Therefore, to ensure an adequate sample size and a balanced sample distribution among the three groups in this research, the number of participants in each group was controlled at around 20, and students’ ages and genders were also taken into consideration. The rural group consists of 20 participants from three rural primary schools in Hebei Province in North China, the urban-rural group includes 21 students from one urban-rural primary school in County Y of Zhejiang Province in the east coastal area, and the urban group comprises 22 participants from seven primary schools in City Q of Hebei province and Beijing. The participants were selected by their teachers as representatives of the class. Table 1 shows the basic information of the participants under study.

Data collection

Semi-structured and personal interviews conducted in Mandarin were employed to collect data in this research. Guided by phenomenography, the starting point and focus of the semi-structured and personal interviews were to explore the interviewees’ conceptions about technology. During the interviews, the interviewer is required to be mind-opened, to be interviewee-centered, to ‘suspend’ his /her own cultural values and expectations, and to focus on understanding and capturing the interviewees’ views and perceptions (Bourdieu, 1992). Because of the pandemic of COVID-19, all the interviews of this research (done by the first author) were conducted in a one-to-one webcam format, requiring the interviewer and interviewees to conduct a video conversation in a room free from outside interference, with the equipment working properly and the network running smoothly, and the interviewees to be interviewed independently, forbidden from seeking help or consulting relevant information during the interviews. In terms of the ethics of the interviews of this research, (a) interviewees were briefed on the purpose and flow of the interviews before they began, (b) during the interviews, efforts were made to focus on and not interrupt the interviewees’
talking arbitrarily, (c) interviewees were informed that they could interrupt the interviews at any time if they wished, (d) all the interviews were tape-recorded with the consent of the interviewees, and (e) interviewees were told that their names and the content of the conversation would be kept strictly confidential. Each interview lasted about thirty minutes. And the research concentrated on the interviewees' conceptions on (a) their understanding of the concept of technology, (b) what they thought of the effect of technology on nature and human life, and (c) their views of the relationship between technology and science. The procedure of the interview in each thematic area was as follows.

**Part I: Picture/photo eliciting activity and discussion**

The most successful phenomenographic research takes place in situations with a meaningful context within which the interviewer and interviewee can explore together (Säljö, 1997). In order to create such a context, and considering the fact that merely asking the question of ‘what is technology in your opinion’ at the beginning of the interview seems too abstract to answer (Constantinou et al., 2010; Säljö, 1997), especially for 9–12 years old pupils, the interviews of this research started with a picture/photo eliciting activity (Cappillo, 2005; Clark, 1999; Epstein et al., 2006; Leon, 2012). Using pictures/photos to elicit interviews, (a) is more visual and vivid, providing an entry point for students to think about what technology is, (b) is fun and interesting to the interviewees, (c) can help build trust and rapport between interviewer and interviewees (Cappillo, 2005), (d) is more likely to induce in-depth interviews, (e) can assist to create a meaningful context (Säljö, 1997), and (f) can provide rich information for researchers to analyze.

During the picture/photo eliciting activity, the participants were asked to watch 22 pictures/photos (see Appendix) carefully and categorized those that they considered as technology and those that were/were not. The pictures/photos for this research were selected based on Mitcham’s (1994) framework of technology: technology as objects (pictures No.1, No.2, No. 3, No. 4, No. 5, No. 8, No. 9, No. 11, No. 16, No. 17, No. 21, No. 22),
technology as activity (pictures No. 6, No. 7, No. 12, No. 13, No. 14, No. 15), and technology as knowledge (pictures No. 18, No. 19, No. 20). Since the dimension of ‘technology as volition’ is difficult to represent in suitable pictures/photos, the interviewees’ views of it were judged by asking the question ‘Do you think that the production and use of technology reflect the will of human beings?’ Simultaneously, de Vries’ (1996) classification of different types of technology, i.e., experience-based technologies (pictures No. 2, No. 3, No. 4, No. 6, No. 7, No. 8, No. 13, No. 17), macrotechnologies (pictures No. 5, No. 11, No. 12) and microtechnologies (pictures No. 1, No. 9, No. 14, No. 15, No. 16, No. 21, No. 22) was also considered as a criterion to further select the pictures/photos of ‘technology as objects’ and ‘technology as activity’. Solomonidou and Tassios’s (2007) study also provided some references for the picture/photo selection of this research, some of the pictures in our study are similar to theirs (pictures No. 5, No. 6, No. 8, No. 9, No. 10, No. 11, No. 12, No. 15, No. 21, No. 22), while some are different (pictures No. 1, No. 2, No. 3, No. 4, No. 7, No. 13, No. 14, No. 16, No. 17, No. 18, No. 19, No. 20). And these differences in the picture/photo selection are mainly due to factors including the cultural background (pictures No. 2, No. 7, No. 13), Mitcham’s (1994) framework of technology (pictures No. 18, No. 19, No. 20), and de Vries’ (1996) classification of different types of technology (pictures No. 1, No. 2, No. 3, No. 4, No. 16, No. 17).

After the picture/photo eliciting activity, interviewees were asked to discuss the following questions with the interviewer: ‘Which picture(s) do you think is/are related to technology?’, ‘Which picture(s) do you think has/have nothing to do with technology?’, ‘Why do you make this judgment?’, ‘What are your criteria to decide whether a picture is a technology or not?’. This part of the interview lasted about 15 min.

**Part II: Further questions of conceptions about technology**

After the first part of the interview, some concrete images of technology have already existed in the interviewees’ minds, so it would become easier to discuss further questions about technology with them. In this part, the participants were asked to define technology and answer the following questions: ‘After watching so many pictures, can you define technology, then what is it?’, ‘Do you think that the production and use of technology reflect the will of human beings?’, ‘In your opinion, what impact has technology had on human lives?’, ‘What impact has technology had on nature?’, ‘How do you think of the relationship between technology and science?’, ‘Are they the same or not?’, If they are different, then what are the differences?’ This part of the interview lasted about 15 min.

During the interview, the sequence of posing these questions would be adjusted according to the specifics of the interview, and follow-up questions would be asked if needed. Interviewees were reminded that they did not have to think about the correctness of their answers, and the number of their choice of pictures has no limitation. All conversations of the interviews have been tape-recorded.

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1 Picture No.10 is a natural plant, not technology. Some of these photos can be classified into different categories, e.g., mobile phone (picture No.5) and computer (picture No.21) can be seen as microtechnology which refer to the device, and can be seen as microtechnology which refers to the ways of the devices’ signal transmission. In this research, they have been classified as microtechnology, and represent the devices only.
Data analysis

Firstly, the tape-recording was transcribed into text verbatim. And each interviewee was numbered, with the rural group denoted by N, the urban-rural group denoted by X, and the urban group denoted by C. The order of interviewees was expressed in Arabic numerals: male participants were denoted by M and their female counterparts by F. For example, N-1-M indicates the male interviewee No. 1 in the rural group.

Secondly, the transcripts were read repeatedly and carefully, and the relevant fragments that the interviewees used to describe what technology was or to judge whether a picture was related to technology or not were extracted and put together. Then, the researchers focused on the meaning embedded in the fragments, and each possible ‘meaning unit’ which represents the core meaning of relevant fragments of students’ conceptions about technology was identified. Once all the meaning units of students’ experiences have been identified across all the transcripts, the interviews have been deconstructed. Then, these meaning units were put together to form a ‘pool of meanings’ (Marton, 1986, p. 43) of the data. Each fragment had two contexts, one was the original interview from which it was taken, the other was the ‘pool of meaning’ to which it belonged (Marton, 1986, p. 43). Since the same expression of different fragments may represent different meanings in different contexts (Sandbergh, 1997), the interpretation of the fragments must be made between these two contexts iteratively until meaning units were identified and final categories were formed. At last, these categories of description were organized logically to constitute the outcome space of this research. Typically, the categories of descriptions in the outcome space for phenomenographic research are hierarchical, with some conceptions at lower levels, while some at higher levels. In this study, the first-level indicators of the outcome space were arranged according to the attributes of technology, the production, the operation/use, and the function of technology. And the second-level indicators of the outcome space were arranged based on their complexity, with the less complex categories of conceptions arranged in front of the more complicated ones.

Thirdly, as regards the scrutiny of the outcome space, since the validation of the results of the research can be seen as a social construction of knowledge (Mishler, 1990), the approach of communicative validity is applied to test the validation of the outcome space in a dialogue. Specifically, the two authors of this research analyzed the data and constituted their categories and outcome space separately, and then discussed and modified them together to reach a consensus on the discrepant content to reach a communicative validity (Booth, 1992; Kvale, 1996).

Results

The outcome space of primary school students’ understandings of the concept of technology

The outcome space of students’ answers to the first question of this study consists of four qualitatively different categories of description. Each category of description reveals a unique way of how students define technology. The first-level indicators of the outcome space of students’ understandings of the concept of technology include four categories: the attributes of technology, the production of technology, the operation and use of technology,
A phenomenographic study of Chinese primary school students’ understandings of technology and the function of technology. Each of the first-level indicators includes several secondary level indicators, with some of them further being divided into tertiary level indicators. (see Fig. 1) Each level indicator has been explained by providing one or two typical examples of pupils’ talk fragments. These selected fragments can be seen as the representatives of each category.

A total of forty-five (71% of the total) students talked about all the four categories of the first-level indicator in the interviews, fourteen (23%) students about three dimensions, two (3%) students about two categories, and two (3%) students about one category, respectively. It may seem that most students in the sample view technology from the same perspective, but data analysis revealed that each student has different descriptions of technology, and the reason lies in the secondary and tertiary level indicators. Each interviewee’s understanding of the concept of technology is a different combination of secondary and tertiary level indicators. Even if some interviewees view technology from the same category, the combination of secondary and tertiary level indicators of their conceptions is not identical. All levels of indicators will be described and analyzed below, and each indicator is attached with some students’ statements that serve as evidence to support the indicator. The details are as follows.

The attributes of technology

There are fifty-two (83%) students who defined technology from the attributes of technology itself. Specifically, five secondary level indicators are included, namely,
technology is something that looks advanced, beautiful, and interesting; technology is the most advanced product in its era; technology requires electricity; technology is high-tech; and technology refers to information technology.

**Technology is something that looks advanced, beautiful, and interesting** There are six (10%) students who consider that technology is something that looked advanced, beautiful, and interesting. The students who hold this kind of conception have not moved from perceptual cognition to rational cognition towards technology, and each interviewee had different criteria for judging ‘advanced’, ‘beautiful’, and ‘interesting’ due to the differences in their own life experiences. The students’ statements on this conception are as follows.

X-15-M: Technology is something that looks very advanced. For example, an artificial satellite looks advanced, it is technology.

C-2-F: A technical product looks more aesthetically pleasing, e.g. a washboard is made of wood that is not so aesthetically pleasing, so it is not technology. Washing machines look more advanced and aesthetically pleasing, so it is technology.

X-13-M: I think that ancient wine glasses look odd and bulky, it is not technology. A dandelion is a technology because it looks very interesting.

**Technology is the most advanced products in the era** Twenty-eight (44%) students consider technology is the most advanced product in the era in which it is used. In other words, products that they view as more advanced compared with their similar functional counterparts are considered technologies. Below are student statements regarding this conception.

N-12-M: Compared with previous similar things, technology is more advanced. For example, the washing machine is a technology while the washboard is not, since it is the invention of washing machines that made washboards eliminated. The mobile phone has brought so much convenience and benefit to people in the new age, so it is technology. While the old-fashioned telephone with a wire is not technology since it has been phased out by the new age, it is rare, and it doesn’t belong to technology anymore.

X-20-F: The old-fashioned telephone is technology compared with what came before it, and it is not technology if compared with what comes now. So, technology always refers to the most advanced products of its era.

**Technology requires electricity** Whether electricity is required or not is an important criterion for some pupils to define technology. And this is consistent with the findings of many international surveys of students’ or adults’ concepts of technology, in which many respondents equated technology with electronics, especially modern electronics (de Vries, 2016; Garmire et al., 2006; Kőycű, 2015). In this research, thirty-nine (62%) students hold this view and consider that technology needs to be powered by electricity. Here are the students’ statements about this category.

N-1-M: Roads are technologies because there is a lot of electricity on the road, like street lights. Building cables is technology because it requires electricity. Mobile phones, computers, watches, and stereos all require electricity, so they are technologies.

X-3-F: An electronic toothbrush is a technology while an ordinary one is not, since the former needs electricity and the latter does not.

**Technology refers to high-tech** Twelve (19%) interviewees equate technology with high-tech, and they consider that technology is advanced in that it has a significant impact
on the development and progress of human society. The following selected fragments are samples of the perceptions of the students.

C-7-M: The magnetically levitated train that I saw in a science and technology museum is a technology, and the cars that can run in the air that I saw in this museum are also a technology. So in my opinion, technology means these high-tech things.

X-10-M: Technology is high tech, for example, a convertible sports car is high-tech, so we can call it a technology.

**Technology refers to information technology** Seven (11%) students consider technology as information technology. Among them, four students (6%) equate technology with the application of a wireless network. And three (4%) students consider technology as the writing of computer programs. For example, some of the students are of such opinions as:

C-2-F: Technology is the application of wireless networks. For example, with the help of wireless networks, people can use mobile phones to talk remotely, so we can call them a technology. While those old-fashioned telephones are not connected by wireless networks but by long wires, so they are not technology.

C-8-F: The ancient cups are not technology because there are no programs in them. I think that programs and technology are interconnected, and programs refer to computer programming.

**The production of technology**

A majority of (sixty-one, or 97%) students define technology from the dimension of technology production. Specifically, three secondary level indicators are included: technology is man-made rather than naturally generated, technology is difficult to produce and maintain, technology is produced either in ancient or in modern times. Each secondary level indicator contains several tertiary level indicators.

**Technology is man-made rather than naturally generated** Students who hold this view argue that technology is not the product of nature but produced artificially, it reflects human intelligence. There are three different perspectives on the mode of artificial production, resulting in three tertiary level indicators.

Technology is machine-made rather than hand-made

This view is held by twenty-four interviewees (38%) who believe that technology is produced by using machines rather than by hand. The following are samples of what students perceive technology to be.

N-11-F: Technology is not hand-made but machine-made. For example, if a road was made by laying some bricks by hand, it would not be technology. If it was paved by machines, then it would be technology.

X-5-F: What is made by hand is not technology, while what is made by a machine is technology. For example, homemade baskets which are made purely by hand are not technologies, but those made by a machine are technologies.

Technology is hand-made rather than machine-made

Two (3%) students hold this view, but contrary to the previous view that technology is machine-made rather than hand-made, these students argue that technology is hand-made rather than machine-made. If a product was made by machines, it would not be technology.
X-21-F: It is complicated to make something by hand, so hand-made things can be called technology. While those produced by machines are easy, so they are not technologies.

C-12-F: Technology is something made manually. Those that are mass-produced by machines are not technologies. Because manual production requires skills and methods, which are the embodiment of technology.

Technology is both hand-made and machine-made

Thirty-six (57%) students hold this view. They believe that as long as an object is human-made rather than naturally produced, whether it is machine-made or hand-made, it is a technology. The students’ statements of this conception are as follows.

C-7-F: I think clothes produced by machines are a kind of technology, and it is technology as well when produced by hands. Since the machine itself is technology, producing clothes by a machine is certainly technology. And hand-made clothes are also a kind of technology since if you did not own the clothes making technique, you could not make the clothes well.

N-1-M: Technology is made by humans, while plants are the products of nature, so plants are not technologies. As long as something is made by human beings, no matter in what way, it is technology.

Technology is difficult to produce and maintain

Students who hold this conception believe that technology is complicated since it is difficult to produce and maintain. Those that are easily made and maintained are not technologies. This secondary level indicator can be further divided into three tertiary level sub-indicators.

The materials used in technology are complex

Fourteen (22%) students define technology from the dimension of the complexity of materials used. In their opinion, the products made of common, cheap, and easily available materials are not technologies, such as cotton, wood, plastics, glasses, etc. On the contrary, the products made of materials with higher practical value or difficult to obtain or uncommon in daily life are technologies, such as minerals, petroleum, electricity, metals, etc.

X-5-F: The clothes made of nanomaterials which are waterproof and dustproof are technology, while clothes made of cotton are not technology since the material used is very common in our daily life.

N-4-M: Satellites are technologies since adequate minerals are needed in the process of their production. And they also need electricity and energy, such as oil. While cups are made of glass or plastics, they are not technologies.

The design and manufacturing process of technology is complex

A majority of (fifty-three, or 84%) students consider that technology is complex in the design and manufacturing process. The design of technology is complex since the process involves a large amount of professional knowledge and skills and takes plenty of time. Besides, designers are required to own rich imaginations. The fact that the manufacture of technology is complex means that the production process involves complex steps, requires manual operation capability and needs manpower resources, material resources, and financial resources. The students’ statements of this conception are as follows:

N-10-M: technology is hard to produce. Cups are not technology because they are easy to make. A highway is a technology since the road is very long, there must be a lot of people working together to make it. A car is also technology because it is very difficult to make, it must take more than ten months, and its design paper is not easy to draw. It
requires rich imagination, knowledge and brainpower to draw the design paper. A computer is also technology because it is not easy to make, it needs long-term design and production.

C-20-F: Bridges are technologies because, before the construction, they have to be designed well, and the building process takes a long time, we have to think about a lot of things, so the design is very complex. A highway is also a kind of technology because its production is very difficult, it requires manual operation skills to get the earth flat, to draw lines, and to make sure the distances are the same. An ordinary road is not technology because it is a matter of bringing in sand and soil and laying it on the ground.

The maintenance of technology is difficult

Thirteen (21%) students define technology from the perspective of whether its maintenance is difficult or not. They consider that technology is difficult to maintain, which is a typical feature of technology. Specifically, it means that the maintenance of technological products requires professional knowledge, or the maintenance process is dangerous, or it costs vast human, material, and financial resources. Here are some of the students’ statements of this conception, as follows:

X-15-M: Generally speaking, technology is difficult to maintain. For example, repairing cables is a technology\(^2\) since it requires knowledge of cables. And it is dangerous to repair cables since the worker who repairs them is possible to get an electric shock.

C-1-F: In my opinion, repairing cables is technology, because cables are very complicated, accordingly, repairing cables becomes very complicated, too. Many techniques will be used, such as how to connect the wires well and how to prevent rain. Repairing cars is also a technology\(^3\) because cars are very complicated. I used to repair a car with my father. I do not understand what he said. Since my uncle is a car designer, I have the opportunity to see many design drawings of cars. From these drawings, it occurs to me that the structure of cars is very complex. Firstly, I have to understand the internal structure of a car very well, then I have to have the ability to fix it well. This is not easy.

**Technology is produced in ancient or modern times** Twenty-three (37%) students define technology from the historical perspective of technological generation, but they have different opinions on its generation time, which can be divided into two tertiary level indicators.

Technology is not generated in ancient times, but in modern times

This view is held by eleven (17%) students who use modernity as a criterion to define technology. They believe that technology is the product of modern society and that there is no technology in ancient times. The students’ statements of this conception are as follows.

N-6-F: Technology is not invented in ancient times but in modern times. There is no technology in ancient times. For example, satellites are technologies, they are only invented in modern times. It is something made with the help of science, and only when it is made with the help of science, can we name it technology.

X-5-F: The products made in ancient times are very old, so they are not technologies. For example, making an ancient wine glass takes a long time and dedication, it is artistic, but it is very old, so it is not technology. A washboard is something invented in ancient times, so it is not technology either. In contrast, the washing machine is a modern invention, so it is a technology.

\(^2\) &\(^3\) ‘Technique’ is the proper word here, but since students cannot distinguish between ‘technology’ and ‘technique’, they used the word ‘technology’. 

\(^3\) ‘Technique’ is the proper word here, but since students cannot distinguish between ‘technology’ and ‘technique’, they used the word ‘technology’. 
Technology was invented in ancient times while it still exists in modern times.

Twelve (19%) students hold this view and believe that technology exists in both ancient and modern times. Here are some of the conceptions of the students:

C-3-M: There were technologies in ancient times, they just were not as developed as modern technologies. The stones that people polished in ancient times were considered technology. I have seen documentaries on television where people in ancient times polished stones to a sharp point and it was technology. In ancient times, people made clothes with sheepskins and tiger skins. Those clothes are uglier compared with modern clothes, but they are also technologies. Modern clothes are warm, cool, and made of fewer materials, so they are also technologies. It took a long time to evolve from ancient clothes made of animal skins to modern ones, and it has something to do with people’s thinking ability.

X-10-M: Technology exists not only in modern times but also in ancient times, such as pottery production, which is a traditional technique in our country.

The operation and use of technology

Sixty-one (97%) students define technology from the perspective of its operation and use, which involves the difficulty of its operation, the way to master it, and its influence on nature. Specifically, four secondary level indicators are included: technology is arduous physical labor, technology is to operate machines that are intelligent and simple, technology is some kind of skill that requires learning to master, and technology is operated and used in a way that will not harm the natural environment and human health.

Technology is arduous physical labor

Five (8%) students consider that technology is arduous physical labor. Here are two examples of students’ statements:

N-18-M: Technology is hard labor. Washing clothes with a washboard is arduous, and it was used to be technology in ancient times. While washing clothes with a washing machine is not technology since it is not arduous labor for people. Farming is technology since it is hard work, I used to see my family members do farm work, they had to work very hard.

X-2-M: Technology is hard work that shows how diligent people are. For example, farmers work very hard to grow rice so that the rice can taste good, while the rice-growing with a nutrient solution is not tasty that well compared with farmers’ hardworking, so the farmers’ own hardworking is technology while the rice-growing by using a nutrient solution is not. Washing clothes with a washboard is also technology that shows people’s hardworking, washing clothes with a washing machine is not technology, because it is not hard working.

Technology is to operate machines that are intelligent and simple

Fouty-eight (76%) students believe that the operation and use of technology are achieved by using machines, which are intelligent and simple compared to manual labor. On the contrary, working by hand is backward and cumbersome, so it is not technology. The students’ statements of this perception are illustrated as follows.

X-7-M: Technology is operated by automatic machines, and it is not manual labor. For example, the ancient drinking cups are very ordinary and old, they are not technology. If they were equipped with a robot arm so that it could pour water into people’s mouths automatically, then they are technologies. Clothes are not technologies either, but clothes that can gather heat automatically when it is cold and can dissipate heat when it is hot, then the clothes can be called technology.
C-11-F: Technology relies on machines, so it is automatic, simple, and easy to operate. For example, an electric toothbrush is a technology since it has a small machine in it that can brush your teeth automatically, so it is a technology. An ordinary toothbrush that requires manual brushing is not technology. Ancient drinking cups are not technologies, but if you added a device to them and turn them into cups that could automatically turn cold water into hot water, then they would be technologies. A highway is not a technology, but if there was an electronic traffic policeman on the highway who could direct the traffic automatically, then it would be technology.

**Technology is some kind of skills or techniques that require learning to master** Fouty (63%) students consider technology as some kind of skills and techniques that need to be learned to master. Below are some illustrations of students’ accounts of this conception.

C-20-F: Technology is some kind of craft or skill that requires special learning and practice to master. For example, making pottery is a skill because it requires learning, taking a shape, getting them even, and baking, which is very hard to make. Weaving baskets by hand is also a skill since it requires techniques to connect the handles with baskets and to ensure the things in the baskets will not leak.

N-4-M: Technology can only be mastered by learning. Making potteries is a skill, when I was a child, I watched a cartoon named *Peppa Pig*. In the cartoon, Peppa Pig made potteries but she messed up in that she did not know how to make them well, so technology requires relevant knowledge and skills.

**The operation and use of technology will not harm the natural environment and human health** Eleven (17%) students consider that the operation and use of technology will not endanger human health and the natural environment. And if it harmed the natural environment and human health, it could not be called technology. Here are some of the perceptions of the students.

X-2-M: Technology is something that does not easily cause injury or death. I don’t think the glass is a technology because when it is broken, it may stab or hurt someone. Roads are not technologies, because cars driving on them may cause accidents or casualties. Using mobile phones and computers is not technology, because if people always fix their eyes on mobile phones or play on computers, they will harm their eyes. If people always typed on computers or mobile phones, they would forget how to write by hand.

C-3-M: I don’t think repairing cables is technology because it’s not safe for workers to repair them by hand. Wood baskets are not technologies either. They are made of wood. Cutting down wood may likely cause soil erosion and natural disasters, which is bad for the environment of the earth, so a wood basket is not a technology. Technology does not harm human beings or destroy the natural environment. If it harmed, it would not be technology.

**The function of technology**

Fifty-three (84%) students define technology from the functional dimension of technology. They believe that technology could provide convenience for human life and benefit mankind. This dimension can be further divided into two secondary level indicators: technology can help improve human life, technology should have multiple functions, and technology can inspire the subsequent invention of artifacts.
Technology can help improve human life  Fifty-one (81%) students believe that technology has brought convenience to human life and can help improve human life. Below are some students' statements on this idea:

C-19-M: Technology makes our lives more convenient and easier. For example, in the past, the toothbrush was made of animal fur, which could clean teeth deeply. Electric toothbrushes are more convenient for our life. Tool kits are also technologies because they bring convenience to our life.

X-15-M: Mobile phones and computers make it easier for us to collect and process information. So, they are technologies. Design drawings of bridges and cars are technologies too because they can help us build bridges and manufacture cars. Refrigerators are technologies because they make it easy to store things. I think technology can always bring us convenience in one way or another.

Technology should have multiple functions  Thirty (48%) students consider that technology should have multiple functions, and if it had only one function, then it would not be technology. Some students talked about this conception as follows:

C-13-F: Technology has many functions. Mobile phones and computers are both technologies because they have many functions, such as uploading files, communicating, and conserving information. A man-made satellite has many functions in many aspects, so it is technology.

C-10-F: Technology should have many functions. If it had only one function, it would not be a technology. For example, glass is not a technology, because it is just an ordinary device and can only be used to drink water or wine. If it became an intelligent glass and had more functions, it would be a technology. T-shirts are not technologies. If they became protective clothing with many functions, they would be technologies, just like the protective clothing in science fiction movies.

Technology can inspire the subsequent invention of artifacts  Two (3%) students consider that technology can inspire the subsequent inventions of artifacts. The students' statements of this perception are as follows:

C-15-F: I think technology should be able to inspire the invention of other things. For example, washing clothes with a washboard is technology, because it inspires the invention of washing machines. Farming with a hoe is also technology because it inspires the invention of farming machines later on.

C-19-M: The new things developed based on the wisdom of ancient people are technologies, because ancient people invented washboards, then washing machines were invented based on them. Farming with a hoe is a technology since it shows the wisdom of ancient people. Machines developed from the wisdom of ancient people are also technologies.

The outcome space of primary school students’ understandings of the impact of technology

This research also reveals that students have two fundamentally different conceptions about the impact of technology, i.e., technology has both positive and negative effects, and technology has only positive effects but no negative ones. (see Fig. 2).
Technology has both positive and negative effects

Fifty-five (87%) students consider that technology is a double-edged sword. On the one hand, it brings convenience to human life, alleviate people’s physical labor, and makes people live happier; on the other hand, it also brings negative effects such as polluting the environment, harming human physical and mental health, hindering interpersonal communication, making people acquire bad living habits easily. Some students even think that machines may dominate human beings in the future. The students’ statements of this conception are as follows:

N-10-M: I think technology can bring bad as well as good effects. The good side is, for example, that technology makes us live a happy life, while the bad side is that, I think, some robots may provoke wars just like what I ever saw in some movies, so I think they would take revenge on human beings.

X-20-F: The impact of technology can be both good and bad. For example, an air conditioner can blow cold air in summer and warm air in winter. The bad side is that the use of air conditioning can raise the earth’s temperature. Besides, the exhaust fumes from cars can pollute the air.

Technology has only positive effects but no negative ones

Eight (13%) students consider that the influence of technology is positive and there is no negative influence. They believe that technology has enabled humans to lead a happy life and has brought convenience to human beings. Some students stated their conceptions as follows:

X-3-M: I think the impact of technology is good, for example, a light bulb can help illuminate and bring benefit to our life. Ancient people drilling wood to make fire is a kind of technology so that people can eat cooked food which helps reduce the risk of disease. Technology has no bad effect.

N-8-M: The impact of technology is good. For example, electric rice cookers can heat automatically, which is very convenient. I don’t think technology has any bad effects.

The outcome space of primary school students’ understandings of the relationship between science and technology

This research reveals that students have five different conceptions of the relationship between technology and science, i.e., there is no difference between technology and
science, there is an intersection between technology and science, technology includes science or science includes technology, technology and science are different, and the relationship between technology and science is unclear. (see Fig. 3).

**Fig. 3** The relationship between technology and science

There is no difference between technology and science

Twenty-three (37%) students consider that the meaning of science and technology represents the same thing though they have different names (see Fig. 4). Science and technology serve the same purpose, both bringing benefits to mankind. Here are the students’ statements of this conception:

N-6-F: Science and technology mean the same thing, which is evident from the word ‘KeJi’ (a Chinese word, which is the abbreviation of science and technology in Chinese). These two Chinese characters are often mixed-used together. For example, a satellite is a technology, and I didn’t know how a satellite was made before. Later, I watched TV and found that the satellite is such a great science.

X-6-F: Science and technology are almost the same. They are all about electronic things that are beneficial to human life.

C-4-M: Science and technology are the same. Scientists and technologists do the same work.
There is an intersection between technology and science

Thirteen (21%) students consider that science and technology have differences as well as similarities, so there is an intersection between them (see Fig. 5). The students expressed their opinions as follows:

X-10-M: There are some similarities between science and technology, such as circuits. But there are also some differences between them. Science studies plants and animals which have nothing to do with technology.

C-8-F: Science and technology have something in common, but not identical. Science studies animals and plants, which are not technology. The profound content of machines studied by science is technology.

Technology encompasses science or vice versa

Five (8%) students consider that the relationship between technology and science is one within another. Specifically, this dimension can be further divided into two secondary level indicators.

Science encompasses technology  Three (5%) students believe that science is a superordinate concept to technology, that the scope of science is larger than technology, and that science encompasses technology (see Fig. 6). Here are two examples of the students’ statements of this conception.

C-19-M: Technology belongs to science, but science does not belong to technology. Technology needs science to serve people. Science has a deeper meaning and a more comprehensive connotation compared with technology.

X-7-M: Science includes technology. It is science that leads to technology, and technology is part of science. People use scientific methods and means to create some convenient things, which are technologies.

Technology encompasses science  On the other hand, two (3%) students believe that technology is a superordinate concept to science, that technology has a larger scope than sci-
ence, and that technology encompasses science (see Fig. 7). The students’ expressions of this conception are illustrated as follows.

X-9-F: Science is part of technology, and technology has a much larger scope. Science is one of those impressive things in life. Technology is to make something or to fix something.

C-14-F: Science is making discoveries within the scope of technology. Technology is broader than science.

Technology and science are different

There are 19 students (30%) who consider that technology and science are different. Specifically, there are three secondary level indicators to illustrate these differences: science and technology are different in that they do not influence each other; science and technology are different in that technology is the application of science; and science and technology are different, but they influence each other.

Science and technology are different as they do not influence each other

Twelve (19%) students argue that science and technology are not the same and that they do not influence each other (see Fig. 8). The following are the students’ statements of this perception.

C-18-F: Science and technology are not the same. Science refers to a very wide range of things, for example, epidemics need scientific prevention. A pair of protective glasses that can protect people from being blinded by breathing air is a kind of technology. It can be seen that science and technology have nothing to do with each other.

X-3-F: Science and technology are not the same. Science is about [an exploration of] natural phenomena. There is no special relationship between technology and science. Technology is man-made, but scientific [discoveries] of natural phenomena are not man-made.

Science and technology are different, and technology is the application of science

Six (10%) students consider that science and technology are different, and technology is the application of science (see Fig. 9). Here are the students’ expressions of this idea.
N-5-F: Science and technology are not the same. Science is to understand the unknown in the world. Technology is about making things, but the connection between them is that technology is to make complex things that scientists want. For example, it’s very complicated to make satellites. Scientists have come up with the idea of satellites and technologists come up with drawings and make them.

C-9-M: Science and technology are not the same. Science just teaches us what is more scientific. Technology makes us know the change of times. Scientists and technologists are not the same. Scientists study science. There is a lot we don’t know about science. Technology is the realization of what scientists think.

**Science and technology are different, but they interact with each other** One (2%) student considers that science and technology are completely different, but they interact with each other (see Fig. 10). The student’s statement of this conception is as follow:

C-17-M: Science and technology are not the same. Science involves a lot of artificial intelligence, astronomy, and so on, it has a wide range. Technology contains less content than science. Technology is man-made. Science leads to technological progress and technology updates science, so they have interacted.

**Some students are unclear about the relationship between technology and science**

Four (6%) students said they were unclear about the relationship between science and technology. For example, one student expressed his idea of this conception as follows:

X-2-M: I don’t know the relationship between technology and science.

**The limitation of the research**

Firstly, under the guidance of phenomenography, this research purposefully sampled the rural, rural–urban, and urban groups separately to pursue a diversity of the pupils. As China is a big country, the level of economic development between different regions is divergent. The three selected groups in this research are from different provinces, so they may to a certain degree reflect the typical differences among rural, rural–urban, and urban settings. Meanwhile, although the sample size of this study is adequate for phenomenographic research, the large population of China (around 1.4 billion) makes it impossible for
this research to represent all the pupils’ conceptions about technology in mainland China. While considering the main purpose of this study is to reveal and understand pupils’ various conceptions about technology in mainland China, the results of this research can provide a reference for conducting more quantitative research in the future.

Secondly, students’ attitude toward technology has been studied internationally in the past thirty years. Students’ attitude toward technology consists of the cognitive component (their concepts of technology), the affective component, and the behavioral component (activities) (Ankiewicz, 2019; Ankiewicz et al., 2001; Svenningsson et al, 2021), and revealing students’ concepts of technology is an indispensable part to measure their attitude of technology (Ankiewicz, 2018). But given that the primary pupils’ conceptions about technology in mainland China is a research gap and the restriction of space, this research specifically aims at revealing the cognitive aspect, i.e., the students’ conceptions about the nature of technology, and in the future, more research could be done in primary pupils’ affective of technology and behavioral component.

Thirdly, the possible gender bias has not been taken into consideration during the photo selection, for example, the people look like men in pictures No.12 and No. 14. Besides, the possible bias towards artifacts has not been taken into account since many pictures do not provide contexts, or those that provide contexts are often not pictures but drawings. More attention should be paid to the possible gender bias and artifact bias during the picture/photo selection in further studies in the future.

Discussion

The following section is mainly structured around two major themes. One is concerned about the general findings of primary school students’ conceptions about technology, and the other is the analysis of possible influential factors regarding primary students’ conceptions about technology. For the general findings, on the one hand, pupils can define technology from diverse perspectives, and on the other hand, they lack a comprehensive and rational concept of technology and a proper understanding of the relationship between technology and science. And the possible influential factors discussed include the characteristics of technology, the cultural and historical backgrounds of China, students’ life experiences, and inadequate school technology education.

Comments on general findings of primary school students’ conceptions about technology

The following three points stand out from the findings of this research, and they are worth discussing in detail, as they reflect the state of primary students’ conceptions about technology in mainland China today.

Primary school students can define technology from diverse perspectives

As found out above, pupils in mainland China define technology from broad and diverse perspectives. They describe technology from the attributes of technology, the way of its production, the complexity of technological product making and maintenance, the timing technologies are created, the operation and uses of technology, and the functions of
technology. They can explain their conceptions in detail and can provide some contrasting examples to support their opinions.

Some of their descriptions are reasonable, for example, a huge majority of students (97%) in this research consider that technology is man-made rather than naturally produced. This conception can be found in the literature by technological philosophers (e.g. Arthur, 2009; Jiang, 2009; Mitcham, 1994; Wu, 2008). Some of the pupils (19%) consider that technology was created in ancient times and still exist in modern times, and this conception can find its reference in a great number of history of technology and philosophy of technology writings (e.g. Basalla, 2010; Briggs & Burke 2013; Hu, 2020; Stiegler, 2019). Besides, most of the students (87%) can recognize that technology is a double-edged sword which can find its trace in a lot of philosophy of technology literature (e.g., Feenberg, 1991; Jiang, 2009; Wu, 2008), and they can properly understand the benefits and harms it brings to human life and nature. However, some problematic issues emerged in their conceptions about technology that need to be addressed.

**Primary school students lack a comprehensive and rational concept of technology**

First of all, data analysis reveals that many pupils in our sample lack a comprehensive, systematic, and rational concept of technology. This emerges from the following specific aspects:

Primary school students usually understand technology from their perceptual awareness and tend to define technology from its modern characteristics. For example, some students conceive technology as the most advanced products or activities, as high-tech, as something that requires electricity, and/or as information technology. More notably, the students who define technology from its modern features tend to consider the more advanced artifacts as technology while those less advanced as not, though both of which have similar functions. This indicates that although a majority of pupils can recognize that technology is man-made rather than nature-made, they still own a vague conception of the nature of technology. Students lack the awareness that technology is a human invention no matter it is advanced or not (Arthur, 2009; de Vries, 2016; Hu, 2020; Ihde, 1990; ITEEA & CTETE 2020; Jiang, 2009), which is one of the features of technology and which distinguishes technology from the natural world. Besides, this study reveals that some students use easiness as the standard to define technology, while some claim difficulty as the criterion, which means that both cohorts of students lack understanding of the nature of technology. Meanwhile, some students considered that ‘technology should have many functions, and if it had only one function, it would not be technology’. It is apparent that these students do not have a rational concept of technology, since they do not understand that technology is the modification of nature to satisfy human wants and needs (Arthur, 2009; ITEEA & CTETE 2020; Mitcham, 1994; Wu, 2008), regardless of how many functions a technological artifact owns.

Compared with Mitcham’s (1994) framework of technology, it can be found in this research that all of the four aspects of the framework have been covered in our sample, but with different propositions; among the four versions of technology, students refer to technology as objects most frequently. For example, 57 (90%) students consider mobile phones as technology, while only 38 students (60%) regard using mobile phones as technology. All of the students (100%) consider automobiles as technology, while only 40 (67%) students consider automobile design as technology. In other words, students are more likely to consider technology as an object instead of as an activity, system, as well as knowledge.
In addition, to investigate whether students consider technology as a volition or not, they were asked to answer the question ‘Do you think the production and use of technology reflect human’s will?’, and the results show that 40 students (67%) agree with this idea. Svenningsson’s (2019) investigation of 164 students’ concepts of technology had similar results. In his research, he compared students’ descriptions of technology with Mitcham’s framework of technology, and the results indicated that nearly 80% of students conceive technology as objects, ranking first of all the four versions, and nearly 50% of students considered technology as knowledge and activities, respectively. Different from Svenningsson’s finding that only a few (4.9%) students regarded technology as volition, which is also indicated in other studies (DiGironimo, 2011; Wu & Ding, 2020). This research reveals that 67% of students consider technology as volition. The reason for this difference may be that Svenningsson and other researchers only looked for students’ conceptions of considering technology as volition from the interview dialogues, whereas this research investigated students’ views by asking related questions directly, thus making students reflect more on this aspect and give their opinions. It is also worth noting that there is a contradiction in the findings of this research, i.e., on the one hand, most of the pupils regard technology as volition; on the other hand, students lack the awareness that technology is a human invention no matter the number of its functions, advancement, and complexity. This contradiction indicates pupils’ vague and confused conceptions of what technology is.

Compared with de Vries’s (1996) classification of technology, it is also found in this research that most students regard technology as macrotechnologies and/or microtechnologies, with only a few students recognizing experience-based technologies. For example, 53(84%) students consider electronic toothbrushes (microtechnology) as technology, while only 6 (10%) students regard an ordinary toothbrush (experience-based technology) as technology. All students (100%) consider that washing clothes with a washing machine (microtechnology) is a technological activity, while only 11 (17%) students regard washing clothes with a washboard (experience-based technology) as. Similarly, a survey of 3500 pupils’ technological literacy undertaken by Saskatchewan Education in Canada in 2001 found that almost all of the students considered that computers and airplanes were technologies, while only one-third of students thought that old stone axes were technologies (Saskatchewan Education, 2001, p.25). Primary school students’ lack of adequate recognition of experience-based technologies will prevent them from deeply understanding the relationship between technological change and social development—an important part of the nature of technology.

The fact that primary school students in the present study lack comprehensive concepts of technology also can be seen from the aspect that some of the pupils describe technology from a technology-oriented perspective which focuses on the technology itself only but not on the relationship between technology and human activities, such as the category of the attributes of the technology. Meanwhile, some of the students’ descriptions are human-oriented that concentrate on the links between technology and human activities or society, such as the categories of the production of technology, the operation and use of technology, and the function of technology. Students who own technology-oriented concepts of technology can hardly recognize the relationship between technology and human, so they are more likely to ignore the ‘technology as volition’. Solomonidou and Tassios (2007)’s study on pupils’ conceptions about technology also revealed similar outcomes.

Compared with other studies that investigate primary pupils’ concept of technology specifically, some similar outcomes can be found in this research as well, i.e., many primary pupils associate technology with modern products such as computers, as a recent phenomenon, as some ‘high-tech’, as something with many functions, as closely related to science,
or as microtechnology, while the experience-based technologies are seldom recognized as technology by pupils (Ankiewicz, 2018; 2019; Collier-Reed, 2006; de Vries 1996; Moore, 1987; Rennie & Jarvis, 1995a; Solomonidou & Tassios, 2007). But much of the research interviewed also shows some differences. For example, primary pupils in South Africa also regard technology as the process of artifacts progression, or as a solution to a problem (Collier-Reed, 2006). Some pupils in Greek use the criteria of the purpose for which technology is used to make decisions (Solomonidou & Tassios, 2007). Pupils in England tend to associate technology with model-making and design (Moore, 1987; Rennie & Jarvis, 1995a), while Westen Australian pupils do not (Rennie & Jarvis, 1995a). In this research, primary pupils in mainland China show some unique conceptions of the nature of technology. Specifically, some students consider technology as something that looks beautiful and interesting, that technology is difficult to produce and maintain, technology was invented in ancient times, technology is arduous physical labor, technology is some kind of skill or technique that requires learning to master, the operations and use of technology will not harm the natural environment and human health, and technology can inspire the subsequent invention of artifacts. These unique differences may mirror the different cultural and historical backgrounds in which students exist, the different life experiences pupils own, and the different technology education that schools provide them with. All these differences will be discussed below.

**Primary school students lack a proper understanding of the relationship between technology and science**

This research also reveals that almost all students (98%) under study do not have a proper understanding of the relationship between technology and science. Some students equated or partially equated technology with science, some considered that science belongs to technology or technology is part of science, some completely separated technology from science, and some considered technology as the mere application of science.

Although both science and technology reflect the relationship between human and nature and are closely related to productivity, they are different in principle and essence (Chen, 2019). Science should reflect and understand objective things and processes, answering the questions of ‘what’ and ‘why’. The purpose of science is to explain causality and possibility, to discover and increase human knowledge. Technology, on the other hand, uses and controls nature, coordinates the relationship between man and nature, and answers the questions of ‘what’ and ‘how’. The task of technology is to design solutions, guidelines, standards, procedures, and other operational units to achieve realistic purposes to increase human material wealth and make human life better (Chen, 2019). Before the nineteenth century, science and technology almost developed independently. Since then, the relationship between the two has become increasingly closer and more complicated. On the one hand, discoveries in science often become the basis of technological principles and lead to technological inventions. On the other hand, new technological inventions, means, and methods constantly promote discoveries in scientific research (Jiang, 2009). Therefore, technology and science are essentially different while being interacted with each other. But, in this research, only one (2%) student can properly understand the relationship between technology and science, while the majority of pupils cannot. This phenomenon not only reflects an inadequate emphasis in teaching on the relationship between science and technology but also shows a deficiency in the teaching of the new development of technology as well as the history of technology. For instance, the interviewee X-10-M in
this research considered that ‘science studies plants and animals that have nothing to do with technology’, which shows that he has little information on a new research area named biotechnology. A poor understanding of the relationship between science and technology will prevent the forming of an appropriate understanding of both the concepts of technology and science, respectively.

**Factors that may influence the formation of primary students’ conceptions about technology**

Many studies (e.g. Ankiewicz, 2019; Collier-Reed, 2006; Rennie & Jarvis 1995a; Solomonidou & Tassios, 2007; Wu & Ding, 2020) have revealed that students’ conceptions about technology are influenced by some factors, such as their life experience, school technology education, the mass media, etc. In this research, it is considered that primary school students’ conceptions about technology in mainland China may be influenced by the following factors.

**Some characteristics of technology determine students’ conceptions about technology**

As noted above, students in this study tend to define technology from its modern characteristics. Besides, compared with macrotechnologies and microtechnologies, experience-based technologies are less recognized. This tendency can be explained by one of the characteristics of the technology: self-concealment, which means that technology is self-concealing when it is working properly (Wu, 2016, p. 5). Just as Kelly (2012, p. 20) argued, technology in most people’s minds refers to ‘everything that does not work yet’, which means that the more effective a technology is, the less visible it becomes (Hu, 2020, p. 12). In this research, compared with an electronic toothbrush, an ordinary toothbrush is no longer considered technology by most of the students since the latter has been developed and shaped nearly to its utmost, but an electronic toothbrush has not. Likewise, compared with washing clothes with a washing machine, washboards have a much longer history and have been much more fully developed and shaped, so they are no longer considered technology by most students.

The second characteristic of technology that affects students’ conceptions is technology as media, which communicates the ‘inside’ and the ‘outside’. (Hu, 2020, p. 20) The ‘inside’ refers to the technology that is inside the humans’ mind or shows humans’ technical ability, and it also can be called a technical skill or technique which is gained through learning and practices and which has been internalized into individual capabilities. In Mitcham’s framework of technology, the ‘inside’ refers to technology as knowledge and as volition. The ‘outside’ means putting the internal knowledge or technique into the external instruments or products. In Mitcham’s (1994) framework of technology, the ‘outside’, in contrast, refers to technology as objects and as activities. Technology combines the ‘inside’ with the ‘outside’ and communicates them, so technology serves as media, which is why McLuhan (2019) regarded media as synonymous with technology. Technology as media determines the expression of internal consciousness and the presentation of external objects, it is not only a transmission channel but also is involved in shaping all internal and external things (Hu, 2020). In this research, students who consider technology as objects and as activities are those who have noticed the ‘outside’ or external embodiment of technology; and the students who consider that technology is difficult to produce and maintain
since it requires professional knowledge, and that technology is some kind of skills or techniques that require learning to master, are those who notice the ‘inside’ or regard technology as technique.

In addition, some students in this study conceived of technology as some kind of skill or technique that requires learning to master, which also can be explained by another characteristic of technology, i.e., technology as something that can be acquired through learning (Hu, 2020). Technology is not something that humans have mastered since their birth, but something that could be acquired through learning. In the learning process, the human body interacts with an external object. The learning of technology involves two aspects: one is the manufacture of technology, and the other is the operation or use of technology. These two aspects meet in technological objects, where makers and users ‘interact’ with each other, resulting in the production and dissemination of technological objects (Hu, 2020, p. 24). In this research, students also view technology from the manufacturing and operational aspects, which are in accordance with the two aspects of the learning of technology.

Primary school students’ conceptions about technology are closely linked to the cultural and historical backgrounds of China

The history of technological development within China might be another factor that probably influences pupils’ conceptions about technology. Before the year 1840, as a big country whose economic development mainly relied on agriculture, technology was the ‘experiential technology’ (Jiang, 2009, p. 79), and mainly expressed as handicrafts, techniques or skills that relied on the accumulation of experience, apprenticeship, and handed down from generation to generation. Some experiential technologies have a long history in China and have been handed down up to now, so this traditional form of technology has not completely disappeared nowadays. In this research, some students hold the views that technology is hand-made, technology is arduous physical labor, technology was created in ancient times, technology is some kind of skills or techniques acquired through learning, and technology requires hands-on abilities—all of these are the embodiment of the conception of ‘experiential technology’.

The failure of the Opium War in 1840 prompted China to begin to learn advanced western science and technology, and ‘experiential technology’ gradually has been eclipsed whereas ‘scientific technology’ has been highlighted. Influenced by the major historical events such as the Westernization Movement (from the 1860s–1890s), the May 4th movement of 1919, the Cultural Revolution between 1966 and 1976, the reform and opening up since the late 1970s, etc., the Chinese people have become more respectful of the important values of science and technology and regard them as the ‘first productive force’, and ‘science and technology’ have been vigorously developed in China. Some students hold the view that technology is machine-made, technology is to operate machines that are intelligent and simple, which are closely linked to the Chinese idea of ‘science and technology’, being interchangeable in the minds of most Chinese, as mentioned earlier. However, the excessive esteem for science and technology has also given rise to the idea of scientific and technological determinism or scientism, with science and technology being brought to a decisive position (Qiu, 2018, p. 260). Influenced by this idea, the public and social media sanctify technology, which affects students’ conceptions about technology. For example, in this research, 30 (48%) students consider that technology has multiple functions and can bring multiple benefits to human beings, 11 (17%) students hold the opinion that technology
will not harm the natural environment and human health, and 8 (13%) students argue that the impact of technology on human beings is positive, without any negative impact.

Besides, influenced by the unique history of science and technology in modern times (discussed in the literature review) and in the Chinese language context, a consensus has come to form in the Chinese mind that those who have learned science and technology well are those who have received a good education since science and technology are considered as difficult to learn compared with the liberal arts. So, this consensus can be seen as another explanation of why some students tend to define technology from the criteria of complexity, and hold the opinions that technology is difficult to design, produce and maintain, and the materials used in technology are complicated. On the one hand, Chinese primary pupils’ unique conceptions about technology may reflect the unique cultural and historical backgrounds of China; on the other hand, it also reflects the inadequate technology education school offers, so students tend to form their concepts of technology from their life experiences, e.g. C-15-F considered that technology is about making design drawings and collecting data since she always saw her mother as an engineer doing this work.

**Primary school students’ life experiences may have a direct impact on their conceptions about technology**

Students’ personal and first-hand experiences of life such as the experiences from incidental and out-of-school sources or family conversations may have a direct impact on their conceptions about technology (Rennie & Jarvis, 1995a). In this research, the students (aged 9–12) in question were born between 2008 and 2011, and they have been exposed to a technologically rich environment since their birth. Modern household appliances, equipment, and devices such as smartphones, televisions, air conditioners, computers, refrigerators, modern machinery, the Internet, cars, high-speed bullet trains, and technical toys are available abundantly in their daily lives. The majority of technical products or activities students can find access to require electricity, and this can be another reason to explain why most of the students use whether a product or activity requires electricity, whether it is high-tech, and whether it requires websites, as the criteria to define technology.

The mass media is also not a negligible factor in daily life that, to a large degree, impacts students’ conceptions about technology. Nowadays, the rapid development of science and technology has always been the focus of the mass media. A variety of high-tech products, such as artificial satellites, magnetically levitated trains, nanotechnology, robot technologies, rockets, among others, have been widely reported by the mass media. Through news, books, networks, science and technology education programs, and other channels, students learn about these high-tech products, which contributes to further strengthening their images of technology as high-tech, technology as more advanced products, and technology as having multiple functions in the students’ mind. It should be pointed out that 62 (98%) students in this research cannot understand the relationship between science and technology correctly: they either equate technology with science or consider science contains technology or vice versa. The word ‘science’ and ‘technology’ often go hand in hand in television programs, radio broadcasts, and newspapers. In the Chinese language, ‘science and technology’ are abbreviated as one word ‘Keji’ (科技), and expressions such as the ‘development of Keji’, ‘levels of Keji’, ‘Keji is the first productive force’, ‘talents of Keji’, ‘innovation of Keji’ and ‘high-Keji’ (high-tech) are often on everybody’s lips or on-air.
which makes students more likely confuse science with technology or consider technology as the application of science.

Inadequate school education may result in primary school students’ vague concepts of technology

Rennie & Jarvis’s (1995a) study indicated that the technology education programs provided by the school play an indispensable role in shaping pupils’ conceptions of the nature of technology. In that study, pupils in England tend to associate technology with model-making and design while those in Western Australia do not since the England national curriculum for technology emphasizes the design cycle, an aspect generally ignored in Western Australia. School education should be the primary approach to cultivating students’ comprehensive and rational understanding of technology. In the latest Chinese science curriculum standard for elementary schools issued in 2017, a module of ‘technology and engineering’ accounts for a quarter of the standard content (MoE, 2017). But the results of this research reveal that (a) most of the students (98%) lack a comprehensive and rational concept of technology, (b) nearly all the students (98%) cannot understand the relationship between science and technology properly, and (c) the difference between technology and engineering is blurred on the part of some students. Through the analysis of primary school science curriculum standards (MoE, 2017), it is found that the curriculum standards only emphasize that invention is the nature of technology and does not provide a comprehensive introduction to technology. As for the relationship between science and technology, the science curriculum standards merely emphasize that the nature of science is discovery, and the nature of technology is invention, thus lacking a comprehensive explanation of the relationship between science and technology. Evidently, the concept of technology and the relationship between science and technology do not get enough attention either in science curriculum standards or in the day-to-day science classroom instructions. Therefore, students can hardly gain a comprehensive understanding of them through science courses learning in school. With regards to some students’ confusion between technology and engineering, one possible reason for this might be that though the module of ‘technology and engineering’ has been added to the latest science curriculum standard for elementary schools (MoE, 2017) and the difference between them has also been included, this part still receives little attention in the day-to-day science classroom instructions. In addition, it is worth mentioning that the results of this research reveal that 55 (87%) students can correctly understand the positive and negative effects that technology brings to human life and nature, which is closely connected with the fact that the relationship among nature, society, science, and technology has been attached great importance in the science curriculum standards and science instructions. And it also indicates the significant role school education plays in shaping students’ appropriate understanding of technology. Therefore, the concept of technology, the relationship between technology and science, and the distinction and connection between technology and engineering should be attached more importance in science curriculum standards formulation and science instructions.

Currently, the required curricula for technology education in primary schools throughout mainland China are information technology (IT) and labor-technical education. But the IT courses take computer and Internet technology as the main teaching content, barely involving the nature of technology. Compared with IT courses, labor-technical courses which aim at cultivating students’ technological literacy are far from receiving adequate attention in schools (Ding, 2009). And currently, the main content of labor-technical
education is about handicrafts making, Chinese folk customs, traditional technical skills, designing and making simple daily-life crafts, plant growing, and the art of flower arranging, lacking in the content of modern technology, let alone the nature of technology (Ding, 2009). Therefore, it is difficult for students to gain a comprehensive and rational concept of technology in the labor-technical courses learning in schools, which may result in primary school students’ vague concepts of technology. Compared with the US technology education, there seems to be a big gap between China and the US as to the importance paid to technology and engineering education, where the nature of technology is included as an important element in the curriculum standards (ITEEA & CTETE 2020). Besides, many labor-technical education teachers lack the technology or science-related academic backgrounds, most of them are ill-prepared in technology teacher education (in fact, there are no labor-technical teacher education programs available in teacher education institutions) and so teachers with art, IT, or other subjects backgrounds take place of them, which also affects the quality of the technology education instruction.

From the above analysis, it can be seen that to help students form a comprehensive and rational understanding of technology, on the one hand, schools should pay much attention to labor-technical education and ensure that students have adequate opportunities to attend the courses; on the other hand, the compilation of national curriculum standards should include the content of the nature of technology and history of technology, etc., to help students form a comprehensive and rational understanding of technology.

**Conclusion**

In summary, this research reveals that primary school students in mainland China can define technology from the dimensions of its attributes, production, operation and use, and function, with each dimension being further divided into several lower-level categories of conception. Students’ understandings of the concept of technology are a mixture of different conceptions, which shows that they can define technology from diverse perspectives. Besides, compared with other studies on the same topic, many students in this research can define technology as volition and most of the students can recognize the impact of technology on society and regard it as a double-edged sword.

Meanwhile, this research also reveals that students lack a comprehensive and rational concept of technology and cannot understand the relationship between technology and science properly. Specifically, they tend to define technology (a) from their perceptual awareness, (b) from its modern character, (c) as objects, (d) as macrotechnologies and microtechnologies more than as experience-based technologies, and (e) as science or the application of science, which is similar to the research results found in a related field outside mainland China. Furthermore, this research also shows the differences in pupils’ conceptions about technology in mainland China. Specifically, some students consider technology as something that looks beautiful and interesting, that technology is difficult to produce and maintain, technology was invented in ancient times, technology is arduous physical labor, technology is some kind of skill or technique that requires learning to master, the operations and use of technology will not harm the natural environment and human health, and technology can inspire the subsequent invention of artifacts.

These findings can help policymakers, teachers, and researchers of technology education gain more understanding of students’ conceptions about technology and provide
enlightenment and scaffolding for better technology and science curriculum and instruction in the future for China and other countries.

Appendix
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