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COMMENTARY

Interweaving Assessment into Students' Authentic Learning

Qingliang Lu

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"Develop a passion for learning. If you do, you will never cease to grow."
–Anthony J. D'Angelo

OVER decades, standardized testing has been the primary form of assessment of student learning. Standardized tests have been used as measurements of students' knowledge retention, but with little capability of evaluating their capacities to apply knowledge in authentic contexts (Cai, 2000). With the advent of the information age, the limitations of conventional standardized tests have become increasingly pronounced. Assessment was one of the key concerns in the education reform in the 1990s. In the U.S., for example, *America 2000: An Education Strategy* emphasizes that measurements of student performance must be accurate, comparable, appropriate, and constructive; that placement decisions for young children should not be made on the basis of standardized tests; and that achievement tests must not simply measure minimum competencies, but also higher levels of reading, writing, speaking, reasoning, and problem-solving skills (Bush, 1991). *Goals 2000: Educate America Act* (1994) declares that its purpose is to provide a framework for meeting the National Education Goals by assisting in the development and certification of high-quality assessment measures that reflect the internationally competitive content and student performance standards, among other means.

As doubt about the legitimacy of standardized tests grew, educators set about exploring more scientific assessment methods that can effectively identify students' academic competence, measure educational outcomes, and provide evidence for instructional improvements (Li & Han, 1991). In this context, alternative assessment became popular in the teaching community. Alternative assessment is an umbrella term for a variety of alternatives to conventional tests, such as direct assessment, performance assessment, authentic assessment, portfolio assessment, dynamic assessment, etc. Despite the differences in name, alternative assessments share some common features: asking students to perform, create, produce, or do something; tapping higher-level thinking and problem-solving skills; using tasks that represent meaningful instructional activities; invoking real-world applica-

tions. Another distinctive characteristic of these new assessments is their stress on the importance of examining the processes as well as the products of learning (Herman et al., 1992).

The rationale underlying alternative assessments is the cognitive learning theory and its constructivist approach to knowledge acquisition. Therefore, under alternative assessment, students are required to construct rather than merely select responses. As opposed to the conventional multiple-choice-dominated testing, alternative assessment may resort to a wide range of methods including teacher observation and recording, student completion of artifacts, group collaborative projects, experiments, presentations, oral speeches, and more. Assessment settings are expanded beyond classrooms to possibly cover homes and communities (Lei, 2011). Some of these assessment approaches may have historically been adopted by good teachers to monitor the progress of their students, but now they are extended beyond individual classrooms to pose a challenge to traditional ways of mass testing (Ewing, 1998).

Good instruction is inseparable from good assessment. By requiring students to perform meaningful tasks and focusing on continuous progress of individual student, the teacher can interweave assessment into the whole process of student learning. *Alternative Assessment and Evaluation in Science Education: Mind Maps and Concept Maps* in this issue is an examination of the effects of mind and concept mapping as alternative assessment methods in evaluating pre-service teachers' mastery of scientific concepts (Eryilmaz Muştu, 2024), with valuable insights into how to integrate alternative assessment tools into conceptual building in science education. It has significant implications for the further innovation of alternative assessments.

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COMMENTARY

The Significance of Innovative Application of Foreign Pedagogic Methods

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"In learning you will teach, and in teaching you will learn."
–Phil Collins

INTERNATIONAL educational conversations, an important component of cultural communication of humanity, play a significant role in advancing the education development of all countries and territories. Meanwhile, it is equally important to remember that all educational theories and practices derive from concrete contexts. The universalization of a well-acclaimed pedagogical method is not as easy as assumed (Yu & Li, 2010).

The principal purpose of introducing foreign educational theories is to address problems with a nation's education system. That means this type of introduction requires a process of "localization" to adapt non-native educational theories to local practical circumstances. Localization is as essential to the application of educational theories as it is to that of any other category of theories in that the origination and development of all concepts are deep-seated in specific historical and geographical contexts, marked by the philosophical principles, thinking patterns, discourse styles, and other cultural elements of a tradition (Zheng & Wang, 2000).

The localization of a foreign pedagogical theory typically entails two key components. First off, a thorough understanding of the tradition and status quo of a nation's education system is the precondition for the adoption of foreign pedagogical theories. What foreign pedagogical theories to borrow depend on profound knowledge of local educational practice? A blindly introduced foreign education paradigm is of no practical significance for educational improvement of the recipient country (Guo, 1993). More importantly, critical evaluation and continuous modification are needed in the process of localizing a foreign educational theory. The successful localization of a foreign pedagogical method is often the result of morphing it into a model that is congruent with the local education needs. The sustainable application of a non-native educational theory depends on its

effectiveness in addressing educational issues faced by the recipient nation. Mechanical replications of foreign educational notions can only result in the disconnection between teaching theories and practices, leading to the failure of their localization (Wang, 2013). Prior experiences have suggested that it is unwise to reject advanced ideas originating in foreign lands, but equally so to take them in blindly without discrimination and modification.

Amid the intensifying educational reform across the globe, new instructional models and paradigms of all sorts have emerged over the past few decades, informing China's ongoing curriculum reform. Nevertheless, years of Chinese basic education curriculum reform have shown that unthoughtful introduction of "internationally popular" teaching approaches did not help fix problems with Chinese education. Mechanically borrowing from world-famous pedagogical theories or rushing into changes to established instructional paradigms proves irrational practices. Instead, a productive application of foreign educational strategies should be based on the innovative adaptation of them to the current education system as well as on the creative integration of native effective teaching methods (Zhang & Zhang, 2014).

The project-based learning model (PBL) was introduced into the Chinese education community in the late 20th century and since has been widely experimented in its basic education. "The Compulsory Education Curriculum Program and Course Standards 2022" clearly stipulate that theme-based and project-based learning be adopted in primary and junior secondary education, initiating a new round of popularization of PBL in China. This issue of Science Insights Education Frontiers includes two papers on the application of PBL in Chinese compulsory education. *Difficulties with the Application of Project-Based Learning in Chinese Compulsory Education* gives a brief overview of the evolution and features of PBL and focuses on analyzing the challenges in the integration of PBL into regular curriculum instruction in China (Zhao, 2024). *Protocol-Guided Learning as a Facilitator of the Integration of Project-Based Learning into Chinese Compulsory Education* explores the significance of the protocol-guided learning method for the successful implementation of project-based learning in Chinese compulsory education by delineating the characteristics of protocol-guided learning and expounding on its potential roles in supporting the application of project-based learning in Chinese compulsory education schools (Lu & Zhou, 2024). We hope that these articles can provide meaningful implications for advancing the localization of PBL in China.

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ORIGINAL ARTICLE

Bibliometric Analysis of Articles Related Misconception in Biology by Country and Journal¶

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2. *Ataturk University, Erzurum, Turkey*

***Abstract**: The aim of this study is to reveal the content analysis and trends of studies on misconceptions in biology education. Within the scope of the research, articles containing misconceptions about biology were accessed from the Scopus database. "Biology and misconception" was searched in the title, abstract and keywords in the Scopus database on September 13, 2022. A total of 410 publications about misconceptions in biology education were found in the search. The years of accessed publications were determined between 1970 and 2022. A total of 410 publications were analyzed in the research, regardless of language. According to the data obtained, 53 countries and 143 journals published articles on misconceptions in biology. However, in order to obtain clearer data, 3 articles were determined as the minimum number of articles for a country, and 31 countries and 27 journals were considered in this research. According to this research, in terms of the number of documents, the USA is the most published country with 199 articles, and Turkey is the second most published country with 39 studies. It was also revealed that the most cited countries were the United States, Australia and the United Kingdom, respectively. "CBE Life Sciences Education" and "American Biology Teacher" journals were determined as the journals with the most publications on the subject. In addition, Journal of Research in Science Teaching, CBE Life Sciences Education, International Journal of Science Education, Journal of Biological Education, Evolution: Education and Outreach were identified as the most cited journals in the studies. The results of this study are thought to be important for the future development of studies on misconceptions in biology education. Regarding the results obtained from the research; Different indexes can be used in future studies, and other types of publications such as theses, conference proceedings or books can be used in analyses.*

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***Keywords**: Bibliometric Network Analysis, Misconception, Biology Education, Vosviewer, Scopus Database*

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¶: This study was presented as a summary text at the 15th National Science and Mathematics Education Congress on September 27-30, 2023 in Kars, Turkey.

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***Author Contribution:** The authors contributed equally to the study.*

***AI Declaration**: The authors affirm that artificial intelligence did not contribute to the process of preparing the work.*

Introduction

ONE OF THE main purposes of biology education is to ensure that students understand and apply concepts in biology subjects correctly. For this reason, before teaching biology subjects, it is necessary to reveal the concepts that students have about the subject. Because students learn some science concepts from previous teaching processes or have prior knowledge from observations in their lives. Students bring this prior knowledge with them when they attend science classes for the first time, and research on students' prior knowledge revealed that they have misconceptions about many biology concepts (Yağbasan & Gülçiçek, 2003). Students' misconceptions about science are one of the important issues brought up by academic studies (Riche, 2000).

Misconceptions are a problematic issue for students and teachers in science education. This may be due to the abstract nature of science subjects (Ayas et al., 2003; Keleş & Kefeli, 2010). In order for biology teaching to be effective with the developed strategies, students' misconceptions regarding science concepts must first be identified and eliminated. As a result, many researchers have focused on detecting and eliminating students' misconceptions (Riche, 2000). Considering that misconceptions are an educational problem, it is thought that the results of a study in which articles published in peer-reviewed journals on misconceptions in biology education are examined in terms of many criteria will provide important information to researchers and academicians, as in other branches of science. Studies conducted in the field of biology education, such as, aim to reveal the current trends in the field, to determine which subjects are satisfied or what kind of new research is needed, and thus to increase the quality of education (Karamustafaoğlu, 2009; Şimşek et al. 2008). In addition, research and published scientific articles guide new researchers about what previous research is (Henson, 2001; Tsai & Wen, 2005). Because people doing research should first seek answers to the questions "what are the previous studies in the literature?", "what topics and problems will need to be studied" and "what are the ways to meet these needs and how can they be done?" (Karamustafaoğlu, 2009; Şimşek. et al., 2008). It is important to examine research in the field of biology education at regular intervals to determine the trends of these studies and ultimately to shed light on researchers who want to work in science education (Çiltaş et al., 2012). This situation makes it necessary to examine these studies with content analysis (Gül & Özay Köse, 2018). Within the framework of the stated reason, this study aims to identify research articles published in peer-reviewed journals published in different countries regarding misconceptions in the field of biology education and to examine these studies in terms of certain criteria. In addition, this study is important in terms of guiding studies on misconceptions in biology education and design-

ing more comprehensive new studies. In this context, the articles scanned in the Scopus database were subjected to bibliometric network analysis. Bibliometric analysis is a method that provides the most accurate data about the historical development and trends of a subject in the literature and helps researchers who want to study in the relevant literature where to start (Özay, 2022). With bibliometric analysis, various features of academic publications are evaluated using quantitative analysis. In this way, it is possible to create a general framework for a particular discipline by examining the statistical data of the studies such as author, subject, cited studies and authors (Akcan et al., 2023; Çetinkaya Bozkurt & Çetin, 2016).

When the literature is examined, bibliometric analysis has been applied by many researchers from different disciplines to detect trends in research (Azer, 2017; Çelik et al., 2021; Çetinkaya Bozkurt & Çetin, 2016; Karagöz & Ardıç, 2019; Kulak 2018; Kulak & Çetinkaya 2018; Kumar et al. , 2021; Moral-Muñoz et al., 2020; Polat et al., 2013; Zhang et al., 2022).

The aim of this study is to reveal the content analysis and trends of studies on misconceptions in biology education. The bibliometric analysis used in the research was conducted to find answers to the questions given below.

- What is the distribution of countries where studies on misconceptions in the field of biology education are carried out?
- What is the distribution of journals in which studies on misconceptions are conducted in the field of biology education?

Method

This research is a compilation study and a descriptive research design was followed. Descriptive research is conducted to identify and explain current and experienced situations (Karasar, 2009). The bibliometric method was chosen to discover the countries and journals that publish the most in hundreds of misconception studies conducted in biology education. Bibliometric analysis is a method that provides the most accurate data about the historical development and trends of a subject in the literature and helps researchers who want to study in the relevant literature where to start (Özay, 2022). This method was preferred because hundreds or even thousands of studies are analyzed in depth with the bibliometric method and the visual mapping technique for the research field is given with graphic descriptions (Zupic & Cater, 2015).

Data Collection Process

Within the scope of the research, articles containing misconceptions about biology were accessed from the Scopus database. Scopus is an Elsevier or-

ganization that hosts many journals from many publishers, providing summaries, citations, full documents to the user, and also includes author attributes (Özgirgin, 2010). In addition, Scopus is a heterogeneous database that makes publications from many sources available to researchers (Ramalho et al., 2020). The reason for using the Scopus database instead of Web of Science or Google Scholar for bibliometric analysis is that the Scopus database is the largest database in the literature, produces information with better decisions and results, and bibliometric studies are comprehensive in fields such as technology, science, art, medicine and social sciences, and is more preferred because it provides a broad perspective (Ekinci & Özsaatçi 2023; Işın, 2022; Martín et al., 2018).

First of all, the "Article Title, Abstract, Keywords" section was selected in order to get the most results from the "Search" button in the Scopus database. Then, a search was made by typing "biology and misconception" in the "search document" section of Scopus. The reason why it is searched this way is; Misconception is expressed in different ways by different scientists in the literature (Gülev, 2008; Helm, 1980; Sutton, 1980). For example; According to Novak (1977), prejudices, pre-concepts, erroneous ideas, alternative frameworks are in the form of pure concepts, intuitive or internal concepts, and alternative interpretations. Although these terms generally express the same concept, the term misconception is used more in the literature. For this reason, the term "biology and misconception" was preferred when searching. Therefore, the limitation of this study is that the research was conducted only in the form of "biology and misconception". As a result of the search, 751 publications were found. However, since not all of these publications were related to misconceptions in biology education, the "Social Sciences" section was selected from the "Subject Area" section of Scopus and a filter was made, and a total of 410 publications regarding misconceptions in biology education were reached. The searches were made on September 13, 2022. Since the years of the accessed publications started in 1970, studies between 1970 and 2022 were included in the research. No language discrimination was made in the research. The publications were then exported to CSV form and then subjected to bibliometric analysis using VOSviewer (Visualization of Similarities) Software.

Data Analysis

Bibliometrics is a measurement method used to describe and analyze the progress of a particular discipline or a particular field of research, using computer technology to display the results of visual literature analysis in a simple and clear graph (He et al., 2022; Merigó et al., 2015). Bibliometric network analysis used in the bibliometric method is an approach technique used in the context of analyzing the relationships between research subjects,

authors and institutions within a discipline and showing and interpreting how these relationships are (Buonocore et al., 2018; Taddeo et al., 2019). The reason why bibliometric network analysis was preferred as the method in the study is that the holistic and temporal plane, which is difficult to understand due to the continuous cumulative development of the literature on misconceptions in biology, will be summarized in an understandable way. Another reason for using bibliometric network analysis in the study is that scientific research is determined by visualizing the relationships between certain topics, journals, authors, institutions or countries (Van Eck & Waltman, 2010).

VOSviewer is the software that can be used in mapping for bibliometric data analysis (Al Husaeni & Nandiyanto, 2022; Al Husaeni et al., 2023; Hamidah et al., 2020; Mulyawati & Ramazan, 2021). This software allows collecting the literature efficiently and establishing mutual relationships between selected publications within the options (Kuzior & Sira, 2022). VOSviewer software visualizes bibliometric networks for easier analysis. With the VOSviewer program, analysis of certain subject areas, analyzes to determine word density in studies, content analysis of websites, analysis of theses and co-authorship, and detection of relevant words in the field can be provided. At the same time, detecting meaningful relationships in big data can be made more possible (Artsın, 2020). In this research, VOSviewer v.1.61 (Centre for Science and Technology Studies) program was used for bibliometric analysis of 410 publications.

Findings and Discussion

Country Analysis: Countries where Articles are Published Most

Country analysis was conducted to reveal the spatial distribution of publications. According to the data obtained, 53 countries have published articles on misconceptions in biology education. However, in order to obtain clearer data, the minimum number of articles for a country was determined as 3 articles and 31 countries were considered. For each of the 31 countries, the total strength of co-authorship affiliations with other countries was calculated (**Table 1**).

According to **Table 1**, the USA is the country that publishes the most with 199 articles, and Turkey is the second most productive country with 39 studies. This can be considered as an indicator that the USA attaches importance to studies in the field of biology education. Abdullah (2022) stated in his research that the USA has been the country with the most publications in biology education for 63 years. As a result of examining the articles published in the field of science education in their study, Yurdakul and

Table 1. Countries Publishing the Most Articles.

Country	Documents	Citations	Citations Per Document	Total Link Power
United States of America	199	4,632	23.3	20
Turkey	39	295	7.6	0
United Kingdom	28	433	15.5	3
Canada	17	432	25.4	7
Germany	15	162	10.8	3
Australia	14	994	71.0	4
Indonesia	12	67	5.6	2
Brazil	6	27	4.5	0
Greece	6	28	4.7	1
Malaysia	6	26	4.3	3
Israel	6	107	17.8	3
Singapore	5	148	29.6	2
South Africa	5	39	7.8	0
Argentina	4	62	15.5	1
Chile	4	50	12.5	2
Hong Kong	4	111	27.8	0
Portugal	4	60	15.0	0
Slovenia	4	7	1.8	0
Thailand	4	10	2.5	1
Chinese	3	8	2.7	1
Czech Republic	3	6	2.0	1
Denmark	3	146	48.7	4
France	3	2	0.7	0
Holland	3	4	1.3	1
Nigeria	3	85	28.3	1
Slovakia	3	8	2.7	1
Spain	3	12	4.0	0
Sweden	3	19	6.3	2
Switzerland	3	26	8.7	1
Taiwan	3	88	29.3	0
India	3	47	15.7	0

Bozdoğan (2022) stated that the USA is the most active country in this field and that the USA hosts 40% of the articles published in this field. As emphasized in the Demir and Çelik (2020) study, it is stated that the USA plays a key role in the development of scientific relations and communication in the international arena and acts as a bridge. It is seen that Turkey is the second most productive country with 39 studies. Similarly, Yurdakul and Bozdoğan (2022) stated in their study that Turkey is the second most active country within the scope of articles published in the field of science education. However, total citations of documents by country are also given. In this study, it

is seen that the United States ranks first with 4,632 citations and Australia ranks second with 994 citations. These countries are followed by the United Kingdom with 433 citations and Canada with 432 citations. Developed countries place significant emphasis on science education and continually strive to enhance and update their science teaching programs, recognizing that every success achieved in education is vital for the future development and competitiveness of their societies (Yavuz Topaloğlu & Balkan Kıyıcı, 2015). In the study of Orhan and Aydın (2022), according to the results obtained by a similar analysis, it was determined that the country with the most publications was the United States of America and it was stated that this country was followed by Turkey.

The study also determined which countries researchers took part in joint studies. It has been determined that the USA is the country with which we cooperate the most and that Turkey does not have co-authored studies with different countries on this subject (**Figure 1**). Contributing countries appear in the analysis in a single row around the circle. A high betweenness value of a node in the network indicates that it has the most impact on the relationships within the cluster (Demirgil, 2018). It can be seen that the USA is at the center and its most important partners are the United Kingdom, Canada and Argentina. It is seen that the USA is included in the network structure where different countries are connected to each other and plays an intermediary role between countries. In addition, according to the time trend of the country analysis, studies conducted in recent years have found that the USA is in cooperation with Indonesia (**Figure 2**).

Journal Analysis: Most Popular Journals on Misconceptions in Biology

In order to determine the journals with the most publications based on the articles obtained, journals with at least 3 publications on the subject were selected. 27 out of a total of 143 journals meet the relevant threshold (**Table 2**).

According to **Table.2**, "*Cbe Life Sciences Education*" and "*American Biology Teacher*" were determined as the journals with the most publications (41 articles) on the subject. Additionally, citation analysis of the journals with the most publications was conducted. Accordingly, *Journal of Research in Science Teaching* (23 articles, 1,314 citations), *Cbe Life Sciences Education* (41 articles, 1,206 citations), *International Journal of Science Education* (15 articles, 742 citations), *Journal of Biological Education* (35 articles, 1,206 citations). 721 citations), *Evolution: Education and Outreach* (31 articles, 673 citations) were the most cited journals in the studies. When the citations received by the publications in the mentioned journals are examined, it is seen that a few journals stand out. For example, *Journal of Research in*

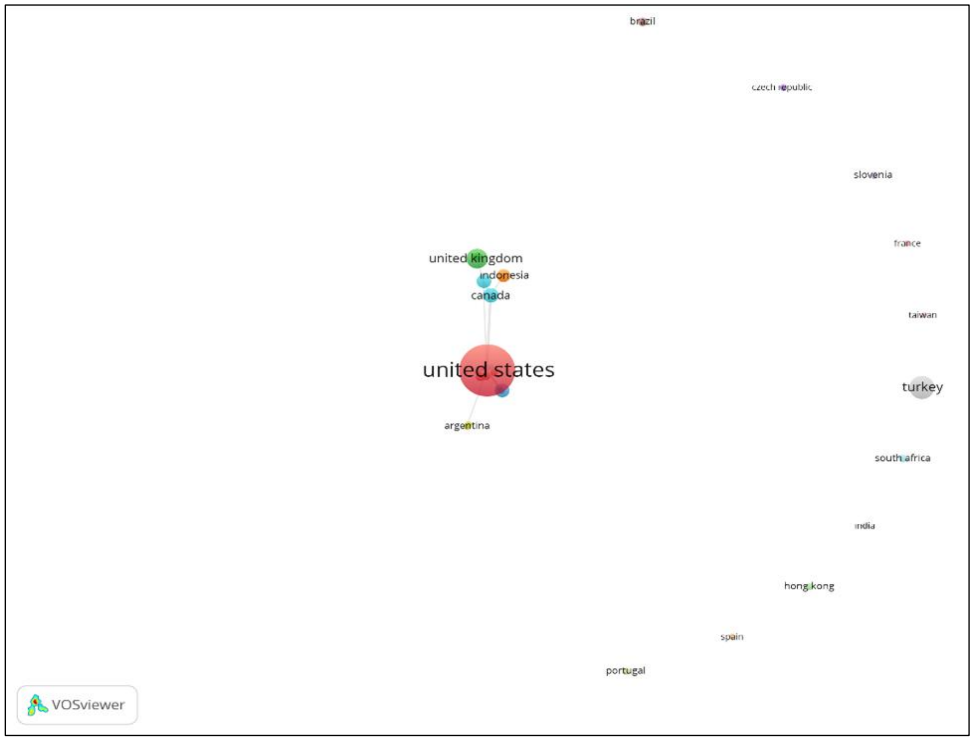

Figure 1. Cooperation between Countries.

Figure 2. Temporal Trend of Clusters.

Table 2. Most Popular Journals on Misconceptions in Biology.

Journal	Documents	Citations	Total Link Power
American Biology Teacher	41	311	46
Cbe Life Sciences Education	41	1206	115
Journal of Biological Education	35	721	83
Evolution: Education and Outreach	31	673	86
Journal of Research in Science Teaching	23	1314	99
International Journal of Science Education	15	742	50
Research in Science Education	10	134	15
Journal of Baltic Science Education	7	35	16
Science Education	6	594	44
Asia-Pacific Forum on Science Learning and Teaching	5	3	1
Education Sciences	5	41	8
Energy Education Science and Technology Part B: Social and Educational Studies	5	21	5
Science and Education	5	35	16
Bioscene	4	11	3
Cell Biology Education	4	176	14
Journal of Science Teacher Education	4	193	27
Jurnal Pendidikan Ipa Indonesia	4	50	3
Procedia - Social and Behavioral Sciences	4	68	2
Computers and Education	3	81	6
Journal of Geoscience Education	3	30	0
Journal of Microbiology and Biology Education	3	4	1
Journal of Science Education	3	8	10
Journal of Science Education and Technology	3	60	6
Research in Science and Technological Education	3	80	4
Zygon	3	8	0
International Journal of Science and Mathematics Education	3	92	11
International Journal of Innovation in Science and Mathematics Education	3	5	7

Science Teaching (1,314) is in the middle of the list in terms of the number of publications, but it ranks first in terms of the number of citations. When we look at the journal "*American Biology Teacher*", we see that the journal, which publishes a large number of articles (41) and has high link strength, receives very few citations per article. As a matter of fact, a similar situation is seen in some other journals. This may provide guiding information regarding journal selection for future biology education researchers. In addition, according to this research, "*Cbe Life Sciences Education*" journal stands out as the journal with the highest link strength (115) among all journals.

Looking at the figure created with VOSviewer, it can be seen that the most cited journals are grouped around 8 clusters (**Figure 3**) and in **Figure 4**, according to time, it can be seen that the "*Science and Education*" has been

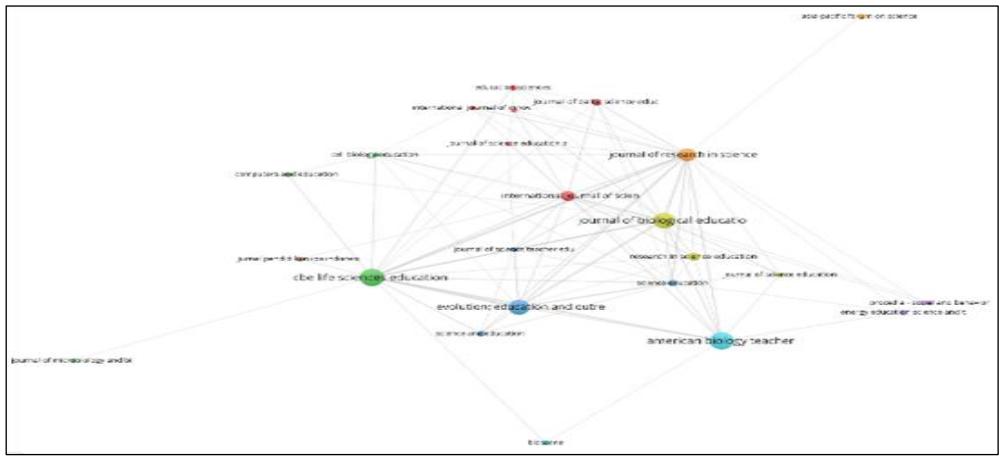

Figure 3. Most Cited Journal Clusters (Co-Citation Analysis).

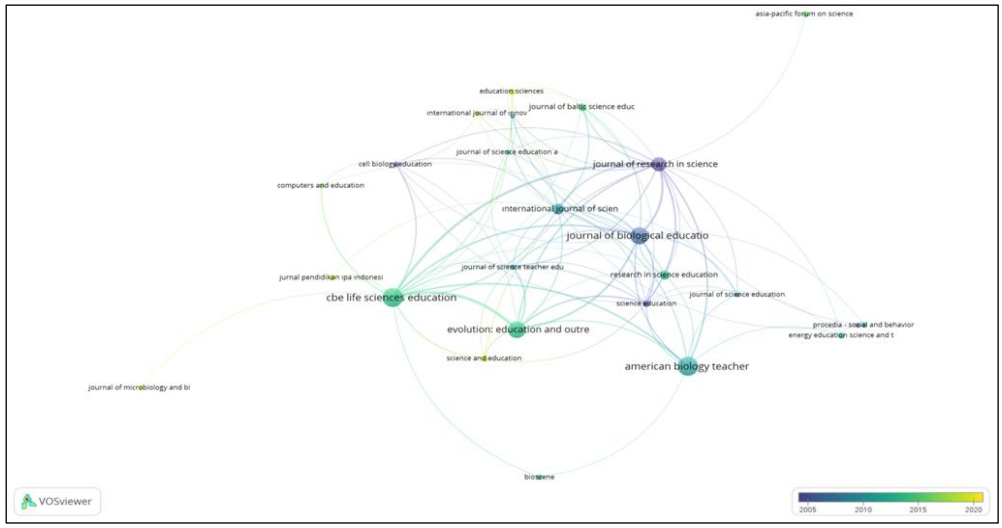

Figure 4. Temporal Trend of Clusters.

preferred by researchers in recent years. There also appear to be many connections between the clusters. Here, the fact that a node has many connections with other nodes can ensure that it has a central position in the cluster. When the social network is examined, it is seen that the relationships are mostly tied up through magazines such as "*Journal of Biological Education*", "*American Biology Teacher*" and "*Journal of Research in Science Teaching*". This shows that these journals have a very important position in the network. Similar to our study, Orhan and Aydın (2022) stated in their study that, as a

result of examining articles on science (science, physics, chemistry, biology) and mathematics education, the most cited journal was "*Journal of Resource in Science Teaching*". It can be said that academics have recently shown increasing interest in the research in these journals, the journals have influential publications in their field and therefore have an influential position in the sector. The choice of these journals shows that journals with content directly related to the field of study attract attention. Therefore, it can be said that these journals are alternative journals for future research in this field.

Conclusion and Recommendations

In this study, studies on misconceptions in biology education are included. Bibliometric analyzes of published studies were conducted using country and journal parameters. The data set used in this study was created based on 410 works indexed in the Scopus database between 1970 and 2022. In this respect, the study is considered to be the study with the most comprehensive data set, aiming to reveal the general situation regarding misconceptions in the literature.

According to the results obtained, it was revealed that the most cited countries were the United States, Australia and the United Kingdom, respectively. *Journal of Research in Science Teaching*, *CBE Life Sciences Education*, *International Journal of Science Education*, *Journal of Biological Education*, *Evolution: Education and Outreach* were identified as the most cited journals in the studies. The results of this study are thought to be important for the future development of misconceptions in biology education. Although the research is specifically a study on misconceptions, it is generally related to biology education as a research field. Therefore, it gives an idea about how the subject can be addressed in relevant disciplines. The article focuses on the spatial and publication distributions of the existing literature on misconceptions in biology education. In future studies, more comprehensive studies can be conducted by including cultural and regional factors. The study is limited to published articles using misconceptions in biology education. Researchers can perform more detailed biometric analyzes using various keywords to familiarize themselves with basic research in the chosen research field and also benefit from these publications. Additionally, this study is limited to studies available in the Scopus database. Different indexes can be used in studies. The type of publication included in the sample of the study is limited to articles. Other types of publications, such as theses, conference proceedings, or books, may be used in the analysis. Further studies can be conducted using different restrictions when searching for articles.

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ORIGINAL ARTICLE

Alternative Assessment and Evaluation in Science Education: Mind Maps and Concept Maps

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***Abstract**: In this study, concept maps and mind maps, which are alternative assessment and evaluation tools used in science education, were examined. The study aimed to quantitatively evaluate the concept maps and mind maps prepared by pre-service science teachers dealing with the concept of atoms. Thus, it was aimed to describe the concept of atom in the minds of pre-service teachers with different assessment tools. A case study approach was used in the study, which is one of the quantitative research designs. The study group consisted of 15 pre-service teachers teaching science in the fourth grade. Criterion sampling method was used in the study. Attention was paid to ensure that the participating pre-service teachers had undertaken all the relevant courses regarding the subject of atoms. The concept maps and mind maps created by the participants were used to describe their cognitive structures about the atom concept. The concept maps and mind maps created by the pre-service teachers were examined using quantitative analysis. It was concluded that the scores obtained by the pre-service teachers from both the alternative assessment and evaluation tools were close to their total mean scores. It was determined that the pre-service teachers could not advance as the structure grew in both concept maps and mind maps, and they had difficulties in establishing relationships between levels and hierarchies.*

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***Conflict of Interests**: None*

***AI Declaration**: The authors affirm that artificial intelligence did not contribute to the process of preparing the work.*

Introduction

WITH the radical changes introduced to the science and technology curriculum in recent years, the constructivist approach has become popular in teaching processes. In this approach, assessment and evaluation are as important as planning and implementing the learning and teaching process. With the constructivist approach, the classical approaches that focus on evaluating how much information is retained started to be replaced by alternative assessment and evaluation approaches that examine the change in students' conceptual understanding. The assessment and evaluation philosophy of the science curriculum is also based on the fact that each individual is different from another. Therefore, students' assessment and evaluation cannot be expected to take place in a standard structure suitable for everyone (Ministry of National Education [MoNE], 2018). In the alternative assessment process, students participate in the procedure of "what is taught, how it is taught and how it is evaluated" (Kreisman, Knoll, & Melchior, 1995, p. 114). Assessment and evaluation should be done as part of the teaching process, not only at the end, but throughout the learning process. Alternative assessment and evaluation techniques that focus on the learning process require the use of a greater number of, and more diverse, assessment tools or methods than the traditional approach (Gelbal & Kelecioğlu, 2007). Traditional assessment and evaluation techniques try to assess information in a limited period of time. These techniques do not give students the opportunity to perceive their own success and determine their shortcomings. These techniques do not provide enough information about the learning scheme that students create in their minds (Mumme, 1990; Shepard, 1989). Traditional approaches assess basic knowledge and skills, but measuring higher-level cognitive skills is lacking in it (Ryan, 1998; Shepard, 1989). Alternative assessment tools try to reveal not just how much students know, but what they know and what their shortcomings are. Answers given by students in these assessment tools can be evaluated in-depth. For this reason, student responses can be examined in a broader sense and analyzed from different dimensions in these assessment tools (Eroğlu & Kelecioğlu, 2011). The purpose of the evaluation created with alternative assessment and evaluation tools is not only for grading students' academic success or their group work performance. It also aims to demonstrate the progress students have made in different stages as well as the shortcomings they are expected to rectify. Therefore, alternative assessment and evaluation tools provide an opportunity to evaluate both the learning process and the product obtained as a result of the process (Eroğlu & Kelecioğlu, 2011; Okur & Azar, 2011; Yıldız & Uyanık, 2004). Alternative assessment and evaluation comprise all assessments other than conventional assessment, including multiple-choice tests with a single correct answer (Bahar, 2001). Alternative assessment and eval-

uation, also called complementary assessment and evaluation, are student-centered. Since these assessment tools take into account different dimensions such as process, performance and product, they are evaluated with a special scoring key (Bahar et al. 2010). Concept maps and mind maps are among the techniques used as alternative assessment and evaluation tools.

According to Ausebel (1968), meaningful learning only takes place when new knowledge can be associated with existing knowledge in the student's mind. Based on Ausubel's meaningful learning theory, Novak developed concept maps (Willerman & MacHarg, 1991). Concept maps are visual education tools that make use of key concepts and associate these concepts with each other using propositions (Novak, 1991). Like a graph, it shows how students integrate the key concept and other related concepts in their minds (Novak & Gowin, 1984). Students make use of the concept mapping technique to make associations by ranking the relationships between concepts in a certain order and hierarchy. By examining these relationships, information about student'' cognitive structures can be obtained (Briscoe & LaMaster, 1991). Many studies employed concept maps as an assessment tool in order to determine the cognitive structure of students (Kaya, 2003; Kılıç & Sağlam, 2004; Kinchin, Hay, & Adams, 2000; McClure & Bell, 1990; McClure et al., 1999; Novak 1990; Novak & Gowin, 1984; Ünlü, İngeç, & Taşar, 2006; İlgeç, 2008; Wandersee, 1990; Williams, 1998).

Mind maps, developed by Tony Buzan, are a visual representation of concepts related to the main concept (Kortelainen & Vanhala, 2004; Mueller, Johnston, & Bligh, 2002). The mind mapping method can be used to visualize the information learned from different sources with the help of key concepts (Farrand et al., 2002). Therefore, mind maps provide a visual way for remembering and organizing information (Holland, Holland, & Davies, 2003). While preparing a mind map, arms are drawn from the centre of the map to the outside. Colors and visual images are used to emphasize the relationships between concepts. Pictures, diagrams and words can be used collectively in mind maps to express concepts and the relationships between them (Warwick & Kershner, 2006). Mind maps can be used to summarize information about a topic or organize it through associations (Kortelainen & Vanhala, 2004). Mind maps, like concept maps, are also used as an assessment and evaluation tool to determine students' cognitive structures (Akinoğlu & Yaşar, 2007; Aslan & Gündüz, 2019; Bütüner & Gür, 2008; Evrekli, 2010; Gömleksiz & Fidan 2013; Yaşar, 2006).

While classical assessment and evaluation tools give information only about how much information is retained by the student, alternative assessment tools show students' level of knowledge, lack of knowledge, relationships between concepts and any misconceptions they may have, as well (Bahar, 2003). Since creating a concept map requires students to define the relationships between concepts, the mapping process is 'a learning experi-

ence on its own' (Jacobs−Lawson & Hershey, 2002). Concept maps provide a photograph of how the basic concepts in a field are organized and structured in the mind of the individual. Similarly, mind maps are a technique that can express the information, thoughts and concepts in the mental structure of the individual visually (Evrekli et al., 2010). Like concept maps, mind maps show all the concepts related to a subject or concept as well as the relationships between them. The image of science concepts in the mind of a pre-service science teacher is of great importance for the correct transfer of the subjects to the students when they start their career. Every pre-service science teacher should learn science concepts fully and be able to correctly express the relationships between concepts in their minds. For this reason, the cognitive structures of pre-service teachers related to basic concepts should be determined in the process of science teaching in higher education institutions. Alternative assessment and evaluation tools should be included in this process. The present study aims to use concept maps and mind maps as assessment and evaluation tools in science education. For this purpose, concept maps and mind maps prepared by pre-service science teachers about a concept were examined. The atom concept, which is one of the basic concepts of both physics and chemistry, was chosen as the main concept in the study. In addition to being an interdisciplinary concept, the atom concept is frequently used in daily life. Therefore, it is important to know how pre-service teachers organize the atom concept in their minds. The study was conducted to quantitatively evaluate the concept maps and mind maps pre-service science teachers prepared related to the atom concept and describe the atom concept in their minds using different assessment tools. In the study, it was examined whether pre-service science teacher knowledge about the concept of atom changes when measured with different assessment and measurement tools. Based on this, the problem of the research is;

Can different alternative assessment and evaluation tools be used to determine how pre-service science teacher structure information about the concept of atom in their minds? It was determined as. Accordingly, answers to two sub-problems were sought in the study:

- What are the scores of pre-service science teacher when they evaluate their knowledge about the concept of atom with a mind map?
- What are the scores of pre-service science teacher when they evaluate their knowledge about the concept of atom with a concept map?

Methods

Design

Case study method, one of the quantitative research methods, was used in this study to determine the cognitive structures of pre-service science teach-

ers about the subject of atoms using concept maps and mind maps. In the case study method, the aim is to investigate the detailed results of a particular situation by examining it in-depth. Case studies are a way of looking at what is actually happening in the environment, collecting data, analyzing data in a systematic way and presenting results. The resulting product is the precise understanding of why the event in question has occurred in that way and what to focus on in more detail for future research (Aytaçlı, 2012; Davey, 1991). This method was used in the present study in order to determine the cognitive structures of the pre-service science teachers about the subject of atoms using different assessment tools.

Study Group

The study was carried out with the participation of 15 pre-service teachers who were coaching the fourth grade of a science teaching department at a state university. Criterion sampling method, one of the purposeful sampling methods, was used for forming the study group. Purposeful sampling makes it possible to select appropriate situations depending on the purpose of the study for in-depth research (Büyüköztürk et al., 2016). Criterion sampling consists of creating sampling units in line with a set of criteria determined by the researcher in advance (Baş & Akturan, 2017). While determining the study group, attention was paid to ensure that the pre-service teachers participating in the study had taken all physics and chemistry-related courses dealing with the subject of atoms in the previous years and they would normally graduate at the end of the fourth grade. Before proceeding with the study, the participants were informed about the subject and process of the same. In addition, permission was obtained from the students to use the concept maps and mind maps they prepared as research documents.

Data Collection Tools and Implementation

The data collection tools used in the study were the concept maps and mind maps prepared by the pre-service teachers. First, the pre-service teachers were informed about the two types of maps. Then, a concept map preparation activity was carried out with the pre-service teachers. Finally, the pre-service teachers were grouped and each group was asked to prepare a concept map related to physics. Similarly, a mind map preparation activity was conducted with the pre-service teachers. Then, the pre-service teachers were asked to prepare a mind map related to physics by assigning them groups. After it was seen that the pre-service teachers could easily create concept and mind map preparation on a new subject, they were asked to create their own concept maps and mind maps related to the subject of atoms. The concept

maps and mind maps created by the pre-service teachers were examined one by one to provide data for the study.

Analysis of the Data

The data collected with the help of concept maps and mind maps were analyzed using quantitative data analysis methods in order to highlight and compare factors such as the number of concepts and links. Structural scoring method was used in the analysis of concept maps prepared by the pre-service teachers. Structural scoring method was defined by Novak and Gowin (1984) and adapted from McClure, Sonak, and Suen (1999). In this scoring method, concept maps are scored based on the number of hierarchical levels, cross links, connections and examples pertaining to them. Every relationship established between the two concepts in a concept map is a proposition. Hierarchical levels are the structures representing the relationships between concepts in the lower and upper levels. Cross links are the relationships established between the concepts at different hierarchical levels. The structural scoring system, adapted by McClure, Sonak, and Suen (1999) and used to evaluate the concept maps in the present study, is shown in **Figure 1**.

The scoring rubric developed by D'Antoni, Zipp and Olson (2009) and adapted into Turkish by Evrekli, İnel and Balım (2010) was used to examine the mind maps prepared by the pre-service teachers. An example of the scoring rubric used in the study is shown in **Figure 2**.

Results

In this section, the findings related to the scores the students obtained from the mind maps and concept maps were examined. The students' scores from the mind maps they created based on the scoring rubric were examined and given in **Table 1**.

When **Table 1** was examined, it was found that the students received points between 30 and 114 from their mind maps and their mean score was 78.07. It was noted that majority of the students scored above the mean score. When the mind maps were examined one by one, it was determined that the students failed to establish cross links and relationships in the mapping process and did not include examples, pictures and symbols at the levels of the mind maps. In addition, when the mind maps were examined one by one, it was seen that the students mostly used the second level concepts, the number of concepts decreased at the third level and they could progress to higher levels. As seen in **Table 1**, some students used wrong concepts while creating map levels. For example, Student No. 3 used the right concepts in the first and second levels of his/her mind map, whereas out of the ten concepts s/he used in the third level, nine were correct and one was wrong.

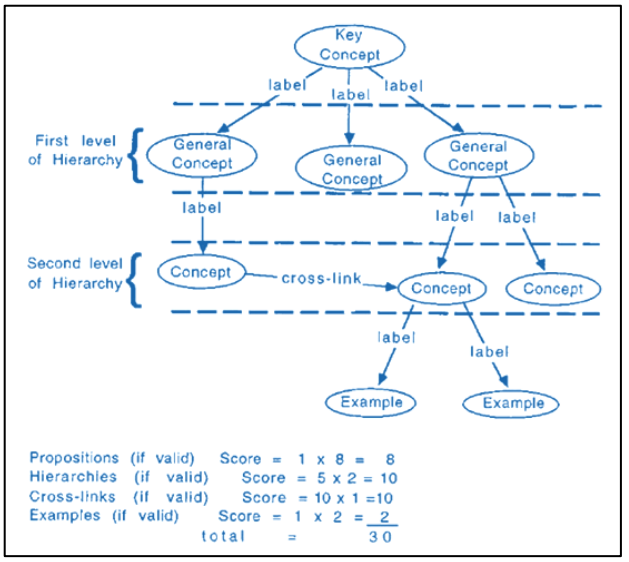

Figure 1. Instructions for the Structural Scoring Method (McClure et al., 1999).

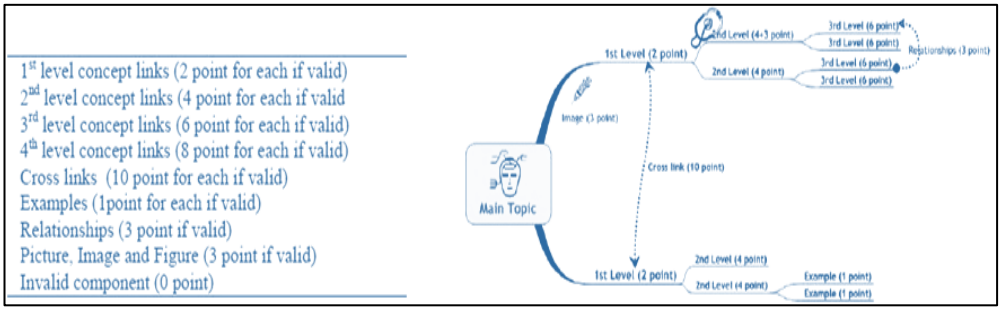

Figure 2. An Example about Scoring Mind Maps (in Mind Manager Program).

The concept maps created by the students were examined and scored one by one according to the structural scoring system, and these scores are given in **Table 2**.

When **Table 2** was examined, it was determined that the scores the students obtained structurally from the concept maps varied between 8 and 43 and the mean score was 22.07. In addition, it was seen from the Table that six students scored above the average and majority of the students received scores close to the average. When the concept maps were examined one by one in **Table 1**, it was determined that the students were able to write a total of 295 propositions, but they could not express the relationships between concepts correctly, and 146 of the propositions were wrong. When the con-

Table 1. The Scores the Students Obtained from Their Mind Maps.

	Concept Links			Cross Links	Examples	Relationships	Picture Symbol	Total Score
Student Number	**1st Level**	**2nd Level**	**3rd Level**					
	C/W*	**C/W***	**C/W***	**C/W***	**C/W***	**C/W***	**C/W***	**C/W***
1	3	12	6	0	0	0	6	108
2	4	8/3	2/6	0	0	0	0	52
3	3	12	9/1	0	0	0	0	108
4	3	15	3	0	0	0	0	84
5	4	15	4	0	0	0	0	92
6	3	13/3	4	0	0	0	0	82
7	4	16	2	0	0	0	0	84
8	3/1	6/2	0	0	0	0	0	30
9	4	19	5	0	0	0	0	114
10	4	13	0	0	0	0	0	60
11	4	8/3	0	0	0	0	0	40
12	4	11	0	0	0	0	0	52
13	4	16	2	0	0	0	0	84
14	4	11	8	0	0	0	0	100
15	3	12	2/1	0	0	0	5/1	81
Mean Score								78.07

**C/W: Correct /Wrong*

Table 2. The Scores the Students Obtained from Their Concept Maps.

Student Number	Proposition		Hierarchy	Cross Link	Example	Total Score
	Correct	**Wrong**				
1	9	14	3	0	0	24
2	5	16	2	0	0	15
3	9	9	2	0	0	19
4	8	14	2	0	0	18
5	16	6	2	0	0	26
6	8	14	2	0	0	18
7	6	22	2	0	0	16
8	9	1	2	0	0	19
9	13	10	3	0	0	28
10	9	12	2	0	0	19
11	8	3	o	3	0	43
12	17	4	2	0	0	27
13	10	12	2	0	0	20
14	16	8	3	0	0	31
15	3	4	1	0	0	8
Total	146	149	31	3	0	331
Mean	9.73	9.93	2.07	0.2	0	22.07

cept maps of the students were evaluated one by one, it was determined that they could not progress further than the 3rd hierarchy. In addition, it was seen in **Table 2** that the students could not write examples and cross links on their maps.

Conclusion

In this study, the concept maps and mind maps prepared by pre-service science teachers were quantitatively assessed in an effort to describe the atom concept in their minds using different assessment tools. As a result of the study, when the mind maps created by the pre-service teachers were examined structurally, it was seen that most of their total scores were above the average. However, it was determined that as the level of mind maps of the pre-service teachers increased, the number of concepts they used decreased. In addition, it was concluded that the pre-service teachers were not successful in providing examples in their mind maps and drawing figures such as pictures and symbols. In the mapping process, the pre-service teachers did not include cross links and relationships between levels.

When the concept maps created by the pre-service teachers were examined structurally, it was determined that their scores were generally close to the average score. It was determined that the number of correct and wrong propositions of the pre-service teachers were also approximate. In addition, it was observed that the pre-service teachers could write many propositions in the 2nd level of hierarchy in their concept maps. The pre-service teachers did not include in their maps cross links between hierarchies and concepts as examples.

In this study, cognitive structures of the pre-service teachers related to the atom concept were assessed using mind maps and concept maps. Based on the tables prepared using the concept maps and mind maps (**Tables 1 and 2**), it was clearly seen whether the relationships that the pre-service teachers established and the propositions they wrote about the concepts were wrong or correct. The wrong or irrelevant concepts of the pre-service teachers could easily be determined in this way and their shortcomings could be identified. The cognitive structures of the pre-service teachers were determined. In addition, final grades of the pre-service teachers were also calculated as a result of the quantitative evaluation. It was concluded that the scores the pre-service teachers got from both alternative assessment and evaluation tools were close to the total average scores. It was observed that the pre-service teachers failed to make progress as the structure of both concept maps and mind maps increased, and they had difficulty in establishing relationships between levels and hierarchies.

Discussion

Concept maps and mind maps are structures that visualize the concepts in students' minds on a particular subject. They facilitate the way relationships between concepts and ideas are organized. It has a visual effect that achieves this in simple terms. With these features, they enable students to express what they have learned clearly, analyze and synthesize their ideas and allow new concepts to be understood quickly and easily (Romero et al., 2017). In this study, when the concept maps and mind maps the pre-service teachers prepared about the subject of atom were evaluated, it was determined that the pre-service teachers could write enough concepts. It was found that the concepts that the pre-service teachers used in their mind maps were generally correct, but they could not correctly place many relationships among the concepts in the concept maps. This result shows that the concepts existed in the minds of the pre-service teachers, but that they were unable to establish relationships between them. This implies that the majority of the participants had knowledge about the atom concept, but had difficulty in creating a concept map. Another reason for this situation may be the fact that the rules for writing propositions for concept maps do not comply with the spelling rules of the Turkish language. This finding is similar to what Ünlü, Kandil and Taşar (2006) reported. In addition, another reason for this shortcoming of the pre-service teachers may be their lack of knowledge about the preparation of concept maps and mind maps. Different studies reported that before the use of mind and concept maps in the learning process, students should be trained for a long time on the creation of visual tools (Evrekli et al., 2010).

Scientific knowledge should be considered as an interconnected and interrelated information network. Students should associate each new topic with existing knowledge and be encouraged to think that way. For this reason, a method which sheds light on the cognitive structure of students facilitates the detection of erroneous concepts and measures meaningful learning to this end is extremely important for teachers (Bahar et al., 2002). There was a decrease in the number of concepts that the pre-service teachers used in their concept maps and mind maps as they progressed to higher levels. It was determined that the pre-service teachers were successful in associating the basic characteristics of the atom concept with each other, but they had difficulties in establishing relationships and writing propositions as their mind maps and concept maps grew. This situation can signify that the pre-service teachers were unable to make in-depth analyses of knowledge as they learned through memorization. In addition, their inability to establish relationships between concepts implies that they failed to engage in meaningful learning. The most important feature of an assessment and evaluation tool is that it can reveal the wrong concepts, lack of information and misconceptions in the cognitive structure. This cannot be done with classical assess-

ment and evaluation tools. Alternative assessment and evaluation approaches that allow the determination of individuals' cognitive structures should be included in the teaching process.

This study was conducted with a small sample. It is recommended that researchers who will conduct parallel studies first use a sample size of more than 30. Based on the findings of the present study, it is suggested that researchers should examine the cognitive structures of students both quantitatively and qualitatively using different methods of assessment and evaluation. Examination of the evaluation process in an in-depth manner by using observation or interview methods regarding their ability to prepare assessment tools is also recommended.

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REVIEW

Protocol-Guided Learning as a Facilitator of the Integration of Project-Based Learning into Chinese Compulsory Education

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***Abstract**: Currently, there are growing conversations about how to successfully integrate project-based learning into regular curricular instruction at the compulsory education level in China. Protocol-guided learning, which originated in Chinese basic education, has proven to be one of the most productive teaching methods in recent decades. It shares comparable educational philosophies with project-based learning and has the potential to compensate for the inadequacy of the latter's application in Chinese compulsory education by providing effective implementation paths for it. The purpose of this article is to reveal the significance of the protocol-guided learning method for the successful implementation of project-based learning in China by pinpointing the issues the project-based learning approach faces, delineating the characteristics of protocol-guided learning, and expounding on its potential roles in supporting the application of project-based learning in Chinese compulsory education schools.*

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THE CURRENT educational reform in China places a high premium on the transformation of learning methods to promote the cultivation of key competencies and all-round development in students. In this context, project-based learning (PBL) has instigated widespread interest and debate in the education world. "*Opinions on Intensifying Educational and Instructional Reform and Comprehensively Improving the Quality of Compulsory Education*," released by the State Council of China (2019), stresses the necessity of introducing PBL in Chinese compulsory education. "*The Compulsory Education Curriculum Program and Course Standards 2022*" (hereinafter referred to as "The New Curriculum Program") underscore the importance of intensifying instructional reform and strengthening practical instruction to foster students' ability to apply knowledge to problem solving and recommend promoting comprehensive learning by introducing teaching strategies such as module-based learning, theme-based learning, and PBL (State Council of China, 2022).

At the same time, Chinese compulsory education schools (including primary and junior secondary schools) are faced with many challenges in applying PBL to their regular teaching, and teachers are making ongoing explorations in an effort to overcome them. Numerous primary and secondary schools have employed the protocol-guided learning (PGL) method, which originated in China more than 30 years ago, as a meaningful experiment of PBL, to varying degrees (Yan, 2023). PGL, based on Chinese educational experiences, has the advantage of suiting the domestic education environment. In the meantime, its emphasis on student autonomy and practical competence conforms to the education philosophy underlying PBL. Using learning protocols to support PBL is likely to help overcome the barriers to its adoption in curricular instruction. This article summarizes the issues with the application of PBL to regular teaching in compulsory education schools, describes the characteristics of the PGL method, and lays out the benefits of integrating PGL into PBL, seeking to provide valuable insights for educators to optimize the application of PBL in China.

Issues with the Application of PBL in Regular Teaching in Chinese Compulsory Schools

PBL, a student-centered instructional strategy, engages students in solving real-world problems or completing specific projects through situated inquiry, practice, and teamwork (Huo, 2023). The Chinese education community has placed a high value on the implementation of PBL in compulsory education. In 2021, the education departments of Fengtai District and Haidian District in Beijing City, Huangpu District in Shanghai City, Jinzhong City in Shanxi Province, and Wenzhou City in Zhejiang Province jointly signed a three-year agreement with Beijing Normal University's China Education Innovation

Institute to establish pilot zones for "regional reform pivoting around PBL for the cultivation of key competences in children" in the said five regions (China.com.cn, 2021). Yet, in practice, PBL poses serious challenges to all actors because it seemingly breaks the original orderly pattern of instruction, disrupts established learning procedures, makes learning outcomes unpredictable, and leaves students to make arbitrary decisions in the learning process on their own (Lyu, 2019).

The Low Fit between PBL and the Current Teaching System in China

PBL, rooted in Western education philosophies and culture, is contradictory to the Chinese teaching system in many ways. Major issues lie in the conflicts between the subject-based instructional system and PBL's interdisciplinary tendency, between the academic results-focused culture and PBL's emphasis on all-round education, and between the established evaluation system and PBL's assessment method.

"*The New Curriculum Program*" explicitly states that the explicit division of subjects in the curriculum forms the basis of teaching at the compulsory education level in China (State Council of China, 2022). Subject-based teaching highlights the importance of the complete knowledge structure of each separate discipline (Li, 2005). On the other hand, PBL requires the integration of multidisciplinary knowledge to facilitate students' reaching solutions to real-world issues. Additionally, PBL demands more diverse, cross-disciplinary education resources, whereas for subject-based teaching, the school tends to deploy assets targeted at each individual subject (Li, 2005). Therefore, how to successfully implement PBL to meet students' needs for integrated knowledge under the current subject-based teaching system is a huge challenge for schools and teachers.

The conflict between the emphasis on academic results in the subject-based teaching system and PBL's focus on competence cultivation is another issue. Chinese compulsory education prioritizes content knowledge delivery to best support students' academic success (Yin, 2021). On the contrary, PBL stresses the development of essential competences through practical exploratory activities such as autonomous inquiry, innovation, critical thinking, and more (Yu, 2023). Yet, it may appear as a disruption to established curricular instruction, compromising students' acquisition of disciplinary knowledge (Yin, 2021). The issue of how to ensure students fulfills the national compulsory education curriculum while simultaneously meeting their needs for competence development by introducing PBL is pending further research.

In addition, there are gaps in the assessment method between the established evaluation system for compulsory education and PBL's evaluation

criteria. Currently, student evaluation at the compulsory education level primarily relies on summative assessments, including quizzes, midterm and terminal examinations, and external high-stakes examinations. Contrarily, formative assessments are central to PBL instruction. The teacher needs to adopt formative assessments to track students' engagement and progress in PBL, as well as the challenges they encounter, in order to give them timely feedback and directions (Zhu, 2023). The absence of formative assessments significantly reduces PBL instruction outcomes. Also, teachers' undeveloped knowledge of PBL assessment criteria is an impediment to achieving PBL's objectives (S. Wang, 2023).

Teachers' Inability to Adapt to New Roles in PBL Instruction

In the traditional classroom, the teacher acts as a provider of knowledge, playing a central role in the process of instruction (Kang, 1986), whereas in a PBL environment, they need to assume more diverse roles, such as research participants, project designer, and PBL manager and evaluator, in addition to being an instructor. These new roles demand higher levels of educational competence and require a student-centered position (Cheng, 2022). According to X. Wang's (2023) investigation into "challenges facing teachers in implementing PBL in mathematics instruction," the majority of teachers had difficulty developing PBL curricula, assessment criteria, and teaching resources, among other matters.

The lack of generalist teachers further complicates the integration of PBL into regular curricular teaching. Generalist teachers' involvement is beneficial to the implementation of PBL. Because of the subject-based teaching system, the vast majority of compulsory education teachers in China are non-generalists with limited interdisciplinary expertise and competence (Liu, 2020). Generalist teachers' education necessitates a special teacher training program that differs from the current mainstream teacher education pattern. The dearth of mechanisms for large-scale generalist teacher training results in the minimal number of these professionals in Chinese compulsory education (Zhang, 2015).

Insufficient Readiness for PBL in Students

PBl poses a serious challenge to students' active learning abilities and skills. Under the traditional transmission-and-acquisition teaching pattern, students are passive receptacles of knowledge; their learning is fraught with textbook-workbook-driven activities. PBL expects students to actively explore and construct knowledge, utilizing their initiative to identify issues, analyze questions, and seek solutions (Zhu, 2023). Central to PBL is students' auton-

omous inquiry, which concerns comprehensive competences including self-directed learning, problem-solving, and critical thinking (Lei, 2023). Due to their dependence on their prior passive role in the classroom, the majority of students have difficulty accommodating the PBL environment in their initial experiments with the new learning model. In addition, compared with traditional learning modalities, PBL requires more input of time and energy on the part of students as it entails a lot of in-person investigations and practical manipulations. Frequently, a PBL activity unfolds in phases over a prolonged duration and involves numerous intricate tasks. Students without a certain measure of perseverance can hardly hold on to the end (X. Wang, 2023).

The History and Characteristics of the PGL Method

The Background of the PGL Method

Based on the principle of "learning by autonomous inquiry," PGL is seen as one of the most significant teaching models in Chinese basic education. It can be traced back to the use of "instruction protocol" initiated in 1996 by Donglu Middle School in Nanjing City, whose mathematics and chemistry teachers adopted "goal-directed teaching" as an instructional reform and developed teaching materials for this purpose, known as "instruction protocols" (He & Xu, 2009).

Inspired by Donglu Middle School's instructional reform, schools across China set about reforming their own classroom instruction to realize mutual promotion of teaching and learning (Xia & Zhou, 2020). In 1998, Dulangkou Junior Secondary School in Liaocheng City, Shandong Province, attempted to morph "instruction protocols" into "learning protocols." Following this instance, other schools undertook comparable teaching reforms, generating a host of learning protocol-based, innovative teaching models, for example, the 271 high-efficiency classroom model of Changle Middle School in Shandong Province, the extended classroom model of Yanzhou No.1 Middle School in Shandong Province, and the module learning model of Tianhui Middle School in Hebei Province, to name a few (Li, 2014). The recent history of classroom instruction in China exhibits a transition from the "teaching protocol-based model" to the "learning protocol-based model," "teaching and learning protocol-integrated model," and "protocol-guided learning model."

The "Compulsory Education Course Standards 2011," released by the Ministry of Education of China (2011), propose to modify the established notions and behaviors of instruction to instigate students' initiative and self-motivation in learning and highlight competence development as a fundamental requirement of the compulsory education curriculum. The course

standards also outline the fundamental procedures and general methods of inquiry-based learning, a recommended key measure for students' competence development. PGL, built on the notion of "learning by autonomous inquiry," was in line with the chief objective of the 2011 curriculum reform. Under these circumstances, the practice and study of PGL took a significant step forward.

Amid the worldwide wave of educational reform in the early 21st century, the Chinese education community made great efforts to modify teaching paradigms and methods, with special emphasis on fostering students' active engagement in learning. This move not only met the actual needs of domestic education but also conformed to the prevailing educational notions across the globe. The U.S. National Science Curriculum Standards advanced the concept of inquiry-based learning earlier in the 1990s (Zhang, 2007). The revised *2000's National Science Education Curriculum Standards* in the UK also reflected a parallel instructional notion (Hu, 2002). Global dynamics in education indicated that learning by autonomous inquiry had been widely recognized as an instrumental strategy for enhancing students' learning gains and fostering their critical thinking and problem-solving abilities. The emergence and development of the PGL model were a reaction to the Chinese education reform as well as a result of drawing on internationally advanced educational concepts. PGL, as a visionary pedagogical method, contributes to the development of a pool of talent with innovative spirit and practical competence in China.

Characteristics of the PGL Method

Protocol-guided learning is now widely accepted as an instruction style in which teachers construct learning protocols for students prior to the session based on course standards, textbook subject matter, and student learning conditions. Typically, these learning protocols include learning goals, materials, methods, and procedures, and instructors use them to lead students toward autonomous learning (Wang, 2022).

The "Four Steps of Guidance" approach is commonly adopted by most schools in their design of learning protocols, which guide students through the whole learning process, from pre-class preparation to classroom inquiry, summary and reflection, and instructional assessment. Each component of the learning protocol pertains to specific objectives. The learning protocol suggests a variety of pre-class learning activities for students to help them integrate into learning situations by presenting familiar concepts and evolving relevant information. It includes specific planning for class activities to guarantee that classroom inquiry is well organized and that the goals of these activities are fulfilled. The following steps of summary and reflection assist students in generalizing approaches and constructing knowledge

structures. Every step of the student learning process, including self-directed learning, problem-solving, mastery of learning methods, and knowledge consolidation after class, incorporates the instructional assessment process (Wang & Zhu, 2022).

In PGL, teachers do not directly impart knowledge to students but rather guide them to inquire and practice independently; the primary purpose of PGL is to enhance students' capacities and skills through student-centered and teacher-led classroom learning (Wang, 2022). The learning protocol not only provides students with basic learning materials and teachers with an instruction framework, but it also serves as a guide for student learning by restructuring textbook substances with well-designed questions that allow them to inquire in an organized and sensible manner. Well-structured learning protocols optimize learning by increasing students' initiative and self-motivation (Wang & Zhu, 2023). Specifically, the PGL method has the following features:

Focusing on Student All-Round Development to Meet the Requirements of "The New Curriculum Program"

Underpinning the PGL method is the principle of education for the all-round development of students, which is the overarching goal of "The New Curriculum Program." It supports student holistic development by fostering students' comprehensive competences and changing the roles of teachers in the classroom. The Ministry of Education of China (2022) claimed that the reformatory aims of "The New Curriculum Program" are threefold: (i) to prioritize the development of key competences for students' lifelong growth and social adaptation, particularly the capacity to solve problems in real-world situations; (ii) to optimize the arrangements of curriculum delivery by revising the traditional categorization of knowledge and integrating curriculum subject matter through theme-, project-, and task-based learning; (iii) to increase the weight of practical education by engaging students in inquiry-based activities, which give them the chances to experience the complete process of spotting the problem, applying prior knowledge, working out solutions, and constructing new knowledge such that they develop and upgrade their understanding of the world on the basis of practice.

Restructuring Textbook Subject Matter with Meaningful Questions to Support Student Autonomous Learning

Learning could be monotonous and boring in a traditional classroom featuring the transmission-and-acquisition style. To make it more engaging and productive, the PGL model requires curriculum designers to restructure

teaching materials with meaningful questions, a crucial strategy for PGL. This strategy can successfully turn students from passive learners into active explorers by piquing students' interest in learning and increasing their critical thinking and autonomous learning abilities, thus significantly improving teaching outcomes (Wang, 2022). Well-designed questions not only make the learning process engaging and inspiring but also provide clear directions to students (Yu & Xia, 2020). To address these questions, students need to actively seek out relevant material, analyze information, and even validate their answers with experiments. In this process, the student develops new knowledge and, more importantly, learns how to learn. According to Lin's (2023) case study of PGL in junior secondary physics education, the use of learning protocols was highly effective in enhancing students' autonomous learning capacities. Among student participants, 85.29% claimed that the regular application of PGL in physics instruction resulted in their more efficient mastery of key concepts in this subject.

Customizing Learning Routes and Providing Diverse Education Resources for Students

The PGL model takes effect through well-crafted learning protocols that contain explicit learning goals, materials, and procedures. Learning protocols provide students with highly efficient learning routes to guide their reading, thinking, and practice (Zhang, 2023). In the traditional education paradigm, the learning routes are often homogeneous among various groups of students. In contrast, with learning protocols, the teacher can prepare legitimate learning routes for students in light of their actual cognitive levels and learning conditions, as well as the teacher's instruction objectives. Such routes can lead students to conduct in-depth, effective inquiry. Furthermore, learning protocols provide students with a wealth of information essential for in-depth learning, often overlooked by textbooks (Liu, 2022). The teacher can leverage all sorts of channels to enrich students' learning materials; these colorful learning materials can take various forms such as text, images, audio, and videos (Li, 2023). Richer learning resources help students comprehend knowledge in historical and cultural settings and give them diverse perspectives on the same knowledge, substantially broadening their knowledge horizons and boosting their enthusiasm for learning. In X. J. Wang's (2023) lesson study of "*Appreciating Patterns and Decorations: Using Shanghoumuwu Cauldron as an Example*," the instructor created a learning protocol that led students' learning route from observing the patterns on the bronze Shanghoumuwu Cauldron throughout drawing national cultural characteristics from the artifact. In order to assist students in gaining a better understanding of the meaning of its patterns, the teacher provided a wealth of

materials on the cauldron, including videos, images, and interactive games; students could discretionarily select those that suited their interests and needs.

Normalizing Inquiry-Based Learning in a Teacher-Led and Student-Centered Classroom Setting

In a PGL classroom, there is a marked shift in the teacher's roles: from an authority of knowledge to the class participant; from a lecturer of knowledge to the learning facilitator and guide (Zhao, 2023). Meanwhile, the PGL model transitions students' learning methods from passively accepting lectures to actively participating in group activities like conversations, debates, and collaborative inquiry (Zhang, 2023). As a result, inquiry-based learning becomes the norm in the PGT classroom, where students delve into certain questions or issues to fulfill exploratory tasks (Li, 2021). Regular inquiry-based learning helps foster students' critical thinking and problem-solving abilities, laying the groundwork for their future academic research and professional development.

Emphasizing the Connection between Learning and Practice and Promoting Learning through Evaluation

Learning and practice are of equal importance for students' mastery of knowledge. Adequate practice helps internalize theoretical knowledge, making its application possible (Yang, 2020). In PGL, the learning protocol includes a reasonable number of pre-class exercises for students to conduct self-directed learning in order to prepare them for the learning objectives and main challenges of the session (Wang, 2023). It also provides well-selected after-class exercises for students to consolidate new knowledge and generate necessary extensions (Li, 2021). The purpose-built combination of learning and practice facilitates the development of textbook knowledge into practical competences in students.

Additionally, the PGL method emphasizes harnessing evaluation and assessment to boost learning outcomes. Not only do assessments occur on a periodic basis to gauge students' academic performance, but they also permeate every stage of their learning journey, enabling teachers to monitor each student's learning progress and enabling students to promptly adjust their study methods for enhanced efficiency and effectiveness (Zhang, 2022).

The Potential Roles of PGL in Integrating PBL into Regular Teaching in Chinese Compulsory Education

Bridging the Gap between PBL and the Current Teaching System in China

The most pronounced challenge of PBL's application in Chinese compulsory education stems from the conflicts between PBL's interdisciplinary tendency and focus on student competence development, and the Chinese subject-based curriculum's primary attention to student academic results. The use of PGL's learning protocols has the potential to bridge the discrepancies between PBL and China's current teaching system. Firstly, students can use learning protocols to build an interdisciplinary knowledge framework and prepare a necessary knowledge background and skill repertoire for PBL execution. The integration of multidisciplinary knowledge using learning protocols enables students to master the basic content knowledge of various subjects as well as develop cross-disciplinary competences (Kang, 2014). The teacher can utilize learning protocols to select relevant subject matter for specific PBL activities based on their respective themes. Such well-designed learning protocols will help students build solid knowledge foundations for curricular subjects and, in the meantime, develop in-depth understandings of the connection and interaction between different strands of knowledge. Second, the process of collaborative inquiry in PGL can serve as a rudimental PBL experiment to help students adapt to the problem-solving-focused PBL style. For Deng's (2023) study on the experiment of the teaching method of "learning protocols plus group cooperative study" in secondary biology education, the results and interviews showed that this way of teaching made students much more interested in studying biology, more aware of collaborative learning, and surer of their communication, critical thinking, and practical exploration skills. Third, PGL-based, structured learning can compensate for the inadequacies of the established compulsory education teaching system by progressively directing students towards more competence-focused learning while also supporting them in achieving academic success. Guo's (2023) empirical research with pre- and post-tests found that the use of learning protocols contributed to reducing the gaps in academic achievements between members within a class while improving their social and emotional skills.

Bolstering the Effects of PBL in Regular Teaching

The absence of meaningful driving questions and formative assessment mechanisms in the curriculum design of Chinese compulsory education contributes significantly to the less-than-ideal results of PBL instruction. There is a great chance that incorporating PGL's learning protocols will significantly enhance the effects of PBL in primary and secondary classrooms. First, the deployment of well-designed questions to restructure textbook sub-

ject matter is a prominent feature of learning protocols. In preparing the learning protocol, the teacher formulates meaningful questions based on thorough analyses of teaching materials, students' life contexts, and social concerns; these questions can elicit deep contemplation and exploration interest among students. For instance, in Ma's (2023) study of the learning protocol for the all-present $CaCO_3$, the teacher asked questions that got the students interested in exploring the idea of $CaCO_3$ and helped them meet the course standards' learning goals in both the preparation before class and the classroom inquiry parts of the protocol. Thus, leveraging learning protocols to provide effective driving questions for PBL activities can render PBL instruction more targeted and productive.

Furthermore, PGL's emphasis on promoting learning through built-in evaluation at every stage of learning could make up for the inadequacy of formative assessments in PBL in Chinese schools. With the learning protocol, the teacher can make a comprehensive, objective appraisal of the whole process of the student's learning by administering the before-class test, observing their in-class inquiry performance, and evaluating the groupwork results. In the study, Ma (2023) used before-class questions to assess students' prior knowledge of $CaCO_3$ and make corresponding adjustments to the teaching strategies for the forthcoming class study. Likewise, based on the evaluation of student in-class performance, after-class activities were assigned to consolidate their understanding of $CaCO_3$. Formative assessments like these could be used as valuable references for establishing evaluation mechanisms for PBL in Chinese compulsory education classrooms.

Assisting Teachers in Fulfilling Their New Roles in a PBL Environment

A major challenge of PBL for teachers is the transition of their roles from knowledge preachers (common in traditional teaching modalities) to class participants, designers of cross-disciplinary projects, and managers of the PBL programs. The introduction of the PGL method can facilitate the transition, helping teachers meet the requirements of PBL instruction. First, by creating learning protocols for a PBL activity, the teacher establishes learning goals and routes as a framework for students' autonomous inquiry. In this process, the teacher naturally becomes a guide for student inquiry. The PGL method gives full play to students' agency in the classroom, making changes to the unilateral, cramming way of instruction (Wang, 2024); it strengthens the connection between teaching and learning and makes it possible for the teacher and students to collaborate to complete the PBL program in a highly efficient manner. Second, PGL's learning protocols play a supporting role in the teacher's construction of cross-disciplinary learning projects. By designing learning protocols in advance, the teacher has the

chance to thoroughly screen knowledge of relevant disciplines and integrate it into an interdisciplinary program. Third, the PGL method helps teachers better manage and evaluate the PBL process. In PBL, the teacher needs to follow up and assess the progression in a timely manner, which is not always easy because of the openness and flexibility of PBL. However, with the aid of learning protocols, which specify learning goals and tasks, the teacher can track students' progress in their PBL program clearly and instantly. The evaluation results generated by the learning protocol are an important consideration for the teacher's instruction planning (Zhou & Li, 2020).

In addition, the application of the PGL method in PBL instruction gives impetus to teacher professional development. The teacher needs to research new educational ideas and teaching strategies in endeavoring to integrate the PGL method into PBL, which places them in a better position to accommodate the current educational and instructional reforms. Moreover, the school's learning protocols for a specific course are often the results of the collective efforts of a group of teachers. That means the incorporation of PGL in PBL instruction is beneficial for promoting inter-teacher communication and cooperation (Xia & Zhou, 2020).

Supporting Student Autonomous Learning in the PBL Paradigm

Through activities involving practical manipulations and group collaboration, PBL fosters students' autonomous learning and teamwork abilities. It is a challenge for students without sufficient levels of self-regulation, perseverance, and teamwork competence. The adoption of the PGL method in PBL instruction can help students better adapt to this challenging education paradigm. First, PBL tasks are mainly concerned with active, self-directed exploration. The before-class learning protocol in PGL provides students with opportunities to research background information and relevant knowledge on the PBL questions on their own, paving the way for their active engagement in the PBL activity. Tang's (2023) lesson study of the learning protocol for teaching velocity found that students became more perceptual of velocity by watching a race on video or reenacting a race before class. They also learned how to convert between different forms of the velocity unit by doing learning tasks outside of class, which made their participation in the next classroom inquiry more active and useful. Second, students with the habit of self-directed learning often do better in PBL in that it requires students to use their initiative to seek out material, analyze underlying issues, and design investigations. The goal-directed nature of PGL happens to be effective in helping students develop the habit of self-directed learning. In his study of learning protocols for Chinese language education, Shi (2017) emphasized the importance of specifying learning goals in the protocol and advanced the

three-dimensional goal-setting approach characterized by three questions: "What do I want to reach?" "What can I do?" "What new ideas can I bring forth?" This approach drove students to delve deeper into the text voluntarily and made their learning more targeted. Third, the majority of PBL activities necessitate student collaborative inquiry to reach solutions to real-life issues. Inquiry-eliciting questions and tasks are the paramount components of PGL's learning protocols, which often need to be addressed through group efforts. Such learning protocols are beneficial for encouraging collaborative exploration in PBL. In her study on learning protocols for teaching essays on natural scenery tours in Archaic Chinese, Yang (2022) found that well-designed group tasks, such as group investigation and group contest, significantly enhanced students' deep understanding of Archaic Chinese and their internalization of traditional Chinese culture.

Conclusion

Against the backdrop of the advancement of Chinese education reform, there is a growing trend towards integrating PBL into its compulsory education curriculum, despite the serious challenges it faces. The incorporation of the PGL method can breathe new life into the practice of PBL in Chinese classrooms by supporting the restructuring of curriculum subject matter, providing explicit learning goals and routes, encouraging autonomous learning and in-depth probe, and more. A more widespread use of the PGL method has the potential to further advance the application of PBL in Chinese compulsory education and contribute to creating an educational climate that promotes student all-round development.

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REVIEW

Difficulties with the Application of Project-Based Learning in Chinese Compulsory Education

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***Abstract**: In China, the recent compulsory education curriculum reform in 2022 set the enhancement of student comprehensive competence and practical capacities as its overriding goal. Project-based learning (PBL), as an effective approach to cultivating students' holistic competence, has garnered wide attention. Nevertheless, there are challenges in the application of PBL in Chinese compulsory education, impeding its popularization and application outcomes. This article focuses on delineating the difficulties with the integration of PBL into regular teaching, aiming to provide implications for promoting its application among compulsory education teachers.*

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Introduction

IN THE context of in-depth research into the development of comprehensive student competence across the globe, project-based learning (PBL) has garnered extensive attention from the Chinese education community in recent years (Ke, 2023). "*The Compulsory Education Curriculum Program and Course Standards 2022*" emphasizes the importance of intensifying teaching reform and strengthening practical instruction to foster students' ability to apply knowledge to problem solving. The revised curriculum program also recommends promoting comprehensive learning in students by introducing teaching strategies such as module-based learning, theme-based learning, and PBL (State Council of China, 2022). The new curriculum program and the development of 21st century skills have highly advocated PBL as a fresh teaching and learning paradigm in Chinese compulsory education.

PBL is a student-centered instructional strategy aimed at connecting academic learning with real-world situations through authentic research questions and scenarios (Liang, 2023). Its application has the potential to become a breakthrough in the reform of education in the new era. However, PBL, being a "non-native" teaching approach, does not align well with the current compulsory education system in China, leading to numerous issues with its implementation in regular teaching. This article focuses on analyzing the difficulties with the integration of PBL into curricular instruction with a view to providing implications for enhancing PBL's application at the compulsory education level.

The Evolution of PBL

The development of PBL was distinguished by three major stages. William Heard Kilpatrick developed the earliest form of PBL, known as the "project method," in the early 20th century, based on his progressive education theory. It advocates allowing the student to explore and experience their environment through their senses, as well as directing their own learning according to their individual interests. This teaching approach views the teacher more as a facilitator than as a provider of knowledge and information (Kilpatrick, 1918). PBL's second stage was based on the theory of constructivist learning, which suggests that learners construct their understanding through experiences and social interaction instead of passively accepting knowledge through direct instruction. Krajcik & Blumenfeld (2006) emphasized the creation of artifacts as an external representation of the PBL process, facilitating the assessment of learning gains. In the early 21st century, hybrid project-based learning (H-PBL) emerged on the basis of connectivism. H-PBL uses modern technology to improve PBL results through online and offline blended learning, to make teachers and students more effective in the classroom,

and to support cross-disciplinary activities that help students connect what they've learned (Chua & Islam, 2021).

In the late 20th century, the Chinese education community successfully drew attention to PBL due to its innovative nature. Since then, Chinese compulsory education has extensively experimented with PBL. *Project-Based Learning Design: International and Domestic Applications of PBL from the Perspective of Student Learning Competence*, authored by Xia (2018), provided valuable theoretical guidance for the application of PBL in China. The Ministry of Education of China (2019) proposed to actively implement task-driven learning, project-based learning, problem-based learning, and collaborative learning in basic education in "Opinions on Strengthening and Modifying Experimental Instruction in Primary and Secondary Schools," giving impetus to the popularization of PBL in China. In 2020, the Shanghai Municipal Education Commission (2020) issued "*The Three-Year Action Plan for Implementing Project-Based Learning in Compulsory Education (2020-2022)*," which marked the regional, systematic introduction of project-based learning in China. The "*Compulsory Education Curriculum Program and Course Standards 2022*" says that theme-based and project-based learning must be used in primary and junior secondary schools. This shows that the government of China supports the widespread use of PBL across the country (State Council of China, 2022).

The Characteristics of PBL

A PBL classroom is a student-dominated one where students engage in collaborative investigations to explore real-world issues and seek out solutions to specific questions (Huo, 2023). Often, a PBL activity is centered around a driving question and enacted in an authentic scenario with the aim of helping students fulfill a prescribed learning goal (Lyu, 2023). In the process of project enactment, students have the opportunity to modify their investigations using their independent judgment to ensure the successful completion of the project (Jia, 2022). The main features of PBL can be summarized as follows:

Meaningful Driving Questions: A well-selected driving question is a key component of PBL. Typically, teachers derive the driving question from an authentic situation, which effectively piques students' interest in inquiry. It should be sufficiently challenging to suit learners' cognitive levels. A meaningful question motivates students to use their prior knowledge in problem solving while also constructing new knowledge (Huo, 2023).

Explicit Learning Goals: The design of PBL activities is directed by concrete learning goals specified in the curriculum. When preparing and implement-

ing the project, the teacher must keep the specific objectives and learning outcomes in mind (Sun, 2023).

Interdisciplinary Learning: PBL entails multidisciplinary subject matter and a wide range of information and skills, necessitating the restructuring of teaching materials and interdisciplinary coordination (Liu, 2023).

Tangible Products: PBL requires the generation of tangible products of knowledge construction. They are publicly accessible representations such as reports, videos, and models, subject to continuous improvements based on feedback (Yang, 2023).

Challenges of PBL in Regular Curricular Instruction in Chinese Compulsory Education

The Chinese education community places high value on PBL, and regional efforts to integrate it into the compulsory education curriculum are considerable, such as the Shanghai Municipal Education Commission's (2020) introduction of "The Three-Year Action Plan for Implementing Project-Based Learning in Compulsory Education (2020-2022)." Nevertheless, many issues have surfaced in the practical application of PBL in primary and junior secondary schools. In a PBL environment, teachers abandon established classroom procedures, transition from progressive study to seemingly unstructured learning, replace predictable learning with an unpredictable process, and replace assigned schoolwork with autonomous inquiry (Lyu, 2019). Radical changes like these are huge challenges for teachers and students alike. There are various complications in integrating PBL as an instructional strategy into the current curriculum program.

Conflicts between the Subject-Based Teaching System and PBL's Interdisciplinary Tendency

The subject-based teaching system has taken the lead for decades in Chinese compulsory education. Following the enactment of the Compulsory Education Law of China, the National Education Commission (the precursor of the Ministry of Education) released the "*Nine-Year Compulsory Education Curriculum Program for Full-Time Primary and Junior Secondary Schools (Trial)*" in 1993, which clearly stipulates that the basic education curriculum be implemented through subject-based teaching. Subsequently, it issued syllabuses for the 24 subjects included in the program (Li, 2005). "*The Compulsory Education Curriculum Program and Course Standards 2022*" provides

standards for 16 subjects, indicating adherence to the subject-based teaching paradigm (Ministry of Education of China, 2022).

The subject-based teaching paradigm emphasizes the complete structure of the curriculum and the individual value of each separate subject, aiming to develop students' disciplinary knowledge and skills through the independent instruction of each subject. However, the rigid division of subjects narrows the overall vision and knowledge of students and constrains the breadth of their thinking (Qiao, 2021). Conversely, PBL aims to dismantle subject boundaries and integrate all essential information and techniques, enabling students to solve real-world problems (Li, 2005). It aims to cultivate students' comprehensive competencies, encompassing creativity and critical thinking skills.

Also, there are distinctive gaps in teaching methods between the traditional subject-based paradigm and PBL. The former is more likely to adopt the transmission-and-acquisition style, focusing on optimizing students' academic progress, whereas the latter pivots instruction around big ideas or pressing issues and engages students in situated inquiry to help them construct new knowledge. As a result, the teacher has difficulty balancing the requirements of the subject-based curriculum and the interdisciplinary teaching method in implementing PBL instruction (Yin, 2021). How to ensure the building of solid knowledge foundations in students and, in the meantime, to follow the pedagogical methodology of PBL is a challenge to the teacher.
According to the subject-based teaching paradigm, the school uses resources that are specific to that subject (Hu, 2023). On the other hand, PBL uses a wider range of resources, such as teaching materials from different subjects, experimental equipment, and support from specialists (Lei, 2023). Due to the limitations of the school's facilities, PBL's requirements for teaching resources are often unmet.

Inadequacies in PBL Design

Despite PBL's benefits as an advanced teaching notion and strategy, its practical applications in Chinese compulsory education classrooms have exhibited many inadequacies, among which the superficiality of driving questions and a lack of pertinent assessment and feedback are the most pronounced problems.

In PBL instruction, a proper driving question is the precondition for the effectiveness of the project, contributing to inspiring students' motivation for inquiry and leading them to in-depth contemplations (Jin, 2023). First off, the hallmark of PBL is its intimate connection with real-world situations, which requires meaningful driving questions that are effective in stimulating students' interest in authentic issues in society (Zhong, 2023). However, in practice, many teachers tend to pose overly theoretical driving questions that

lack real-life relevance, failing to elicit students' genuine concerns and engagement in the learning process. Furthermore, systematic implementation of PBL necessitates the creation of a well-structured cluster of driving questions that ensure the fulfillment of curriculum requirements (Zhong, 2023). Nevertheless, a portion of teachers, with insufficient understanding of PBL or experience in PBL teaching, have shown arbitrariness in designing driving questions for their PBL instruction. Questions as such make learning fragmentary and disorderly, depriving students of the chance of developing structured knowledge and competences (Mao, 2023).

Effective evaluation and feedback are an integral part of a PBL activity. Formative assessment, widely acknowledged as the most beneficial evaluation tool for PBL, focuses on students' engagement, progress, and the challenges they encounter during the learning process (Lin, 2023). Nonetheless, Chinese compulsory education teachers tend to neglect formative assessment in PBL instruction, resulting in a disconnection between evaluation and the teaching process, which is unfavorable for their timely adjustment of implementation strategies and substantially compromises the teaching outcomes of PBL activities (Huang, 2023). At the same time, in Chinese PBL classrooms, there is a lack of explicit, specific evaluation criteria for multidimensional PBL assessment, which entails multiple aspects of student performance such as their contribution to the project, teamwork spirit, problem-solving ability, etc. (Jiao, 2023). That makes it impossible for the teacher to give pertinent feedback on the students' PBL engagement or a reliable, objective appraisal of their PBL products (Zuo, 2021).

In Wang's (2023) survey on the assessment methods adopted by Chinese mathematics teachers in their PBL classrooms, 40% of teachers polled reported that they gave regular feedback to the class, timely summarizing and commenting on students' achievements; only 25% said that they managed to give feedback to individual students. In response to the question about the completeness of the current evaluation framework for mathematics PBL, 60% of teachers stated that it was acceptable but needed improvements; 40% said it was immature and incompatible with the actual teaching situations.

Insufficient PBL Instruction Capacities of Teachers

In traditional teaching practices, the teacher plays pivotal roles as the center of the classroom and the provider of knowledge (Kang, 1986). In PBL, the teacher has additional roles as the PBL curriculum designer, the project manager and evaluator, and the students' collaborator, in addition to being the knowledge imparter. However, a large portion of Chinese compulsory education teachers have difficulty accommodating these new roles, retarding the integration of the PBL method into regular instruction. Also, the shortage

of generalist teachers at the compulsory education level further exacerbates the issue.

In a PBL environment, the teacher needs to break the traditional transmission-and-acquisition pattern and realize a transition from a teaching-centered to a learning-centered position (Cheng, 2022). This requires the teacher to have plural competences in identifying core disciplinary ideas, restructuring teaching materials, and designing PBL programs, as well as managing the classroom in a decentralized manner. When the majority of teachers have not developed sufficient competences like these, the school has the responsibility to provide them with the necessary professional training and guidance that pertains to PBL instruction. Without organizational support, the teacher can hardly adapt to the new teaching paradigm that comes with PBL (Zhang, 2023). According to Wang's (2023) investigation of "challenges of PBL in mathematics instruction," 80% of teachers surveyed had problems with PBL curriculum design and 65% with assessment of PBL outcomes; 60% were reluctant to adopt PBL due to a lack of experience in this regard; and 55% complained of the scarcity of resource backing from the school.

Furthermore, the dearth of generalist teachers in China is another unfavorable factor for the application of PBL in its compulsory education schools. PBL, with interdisciplinary instruction as its key feature, demands that teaching staff have a multidisciplinary knowledge repertoire. The successful practice of PBL in the U.S. is closely related to the stable supply of generalist teachers in this country. Data show that there were 1,078,000 million generalist teachers in the American public primary schools in the 2011–2012 academic year, representing 62.46% of the total teaching force in the public elementary education system (Tao, 2021). The history of Chinese generalist teachers is a different story. There were once a considerable number of generalist teachers in China's rural areas in the last century, where there were acute shortages of teaching staff and every teacher had to teach several subjects (Li, 2020). As the universalization of compulsory education improved, the rural teacher supply saw a significant increase, and the number of generalist teachers underwent a radical fall. Currently, Chinese preservice teacher education is based on a rigid division of disciplines, leading to teachers focusing on developing expertise in a certain specialty but having little knowledge of interdisciplinary instruction (Huang, 2023). In this context, schools have difficulty recruiting generalist teachers qualified for cross-disciplinary teaching when introducing PBL instruction.

The Challenges of PBL for Compulsory Education Students

PBL is a student-centered teaching approach. It seeks to help students develop capacities for self-directed learning, cooperation and collaboration, innovation, and problem solving while acquiring necessary curricular knowledge. Despite its numerous benefits, PBL seriously challenges students' competence in many ways.

First off, PBL requires a fundamental change in the learning methods of students. Under the traditional chalk-and-talk teaching pattern, students are passive receptacles of knowledge; all they need to do is memorize and comprehend information imparted by the teacher (Zhang, 2021). Yet, in PBL, they must adopt a more proactive approach to learning. They must use their initiative to identify issues, analyze questions, and experiment with solutions (Lei, 2023). This is difficult for students who have become accustomed to the long-established teacher-dominated classroom pattern. They may feel left alone all of a sudden and have no idea how to engage. Additionally, students struggle to adjust to the interdisciplinary learning method due to their familiarity with subject-specific learning (Luo, 2023). In Geng's (2021) research on "the status of project-based learning assisted by educational technology" based on four primary schools in Shenyang City, teacher X from C School said that students who could well accommodate the PBL method had fun in the very first PBL activity, whereas others needed longer time to adjust themselves to the new learning method, after which they could understand what PBL was really about and ascertain their new roles in the PBL classroom.

Furthermore, PBL imposes higher requirements on students' comprehensive competences, including self-directed learning, problem-solving, and critical thinking (Lao, 2023). Central to PBL is students' autonomous inquiry. Students need to seek out, analyze, and apply information independently. Due to their dependence on their prior passive role in the classroom and inadequacy in autonomous learning ability, the majority of students may have difficulty finding and leveraging resources in their initial PBL activities (Jia, 2023). Equally important in PBL are students' problem-solving skills. Real-world issues typically serve as the context for PBL. Developing solutions to these issues involves a series of processes, such as investigating problems, raising hypotheses, formulating, and executing plans (Guan, 2023). Students without these practical skills may benefit little from PBL. Also noteworthy is the importance of students' ability to make independent, critical evaluations of information in PBL (Zhu, 2023). Students who rely on established answers and notions are at a disadvantage in a PBL environment, where they are expected to make informed decisions on their own. In Yang's (2023) survey on "issues with the management of interdisciplinary project-based learning in primary schools," students polled scored the lowest on the items related to PBL learning environment and resource management, exhibiting low readiness for engaging in PBL.

In the meantime, the ability to maintain a sustained interest in and involvement in challenging tasks is also essential for students' successful fulfillment of PBL activities. As opposed to traditional learning patterns featured by textbook-workbook-driven activities, PBL entails a lot of in-person investigations and practical manipulations on the part of students, substantially increasing their input of time and energy (Geng, 2021). Furthermore, students often complete a PBL program in stages over an extended period of time, engaging in a variety of complex tasks that require a significant level of perseverance. Students prone to giving up in the face of difficulty and challenges have little chance of reaching the expected outcomes of PBL (Tian, 2023). In his research on "the status of project-based learning assisted by educational technology," Geng (2021) discovered through interviews that a PBL activity not only occupies a few scheduled sessions but also includes many after-class group discussions and preparations, which largely heightens students' workloads. That seriously put students' perseverance to the test.

Conclusion

PBL, an innovative instructional strategy aimed at fostering students' comprehensive competences, is of vital significance for intensifying Chinese education reform. There are many obstacles to overcome in integrating it into the compulsory education curriculum. The current subject-based teaching system needs modifications to become more flexible and open to accommodating PBL. Training on teacher PBL instruction should be strengthened to better serve the genuine purpose of PBL. Targeted assessment and evaluation mechanisms should be developed to ensure effective implementation of PBL. It is also important to adapt the curriculum management and school schedules to PBL to instigate active, sustainable engagement among students. The application of PBL as a regular part of the compulsory education curriculum is promising. What is needed is continuous exploration and experimentation to create educational environments that facilitate PBL implementation as well as student all-round development.

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