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A Comparison of Science Education between Germany, China, and Indonesia

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ABSTRACT

The comparison of science education between Germany, China, and Indonesia is an interesting topic to study because the three countries have different traditions and approaches to developing science education systems. The purpose of this study is to determine the differences in science education in Germany, China, and Indonesia. This research will examine the comparison of science education between the three countries through several aspects, such as curriculum, teaching methods, teacher training, educational infrastructure, challenges and opportunities, and philosophical basis. Secondary data used in this research is obtained from reliable sources such as PISA reports, scientific papers, books, and previous research. The results show that the German science education system is highly organized and focuses on deep concept understanding. In contrast, science education in China is highly competitive and prioritizes academic achievement. Science education in Indonesia tries to combine concept understanding and practical skills. Thus, a comparison of science education in Germany, China, and Indonesia shows differences. By thoroughly understanding science education in these countries, we can find many lessons that can be used to improve the overall science education system. Collaborative efforts and exchange of experiences between these countries will hopefully help improve science education.

Keywords: Comparison, Science Education, Germany, China, Indonesia.

INTRODUCTION

One of the important factors in a country's progress is education. The progress of a country's education level is closely related to the country's progress. Education aims to produce excellent human beings who will become the backbone of a nation's development. One of the goals of national education (Undang-Undang Republik Indonesia No. 20, 2003) is to develop the potential of students to become human beings who are faithful and devoted to God Almighty, noble, knowledgeable, capable, healthy, independent, creative, and become democratic and responsible citizens.

Science education is a type of education that can improve students' thinking skills and consists of four main components. First is the attitude, which includes an interest in living things, natural phenomena, and causal relationships that give rise to new problems that can be solved correctly. Second is solving problems through the scientific method, which includes designing experiments or trials, formulating hypotheses, evaluating, measuring, and drawing

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conclusions. Third, the product, which includes theories, principles, facts, and laws. Fourth is application, which includes the application of scientific techniques and ideas of science in everyday life (Sulthon, 2016). Therefore, science education is expected to improve learners' knowledge. This will enable the nation's young generation to achieve the goal of national education: to make knowledgeable human beings.

According to research results (Sari, 2017), science education is very important for the development of a country. Science is a way of thinking, a way of investigating, a body of knowledge, and its interaction with technology and society. It can be explained that in science there are dimensions of ways of thinking, ways of investigating, building science, and its relationship with technology and society. This becomes the fundamental substance of the importance of learning science that develops the scientific process for the formation of students' mindsets (Chiappetta & Koballa, 2010). Countries such as Indonesia, China, and Germany pay great attention to science education to produce a generation that is proficient in science. To provide science knowledge to learners, each country has a different education system and approach (Li et al., 2019). A comparison of science education in different countries can provide useful insights into the successes and challenges faced by each country in developing science education.

The 2022 PISA results showed that Indonesia scored lower than Germany and China (Kemendikbudristek, 2023). Indonesia has been in a relatively low position in the global rankings since PISA began in 2000. Several factors influence the low results of the PISA study among Indonesians, including students not being familiar with modeling questions and the lack of textbooks that bring up problem-solving in everyday life as tested in PISA questions (Zulkardi & Kohar, 2018). Therefore, teachers must also have sufficient literacy skills so that the objectives of the learning activities developed can be achieved (Argina et al., 2017).

Meanwhile, PISA results are generally better in Germany and China (Kemendikbudristek, 2023). This is because Germany has a strong and quality-oriented education system, which often results in good performance in math, literacy, and science (OECD, 2023b). In China, learners are in a higher category in science. At a minimum, learners can recognize correct explanations for familiar scientific phenomena and can use that knowledge to identify, in simple cases, whether a conclusion is valid based on given data (OECD, 2023a).

Science education is an important foundation for a country's progress in this era of globalization. Indonesia, Germany, and China each have unique education systems in developing their science education. Despite significant differences in infrastructure, curriculum, and teaching methods, all three countries share the same goal: to create a generation competent in science and technology. Nonetheless, the challenges faced by each country are also different, ranging from the accessibility of education, and the quality of teaching, to the implementation of technology in learning. A comparative study of science education in several countries, especially Indonesia, Germany, and China, can provide information about the different systems used to deliver science lessons to learners. By doing this comparison, we can also find the strengths and weaknesses of each science education system, as well as the best practices that can be applied by these countries. This article will compare science education in the three countries, especially in the aspects of the curriculum, teaching methods, teacher training, educational infrastructure, problems and opportunities, as well as the philosophical basis applied.

METHODS

This type of research is a literature study. Data for this research was collected through literature sources. Using literature sources in literature research is useful for the initial stages of collecting research data and strategizing research (Melfianora. 2019). This research uses a narrative review design, which means explaining theory, looking at research, and looking at previous research findings. The review combines different literature on the topic and synthesizes them into an in-depth interpretation (Chris, 2018).

Articles were searched using the terms "comparative science education", "science education in Germany", "science education in China", and "science education in Indonesia". Reference articles were searched using Google Scholar, eric.gov, Garuda portal, or SINTA databases. Approximately 15-20 articles were used to gather the required information. In addition, the data used in this study were also obtained from PISA reports and books. There are three stages to process the references that have been collected (Melfianora. 2019): 1) narrative analysis, which includes data collection and analysis; 2) content analysis, which involves using specialized techniques to conclude; and 3) critical analysis, which explains the information found during the literature study and discusses the meaning of the facts from a scientific perspective.

RESULTS AND DISCUSSION

Results

This research compares the PISA results, curriculum, teaching methods, teacher training, school infrastructure, challenges and opportunities, and philosophical underpinnings of the three countries. The data used in this study were obtained from reliable sources such as PISA reports, scientific papers, books, and previous research. The results of all aspects compared are presented below.

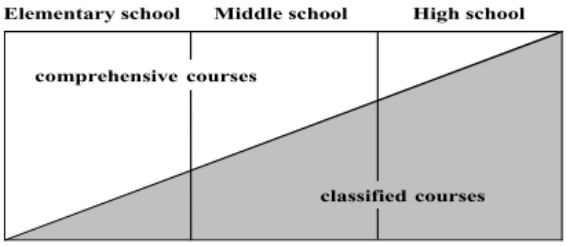
Data on PISA (Program for International Student Assessment) results for Indonesia, Germany, and China.

In 2022, PISA 2022 results showed a decline in international learning outcomes due to the pandemic. Even so, Indonesia's ranking rose 5-6 positions compared to PISA 2018. For reading literacy, Indonesia's ranking in PISA 2022 also rose 5 positions compared to the previous year. The average international reading literacy score in PISA 2022 dropped 18 points. For science literacy, Indonesia's score dropped by 13 points, almost equal to the international average which dropped by 12 points (Kemendikbudristek, 2023). Germany is one of the countries that succeeded in PISA. German students scored close to the OECD average in math and reading, and even higher than the OECD average in science. About 9% of students in Germany are top performers in math, meaning they reach Level 5 or 6 in the PISA math test (OECD average: 9%). In only 16 of the 81 countries and economies participating in PISA 2022, more than 10% of students achieved Level 5 or 6 proficiency (OECD, 2023b). In China 11% of its learners are top performers in science, meaning they are proficient at Level 5 or 6 (OECD average: 7%). These learners can creatively and independently apply their knowledge of science to a wide variety of situations, including unusual ones (OECD, 2023a).

Education Curriculum Comparison Results

The results of the curriculum comparison in each country can be seen in Table 1 below.

Table 1. Curriculum Comparison in Indonesia, China, and Germany

Country	Curriculum
Indonesia	The Indonesian curriculum incorporates science education into its curriculum, for example, in Curriculum 2013. Learners are educated to acquire core competencies, including science competencies, in the 2013 curriculum. Curriculum 2013 encourages students to use a scientific approach: conduct experiments, propose hypotheses, collect data, observe, and conclude (Prihantoro, 2015). Various scientific disciplines, such as physics, chemistry, biology, and astronomy, are taught in Indonesian schools. The local curriculum in Indonesia is usually not directly related to the fulfillment of students' livelihoods (Sari, 2017). For example, the local curriculum is limited to art, regional or foreign languages, and things based on something other than learners' local desires and conditions.
China	The curriculum in China is classified into two specific categories, namely comprehensive and classified, which are distributed differently at the primary, middle, and high school levels. Science education refers to the comprehensive category that combines the contents of Physics, Chemistry, Geology, and others. The curriculum is also divided into three levels ranging from national to local and school levels. These are also called national curriculum, local curriculum, and school curriculum (Feng, 2006). The following figure shows the distribution of comprehensive and classified courses at each school level.  **Figure 1**. Distribution of Comprehensive and Classified Courses at Each School Level (Feng, 2006)
Germany	The curriculum in Germany is formulated by the Ministry of Education according to each state under the control of the Lander (local government), most Lander require subjects in primary education. As for secondary schools, the curriculum varies in emphasis according to the type of school. However, at least each type of secondary school contains the following subjects: German; mathematics; one foreign language (usually English); natural and social sciences; music; art; and sports (Pingge, 2019).

Teaching Method Comparison Results

The results of the comparison of teaching methods in each country can be seen in Table 2 below.

Table 2. A Comparison of Teaching Methods in Indonesia, China, and Germany

Country	Teaching Method
Indonesia	Science teaching methods in Indonesia usually use traditional approaches, such as teacher lectures and textbooks (Fahrudin et al., 2021). However, there is a shift towards a more interactive approach, where learners engage in experiments, discussions, and problem-solving. In addition, the increasing use of technology, such as the internet and multimedia, is impacting how science is taught in Indonesia.
China	Science education in China usually emphasizes innovative learning. With innovative teaching, a teacher should create a positive climate in the classroom, stimulate students' learning motivation, and develop students' attitudes and capacity to master and use knowledge. One of the focus issues in the teaching and learning process is to shift the role of students from passive recipients to active explorers in the learning process (Feng, 2006). Teachers are very important in providing information to learners (Zhang & Diao, 2023).
Germany	Experiments, research, and science-based projects are examples of practical learning that are often used in Germany (Dilber-Özer & Baysal, 2022). Through a more interactive and participatory approach, learners are encouraged to think critically, solve problems, and develop scientific thinking skills.

Teacher Training Comparison Results

The results of the comparison of teacher training in each country can be seen in Table 3 below.

Table 3. A Comparison of Teacher Training in Indonesia, China and Germany

Country	Teacher Training
Indonesia	Science teacher training usually suffers from difficulties and shortcomings in Indonesia. Several training programs aim to improve the quality of science teachers, but the lack of funding, facilities, and an integrated curriculum are obstacles (Pujiastuti et al., 2021). Science teachers in Indonesia often find it difficult to keep up with the latest scientific and technological developments. The weakness of the teacher training system in Indonesia is the management of training implementation. So far, training has always used large funds from the government budget or foreign loans (Sarwanto et al., 2009).
China	The Chinese education system is known to be highly competitive. Before starting teaching, science teachers in China usually receive a rigorous and intensive higher education in science (Yang et al., 2021). In China, teacher training programs focus on a deep understanding of the subject and creative teaching approaches. Science teachers also often have good access to the latest resources and technologies to improve the quality of their learning.
Germany	Teacher training in Germany is the responsibility of the individual states (*Länder*), operating under guidelines set by the Standing Conference of the Ministers of Education and Cultural Affairs (KMK). Teacher training/education consists of two phases: university studies and student teaching. In the first phase, university study (*Lehramtstudium*), prospective teachers learn academic sciences related to the subject they will teach. The second phase is student teaching. In this second phase, teacher training/internship in the German term *Vorbereitungsdienst* or

Country	Teacher Training
	Referendarzeit lasts for 1.5-2 years, during this phase prospective teachers are under the help of mentors from the school level where they will teach later (Pingge, 2019).

Education Infrastructure Comparison Results

The results of the comparison of education infrastructure in each country can be seen in Table 4 below.

Table 4. Comparison of Education Infrastructure in Indonesia, China, and Germany

Country	Education Infrastructure
Indonesia	Indonesia still needs to work on its education infrastructure. Some schools in urban areas have adequate facilities, such as science laboratories equipped with basic equipment, but educational infrastructure is often lacking in rural or remote areas (Haji et al., 2011). The lack of adequate facilities and equipment can limit opportunities to conduct experiments and practical learning in science. Despite efforts to improve education infrastructure in Indonesia, additional investment is still needed to improve the accessibility and quality of education, especially in science.
China	China has made massive investments in education infrastructure, including science education (Lee & Yuan, 2018). Many schools in the country have highly sophisticated science laboratories with state-of-the-art equipment. The government also builds research centers and high-level laboratories to improve research and technology. However, the education infrastructure in cities and rural areas is different. Compared to rural schools, urban schools usually have better facilities.
Germany	Germany is known for its strong education system, including science education (Rohman, 2013). Germany has an excellent educational infrastructure. Many schools have state-of-the-art science laboratories with the latest equipment. Germany has many world-renowned universities and research institutes. Learners can engage in in-depth experiments and research if schools have adequate facilities.

Comparison of Educational Challenges and Opportunities

The results of comparing educational challenges and opportunities in each country can be seen in Table 5 below.

Table 5. Comparison of Educational Challenges and Opportunities

Country	Challenges	Opportunities
Indonesia	According to (Yufarika, 2023), the challenges faced in Indonesian education today are: 1. Globalization in the fields of culture, ethics, and morals. 2. Competition for school and college alumni to get jobs is getting tighter.	The implications for the challenges faced according to (Yufarika, 2023)are: 1. Teacher management efforts 2. Strengthening teacher professionalism 3. Coaching and producing professional teachers.

Country	Challenges	Opportunities
	3. The results of international surveys and PISA on the education index are still low. 4. The problem of the low level of social capital, namely the trustworthy attitude of a person.	
China	Some of the challenges of education in China according to (Feng, 2006): 1. Curriculum standards lack flexibility. 2. Teacher workload is increasing. 3. Students' interests and parents' voices are somewhat ignored. 4. School leaders experience a cultural dilemma. 5. It is unclear whether curriculum reform should be rapid or gradual.	Visible opportunities according to (Feng, 2006): 1. The style of government administration has changed to some extent. 2. The ratio of local and school curricula is improved. 3. Innovative approaches to teacher development have been developed. 4. The emergence of positive trends in the teaching and learning process.
Germany	According to (Dusen et al., 2021), the challenges of education in Germany are: 1. Unbalanced academic study and practical preparation. 2. Theory-practice gap 3. Low or no correlation between teachers' professional knowledge, the quality of their teaching, and student achievement (Cauet et al., 2015).	The opportunities provided by (Dusen et al., 2021) are: 1. Studying various teacher education systems. 2. The implementation of a one-semester internship at the university is one of the efforts to further strengthen the relationship between theory and practice.

Basic Philosophy Comparison Results

The results of comparing the physiological basis of education in each country can be seen in Table 6 below.

Table 6. Comparison of the Philosophical Foundations of Education in Indonesia, China, and Germany

Country	Philosophical Basis
Indonesia	Indonesia has a science education system based on the philosophy of Pancasila, which emphasizes character-building, skills, and knowledge as part of holistic education (Setiani, 2021). This education system aims to produce citizens who understand science and technology and realize the importance of environmental conservation and sustainability. However, the science curriculum in Indonesia still needs to improve. Some are the lack of resources and learning methods that focus too much on memorization.

Country	Philosophical Basis
China	The Chinese philosophy of education is rooted in the philosophy of man as depicted in Chinese monosyllabic letters such as (*dēn*) meaning "man". Then, the realization of education through the teachings of *Kong Fu Tse* produces ethical human beings and bases themselves on God's power symbolized in a high place or the sky or the kingdom of heaven. The teachings of *Kong Fu Tse*, which later became a religion for the Chinese people, are the pillars that support the values of education for the Chinese nation from the past until now. On that basis, education has become a major element in the belief system and social system of Chinese society wherever they are (As'ad, 2014).
Germany	Germany grounds science education in a humanistic philosophy (Sjöström & Eilks, 2021). The German education system has long roots going back to the Middle Ages when the church was an institution that influenced the education of many citizens in Germany (Shaw, 2004). The influence of the church only diminished in the 17th century when education was officially considered the responsibility of the state. Apart from the church, education in Germany was also strongly influenced by two knowledge traditions: humanism and naturalism. The humanist-naturalist view is based on the humanism of Humold, an influential philosopher in Germany. Central to this is Humbold's concept of *Bildung*, the "rational understanding" of the world order. This philosophical view emphasizes the unification of academic knowledge with individualistic moral education. The emphasis on the rational appears in the importance of mathematics and science, while educators are expected to also act as moral educators for their students (Kurniawati, 2015).

Discussion

Each country has its learning system, with advantages and disadvantages that make the world of education continue to make improvements to improve the system. Looking back at the learning system in Indonesia and comparing it with the learning system in China and Germany, it can be an illustration to continue to innovate to improve a better education system in the future, especially in science learning.

Education has been developed in China for thousands of years, making it one of the countries with the oldest cultures in the world. China's ancient culture, especially the *Taoism* of *Lao Tse* and the *Confucianism* of Confucius, still strongly influences education today (Yin, 2013). China has five levels of curriculum management: Ministry of Education, Provincial Education Office, City, District, and School (Fatimaningrum, 2012). Provincial, city, and district governments have the authority to design local subjects according to the conditions of their areas but must receive approval from the central government.

Basic education in China consists of three years of preschool, six years of primary education, three years of junior secondary education, and three years of senior secondary education (Syakhrani et al., 2022). Academic-level higher education lasts two to three years, technical vocational education lasts four years, bachelor's degree education lasts two to three years, and doctoral education lasts three years (Tang et al., 2020). China has a centralized education management system from the central, provincial, and municipal levels and even in autonomous regions at the municipal level.

The State and religion have always influenced education in Germany, particularly the

church (Sari, 2017). In addition, the states also claim the authority to determine their education system. Currently, compulsory education lasts from the age of six to eighteen or for twelve to thirteen years. To fulfill compulsory education, one must attend full-time school for 9 years (in certain states, 10 years) before being able to switch to a part-time vocational school or another full-time school (N. Liu & Neuhaus, 2017). Therefore, the education system in Germany takes longer in some states compared to Indonesia. In Indonesia, it takes 12 years to complete primary school and be ready to attend university, while in Germany, it takes 13 years.

A comparison of science education curricula in Indonesia, China, and Germany can provide an overview of the focus, structure, and approach of science education in each country. Based on Table. 1 Science education in these three countries is different, but both aim to improve learners' understanding of scientific concepts, application of scientific methods, and critical ability to understand natural phenomena. The science education curriculum in each country is also constantly changing to meet the development of science and the needs of society (Maryanti & Nandiyanto, 2021). It is important to note that this comparison is only an overview, and many other factors influence science education in other countries.

Science education in Germany, China, and Indonesia has different teaching methods. Science education in Indonesia, China, and Germany also differs in terms of teacher training. In general, differences in science teacher training in Indonesia, China, and Germany indicate differences in educational approaches and available resources. On the other hand, Indonesia still faces obstacles in the development of science teacher training (Sariyatun et al., 2018). The weakness of the teacher training system in Indonesia is the management of training implementation. So far, training has always used large funds from the government budget or foreign loans (Sarwanto et al., 2009). China and Germany have focused teacher training on in-depth understanding and practical application of science (Dilber-Özer & Baysal, 2022). The existence of educational infrastructure in educational institutions is very important because it can affect the quality of science learning and development in a country (Ohlssen & Krempecki, 2020). If we look at a comparison of science education in Indonesia, China, and Germany based on their infrastructure, many differences can be seen. Overall, the science education infrastructure in Germany, and China, tends to be better than in Indonesia. Indonesia still faces many problems with its education infrastructure. Some schools in urban areas have adequate facilities, such as science laboratories equipped with basic equipment, but educational infrastructure is often lacking in rural or remote areas (Haji et al., 2011). China has invested heavily in education infrastructure, including science education (Lee & Yuan, 2018). Many schools in China have highly sophisticated science laboratories with state-of-the-art equipment. Meanwhile, Germany has an excellent educational infrastructure. Many schools in Germany have advanced science laboratories with the latest equipment (Rohman, 2013). However, it is important to remember that infrastructure is only one aspect of comparative science education.

Science education in Indonesia, China, and Germany has different challenges and opportunities. Overall, China has advantages in government support and strong economic growth (L. Liu, 2023). Meanwhile, Germany has a well-known higher education system and strong business cooperation (Doğan & Saraç, 2022). However, Indonesia still faces many challenges to improve higher education (Cahyati et al., 2021). According to (Yufarika, 2023), one of the challenges facing Indonesian education today is globalization in the fields of culture, ethics, and morals.

The occurrence of globalization in the fields of culture, ethics, and morals requires the world of education to provide learning that can provide a sense of patriotism and can filter the impact of globalization, namely a culture or value that enters our country brought by other countries. The challenge of education by the impact of globalization has provided changes to all aspects of the field of education which is a vehicle for developing quality human potential. Related globalization, can be identified opportunities for solutions related to the problems of the world of education in Indonesia by preparing excellent / quality resources, both human resources and other resources, and maintaining the nation's cultural values while still combining them in learning (Yufarika, 2023).

In terms of philosophical underpinnings, a comparison of science education in Indonesia, China, and Germany can show how different goals underlie the science education systems in each country. Indonesia emphasizes holistic education and sustainability, China focuses on academic excellence and intensive exam preparation (Chen, 2022), and Germany prioritizes creativity, critical thinking, and practical application. Each education system has its advantages and challenges, with Indonesia still focusing on the challenges of globalization, a low education index, and a low level of social capital (Yufarika, 2023). The challenges in China according to (Feng, 2006) are less flexible curriculum standards, increased teacher workload, and also cultural dilemmas. Meanwhile, in Germany, the challenges faced are the imbalance between academic studies and practical preparation and the low correlation between teachers' pre-professional knowledge, the quality of their teaching, and student achievement (Dusen et al., 2021). A deep understanding of these can help in designing solutions and opportunities for a balanced and comprehensive science education system.

CONCLUSION

Based on the research results of the literature study, it can be concluded that science education in Germany, China, and Indonesia differs in terms of curriculum, teaching methods, teacher training, school infrastructure, challenges and opportunities, and philosophical basis. Each country has advantages and disadvantages in the science education system. Some ways to improve science education systems are to establish a consistent curriculum, provide better training for science teachers to improve the quality of learning, expand practical experiences such as experiments and projects in science learning, and increase investment in educational infrastructure and resources to improve student's access to quality science education. By studying each country's education system, we can find many lessons that we can learn to improve the education system as a whole. It is hoped that cooperative efforts and exchange of experiences between countries will help improve the quality of science education.

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