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Education for a Sustainable Future: Transition from Environmental Education to Sustainability Education

Alan C.K. Cheung

The Chinese University of Hong Kong, Hong Kong 999077, China

"We don't have to engage in grand, heroic actions to participate in change. Small acts, when multiplied by millions of people, can transform the world."
–Howard Zinn

THE mid-20th century witnessed an accelerated economic development in industrialized countries as a product of the scientific and technological advances. In the meantime, environmental deterioration intensified in the process of development. The ongoing emergence of environmental issues and public hazards awakened people to the fact that the improper exploitation of the environment and ecology is threatening human existence and development. The increased needs to protect and ameliorate the environment have instigated a plurality of environmental education programs.

Lucas (1972) classifies environmental education into three basic classes: education about, for, and in the environment. Educational programs designed to provide information concerning the environment is classified as "education about the environment." Their objectives are mainly cognitive such as comprehension and interpretation of environmental data; synthesis of explanations of an environmental phenomenon; and evaluation of environmental data and phenomena as well as the possible consequences of human manipulations. The programs of "education for the environment" aim to support the preservation or improvement of the environment by inculcating values and attitudes of environmental conservation for the continuation of human life and enhancement of the quality of human life. As the goal of education for the environment is to produce better environment, this category of programs also provides citizens with necessary skills, either professional or general, and intellectual or practical, to achieve this end. By contrast, "education in the environment" is characterized by the use of a particular pedagogical technique. In most cases of this class of environmental education, "environment" usually refers to "outside the classroom."

The 1992's United Nations Conference on Environment and Development held in Rio de Janeiro, Brazil, officially announced the strategy of sustainable development. "Reorienting education towards sustainable development" was listed as one the action plans in its document "Agenda 21". The critical role of education in promoting sustainable development and improving the capacity of people to address environment and development issues was emphasized (United Nations, 1992). In 1997, the UNESCO's International Conference on Environment and Society: Education and Public Awareness for Sustainability released "*Declaration of Thessaloniki*," which reaffirmed that appropriate education and public awareness should be recognized as one of the pillars of sustainability together with legislation, economy, and technology; and that the reorientation of education as a whole towards sustainability should involve all levels of formal, non-formal and informal education in all countries (UNESCO, 1997). Subsequently, sustainable development-oriented environmental education has been incorporated in the national strategy of education development by many countries.

Currently, despite all individuals being impacted by environmental degradation to varied degrees and most of them developing deeper concern for the sustainability of human development, public knowledge and understanding of relevant issues remains inadequate (Reid, 1995). Enhancing sustainability literacy has the potential to increase their ability to form sustainable lifestyles and to engage in environmental conservation. The cultivation of sustainability literacy requires profounder research into its nature. *The Correlation Between Dimensions of Sustainability Literacy: The Case of British and Turkish Students* in this issue aimed to investigate the interrelationships between sustainability attitude (SA), sustainability behavior (SB), and sustainability knowledge (SK), the three crucial dimensions of sustainability literacy and discovered that there are positive correlations between them (Ozdemir, 2024). It makes a significant contribution to the literature by elaborating on the interrelationships between sub-dimensions of SA, SB, and SK, which were revealed as being more complicated than had been generally assumed.

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COMMENTARY

Propelling High-quality Development of Education: The Promotive Role of Educational Research

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"Do not wait for extraordinary circumstances to do good action; try to use ordinary situations."
–Jean-Paul Richter

EDUCATION, by common consent, is a sophisticated endeavor. As human society advances, people impose increasingly high standards for the quality of education. Educational research has been instrumental in driving educational development and optimizing the function of education. In its broad sense, educational research spans investigations, observations, experiments, systematic discourse and comparative analyses of all phenomena, issues, technologies, strategies, and paradigms arising in the field of education as well as cross-disciplinary studies that relate to education. In its narrow sense, educational research is mainly concerned with education and teaching activities at all levels of schooling (Wang, 1999).

The rise of educational research worldwide was since the turn of the 20th century. In Europe, for example, Sweden established its educational research and development bureau in 1926; England and Welsh set up the national educational research foundation in 1947; France established its national education research institute in the 1960s; Spain built its national educational research center in 1969 (Gretler, 2007). In the United States, the Congress enacted the "2000 Goals: American Education Act" in 1994, which stipulated in Article 9 that the Department of Education establish the Office of Educational Research and Improvement to strengthen the management, popularization, and funding of educational research in primary and secondary schools; to provide educational research training programs; and to improve the quality of teaching in public schools to reach national education goals (Heise, 1994). Japan's Educational Employees Special Law provides that educational personnel have the responsibility to constantly undertake educational research to enhance their professional competence. All types of educational research agencies have been set up in and out of schools in Japan, including the National Institute for Educational Policy Research (Dong, 2005).

In the meantime, chief international organizations have also engaged heavily in educational research to reach thorough understanding of the status quo of global education, provide specific advice to nations around the world, and formulate strategies to coordinate and promote the development of education in various countries. These international organizations include the Organization for Economic Cooperation and Development, the European Council, and United Nations Educational, Scientific and Cultural Organization, among others, having played a significant role in the research and formulation of education policies for the global community (Huang, 2011)

Teacher professional development necessitates organizational support as well as personal endeavor. According to Thomas et al. (1998), contemporary teacher education places a greater value on the “learning community” than on individualistic effort. Teachers should see peer support as an important resource for personal career development and seek to broaden professional horizons through collegial interaction. Education and teaching research provide teachers with opportunities to continuously upgrade their professional competence in a learning community and consequently, enhance the quality of education.

Each country’s educational research system has its own national characteristics, varying in the scale, components, and structure. It has typically gone through basic processes such as initiation, development (localization), and institutionalization. As a country with the largest-scale basic education system and biggest number of teachers in the world, it is particularly important for China to build an educational research system that suits its national conditions. After more than 70 years of exploration, China has successfully developed its five-level education and teaching research system (ETRS), based on its national education experiences (Qi & Hu, 2019).

China’s five-level ETRS is an integral part of its powerful basic education system. *The Five-level Education and Teaching Education System: A Distinctively Chinese Research Mechanism for Basic Education* in this issue gives a relatively complete picture of the evolution of the system and pinpoints its functions and advantages (Zhou, 2024). It facilitates our understanding of the unique value of the ETRS in promoting high-quality development of education and teacher professional development in China. We believe that the article can also provide implications for the worldwide development of educational research.

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ORIGINAL ARTICLE

The Correlation between Dimensions of Sustainability Literacy: The Case of British and Turkish Students

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***Abstract**: The acquisition of the competencies of sustainability literacy through education requires an understanding of how sustainability literacy is shaped. In this connection, in the current study, the interaction between the following dimensions of sustainability literacy was investigated; SA (sustainability attitude), SB (sustainability behavior) and SK (sustainability knowledge). The study was conducted as a survey study on university students in the UK and Turkey within the context of a project entitled "Ecological Literacy Education" and supported by TUBITAK (Turkish Scientific and Technological Research Organization). The participants (n:1023) of the study are students attending several departments of Plymouth University in the UK and Mugla Sitki Kocman University in Turkey. The data were collected by using the Scale of Sustainability Literacy and analyzed using AMOS version 24. Although it was understood that there were mutual and positive correlations between the dimensions of sustainability literacy, it was revealed that the correlations between some sub-dimensions of these dimensions showed variation. The results of the study are expected to contribute to revealing the interaction between the dimensions of sustainability literacy in more detail and accordingly to the effectiveness of sustainability education.*

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***Keywords:** Sustainability, Sustainability Literacy, Sustainability Education, Sustainability Attitude, Sustainability Behavior, Sustainability Knowledge*

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Conflict of Interests: *None*

Introduction

TODAY, conventional environmental education, which focuses on a person's perspective on and behavior towards nature, is evolving into sustainability education aimed at fostering a more harmonious and equitable coexistence with nature. In this regard, the current study attempts to elucidate the interaction among the specified dimensions of sustainability literacy, which has become humanity's vision for the future.

The transition in light of sustainable development goals (SDGs) of the UN (UNESCO, 2017) requires an effective sustainability education which can enhance sustainability literacy of person (Sterling, 2004, p. 6). The scope and meaning of environmental literacy was extended to sustainability literacy due to transition from environmental education to sustainability education recently (Sterling, 2004, p50). Seen from this perspective, sustainability literacy also implies the ability for a sustainable future rather than environmental literacy. In this sense, sustainability literacy was defined as a broad competency for transition toward sustainability (Orr, 1992; Parkin et al., 2004, p. 9; Roth, 1992; Stibbe & Launa, 2014, p. 11; Winter & Cotton, 2012).

The acquisition of sustainability literacy is needed to understand the nature of sustainability literacy in more detail. However, there is also a gap in the literature in terms of examining the interaction between the dimensions such as sustainability attitude, sustainability behavior and sustainability knowledge. Thus, the current study focuses on the examination of the interaction of the dimensions of sustainability literacy such as SA (sustainability attitude), SB (sustainability behavior) and SK (sustainability knowledge).

Literature Review

Interrelationship between the dimensions such knowledge, attitude and behavior of sustainability education has been examined by several studies.

From the early 1970s, it was assumed that there was a linear relationship between knowledge, attitude and pro-environmental behavior (**Figure 1**) and the reason of the discrepancy between them was explained through the deficit model (Burgess et al., 1998, p. 1447)

However, this simplistic assumption was not confirmed by further studies because the change of pro-environmental behavior is influenced by different dynamics (Kollmus & Agyeman, 2002). Numerous studies have showed that there is a gap between attitude and pro-environmental behavior (Kollmus & Agyeman, 2002). Rajecki (1982) explains the discrepancy between attitude and pro-environmental behavior by factors such as direct versus indirect experience, normative influences, temporal discrepancy and attitude-behavior measurement.

Figure 1. Early Models of Pro-Environmental Behavior.

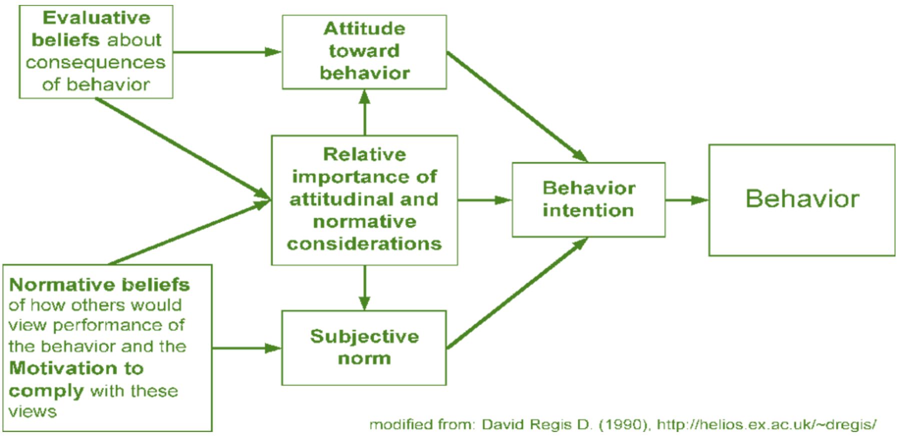

Figure 2. Theory of Reasoned Action (Ajzen & Fishbein, 1980).

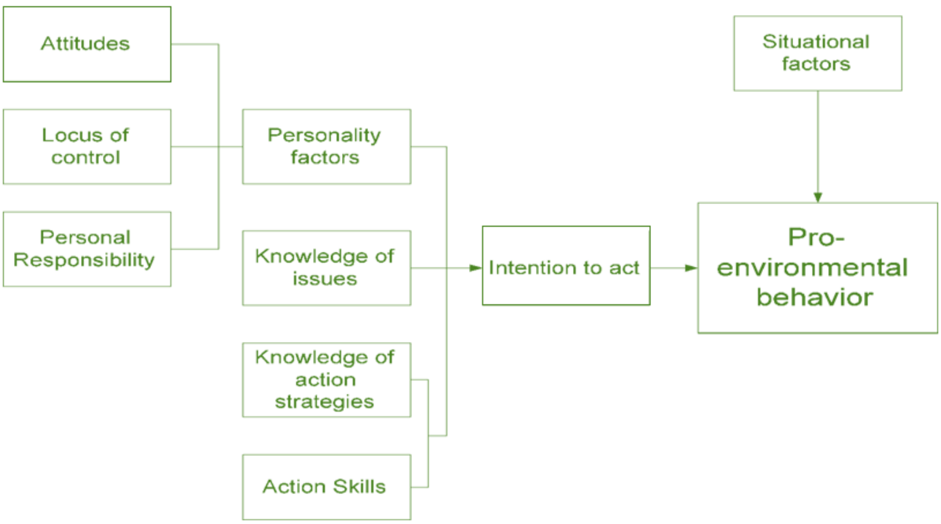

Figure 3. Models of Predictors of Environmental Behavior (Hines et al., 1986).

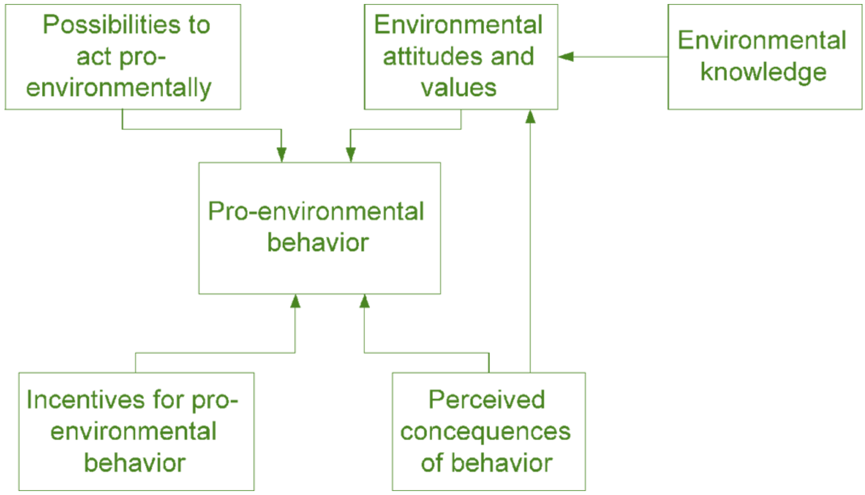

Figure 4. Model of Ecological Behavior (Fietkau & Kessel, 1981).

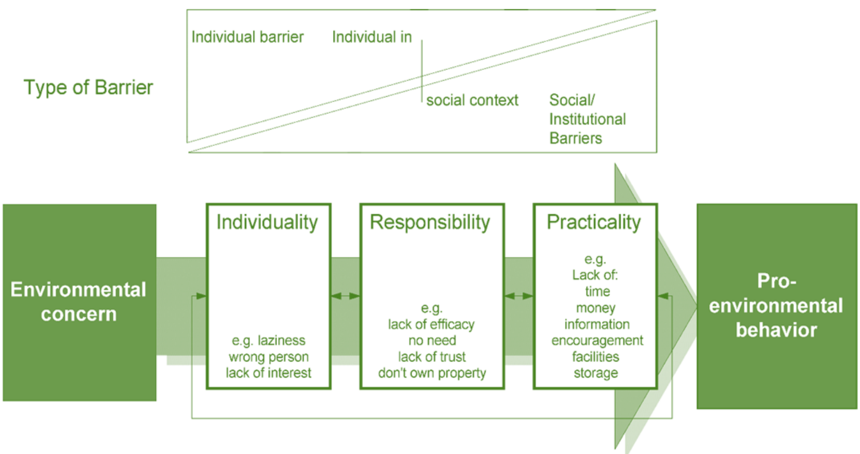

Figure 5. Barriers between Environmental Concern and Action (Blake, 2007).

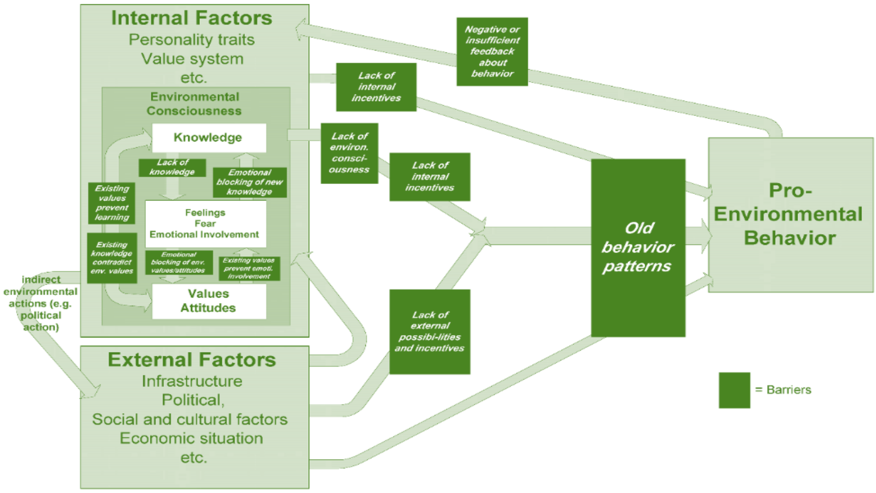

Figure 6. Model of Pro-Environmental Behavior (Kollmuss &Agyeman, 2002).

Numerous approaches have been employed to explain the influences on environmental behavior. In this regard, the dynamics of environmental behavior were tried to be explained through theories such as Reasoned Action (**Figure 2**) and Planned Behavior (Ajzen & Fishbein, 1980)

The approach of reasoned action has become one of the most influential models in social psychology due to its usefulness and has guided empirical studies to understand the nature of the behavior, particularly environmental behavior.

Furthermore, early in the 1990s, Hines et al. (1987) proposed the Model of Responsible Environmental Behavior (**Figure 3**) which shows the influence of the most common predictors on pro-responsible behavior such as knowledge, locus of control, attitude, verbal commitments and individual sense of responsibility. This model is the most common approach that has directed the studies and training on environmental education.

The nature of environmental behavior has also been tried to be explained through other approaches such as altruism, empathy and pro-social behavior models (Eisenberg & Miller, 1987; Lehmann, 1999, p. 34). These approaches are based on the following hypotheses (Kollmuss & Agyeman, 2002):

Fietkau & Kessel (1981) tried to explain the pro-environmental behavior with the model of ecological behaviour (**Figure 4**).

On the other hand, Blake (1999) tried to explain the nature of environmental behavior focused on value (**Figure 5**). According to him, the attitude-behavior gap regarding environmental issues stems from the Value-Action Gap.

Lastly, Kollmuss & Agyeman (2002) developed a comprehensive model which explained the predictors of environmental behavior in light of internal and external factors as follows (**Figure 6**). According to this model, the internal and external factors influence each other and ultimately, pro-environmental behavior.

Furthermore, the interaction between the dimensions such as knowledge, attitude and behavior regarding to environmental literacy has been investigated by numerous studies. In this regard, it is seen that environmental knowledge is a significant predictor of responsible environmental behavior (Alkaher & Goldman, 2018; Amaoka, & Dzogbenuku, 2020; Chu et al., 2007; Hsu & Roth, 1998; Liu et al., 2020; Teksoz, et al., 2012). On the other hand, several studies have reported a significant correlation between environmental attitude and environmental behavior (Bomberg & Moser, 2007; Chu et al., 2007; Paço & Lavrodor, 2017; Shafiei & Maleksaeidi, 2020; Teksoz et al., 2012) and a significant correlation between knowledge and attitude (Amaoka & Dzogbenuku, 2020; Liu et al., 2020; Veisi et al, 2018).

Rationale, Purpose and Research Questions

As shown in the literature, numerous factors can predict the environmental behavior. In general, studies take into account the environmental behavior as a final outcome and investigate its predictors. On the other hand, the terminology dominating the literature involves the terms of environmental education and environmental literacy. Today, the evolution of environmental education into sustainability education requires the transformation of the terminology related literature towards sustainability.

From this point of view, this study investigated the interrelationship between the dimensions of sustainability literacy such as "sustainability attitude (SA)", "sustainability behavior (SB)", "sustainability knowledge (SK)" via a cross-national comparison between Turkish and British students.

The following questions were investigated in this study:

1. How do the dimensions of sustainability literacy including sustainability knowledge (SK), sustainability attitude (SA) and sustainability behavior (SB) interact with each other?
2. Which consistencies or discrepancies are there between the sub-dimensions of each dimension?

Table 1. Participants.

		f	%
Nationality	British (1)	522	51.0
	Turkish (2)	498	48.6
Gender	Female (1)	665	64.8
	Male (2)	351	34.2
Place of Residence	Urban (1)	629	61.4
	Rural (2)	392	38.3
Department	Health and Medicine (1)	218	21.3
	Social Sciences (2)	235	22.9
	Environmental Sciences (3)	186	18.1
	Education (4)	222.	21.7
	Sciences (5)	81	7.9
	Engineering and Computer (6)	81	7.9
Total		1,023	100

Materials and Methods

The study was designed as descriptive research that aims to investigate the interrelationship between the dimensions of SA, SB and SK of sustainability literacy via a cross-national comparison.

Participants

The study sample was drawn from British and Turkish students (n: 1023) who were studying in different departments at University of Plymouth in the UK and Mugla Sitki Kocman University in Turkey. Some demographic information of the participants is presented in the **Table 1**:

Instrument

The sustainability literacy scale used for data collection was developed in English as a part of TUBITAK project by Ozdemir (2021). The scale consists of the dimensions of “sustainability attitude (SA)”, “sustainability behavior (SB)”, “sustainability knowledge (SK)” and “sustainable perception (SP)”. The current study was conducted considering the first three dimensions (SA, SB and SK) in the scale.

The scale of sustainability literacy limited to the dimensions of SA and SB has a Cronbach’s alpha reliability coefficient of 0.839. The validity of the dimension of sustainability knowledge (SK) was checked by taking the experts' recommendations into consideration. As a result, it was confirmed that the content of the items in the sub-dimensions of knowledge concurs with the relevant literature.

Sustainability Attitude (SA)

The dimension of sustainability attitude (SA) consists of a Likert-type scale items (n: 14) and includes sub-dimensions that are entitled as "concern/worried (SA1)", "social responsibility (SA2)" and "locus of control (SA3)". The items of SA in the scale assess the responses via self-report of participants in terms of the extent to which they agree with the related statements having five possible response options ('1' = strongly disagree, '2'=disagree, '3' = have no opinion, '4' = agree, '5' = strongly agree).

Sustainability Behavior (SB)

The dimension of sustainability behavior (SB) includes Likert-type items (n: 16) having the following response options; ('1'= never, '2' = very seldom, '3' = sometimes, '4' = often, '5' = almost always). The SB was designed to have the sub-dimensions of "consumption pattern (SB1)", "household use (SB2)" and "participation (SB3)".

Sustainability Knowledge (SK)

The dimension of sustainability knowledge (SK) consists of multiple-choice and close-ended questions (n: 11), which address fundamental ecological processes and principles (SK1, SK2, SK3, SK4, SK5), natural sources- human use (SK6, SK7, SK8) and environmental problems/issues (SK9, SK10). The correct response to each item was scored as "1" while the incorrect response was scored as "0".

Analyses

In order to answer the research questions, SEM (Structural Equation Modelling) was utilized in AMOS version 24. First, based on the previous research findings, a hypothesized model was created; then, the hypothesized model was tested to examine the harmony of the parameter estimates with previous research findings. In order to explore the strengths of the causal relationships among the components, the standardized estimates were examined.

Findings

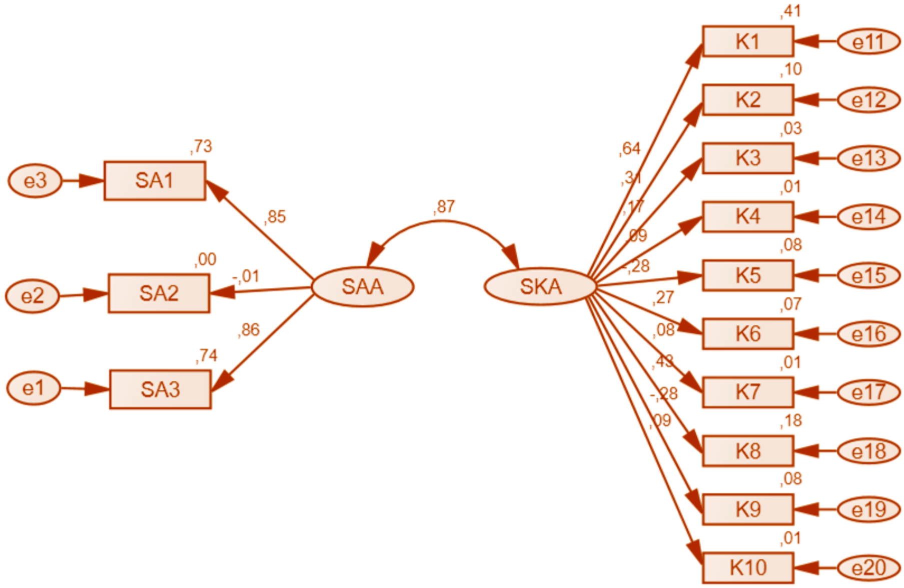

Figure 7. The Relationship between Sustainability Attitude (SA) and Sustainability Knowledge (SK).

Table 2. Correlation between the Dimensions of SA (Sustainability Attitude) and SK (Sustainability Knowledge).

			Estimate
SA1	<-->	SK	-0.046
SK	<-->	SA2	-0.012
SK	<-->	SA3	0.112
SK	<-->	SA	0.221

Table 3. Goodness of Fit Indices.

	χ^2/df	GFI	CFI	NFI	RMSEA
Acceptable fit	< 5	> 0.85	> 0.85	> 0.85	< 0.08
Model	4.021	0.957	0.887	0.856	0.054

The Interrelationship between Sustainability Attitude (SA) and Sustainability Knowledge (SK)

The first research question was "Is there any significant relationship between sustainability attitude (SA) and sustainability knowledge (SK)" of the participants. The proposed model is given in **Figure 7** below.

As indicated in **Figure 7** and **Table 2**, there is a positive and significant correlation between the SA and SK of the participants ($r = 0.87$; $p < 0.05$). To check the model fit, goodness of fit indices (GFI) were used. Goodness of fit indices can be seen in **Table 3**.

In this study, χ^2/df, GFI, comparative fit index (CFI), normed fit index, (NFI) and root mean square error of approximation (RMSEA) were used. To have a fit model, χ^2/df should be less than 5, GFI, CFI and NFI should be above .85, and RMSEA should be less than .08 (Schreiber et al., 2006). As **Table 3** shows, all the goodness of fit indices are within the acceptable range; therefore, the validity of the model is acceptable.

The Interrelationship between Sustainability Attitude (SA) and Sustainability Behavior (SB)

As indicated in **Figure 8** and **Table 4**, there is a positive and significant correlation between sustainability attitude and sustainability behavior of the participants ($r = 0.352$; $p < 0.05$). In addition, there is a positive and significant correlation between SA1 (*concern/worried*) and SB1 (*consumption pattern*) ($r = 0.352$; $p < 0.05$), between SA2 (*Social responsibility*) and SB1 (*consumption pattern*) ($r = 0.177$; $p < 0.05$), between SA2 (*social responsibility*) and SB2 (*household use*) ($r = 0.101$; $p < 0.05$), between SA2 (*social responsibility*) and SB3 (*participation*) (r = 0,166; $p < 0.05$), between SA3 (*locus of control*) and SB2 (*household use*) ($r = 0.102$; $p < 0.05$) and between SA3 (locus of control) and SB3 (*participation*) ($r = 0.462$; $p < 0.05$).

On the other hand there is a negative and significant correlation between SA1 (*concern/ worried*) and SB2 (*household use*) (r = - 0,067; $p < 0.05$), between SA1 (*concern- worried*) and SB3 (*participation*) (r = - 0,076; $p < 0.05$) and between SA3 (*locus of control*) and SB1 (*consumption pattern*) (r = - 0,317; $p < 0.05$).

To check the model fit, goodness of fit indices (GFI) were used. Goodness of fit indices can be seen in **Table 5**.

In this study, χ^2/df, GFI, comparative fit index (CFI), normed fit index (NFI) and root mean square error of approximation (RMSEA) were used. To have a fit model, χ^2/df should be less than 5, GFI, CFI and NFI should be above 0.85, and RMSEA should be less than 0.08 (Schreiber et al.,

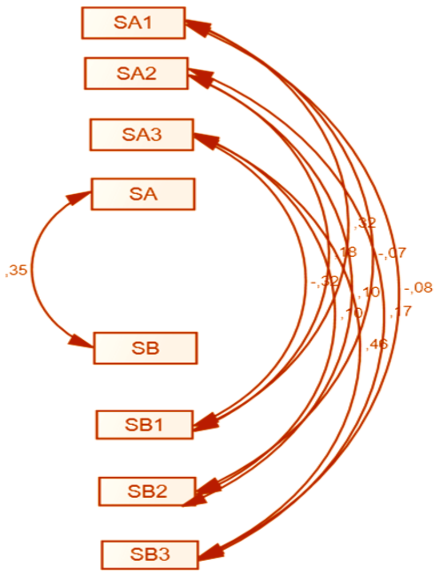

Figure 8. The Relationship between Sustainability Attitude and Sustainability Behavior.

Table 4. Correlation between the Dimensions of SA (Sustainability Attitude) and SB (Sustainability Behavior).

Variables	SA1	SA2	SA3
SB1	0.323	0.177	-0.317
SB2	-0.067	0.101	0.102
SB3	-0.076	0.166	0.462

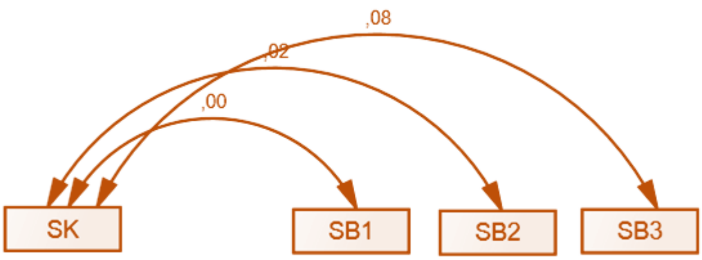

Figure 9. The Relationship between Sustainability Behavior and Sustainability Knowledge.

Table 6. Correlation between the Dimensions of SK (Sustainability Knowledge) and SB (Sustainability Behavior).

			Estimate
SB1	<-->	SK	-0.003
SK	<-->	SB2	0.018
SK	<-->	SB3	0.084

Table 7. Goodness of Fit Indices.

	χ^2 / df	GFI	CFI	NFI	RMSEA
Acceptable fit	< 5	> 0,85	> 0.85	> 0.85	< 0.08
Model	4.250	0.958	0.796	0.878	0.056

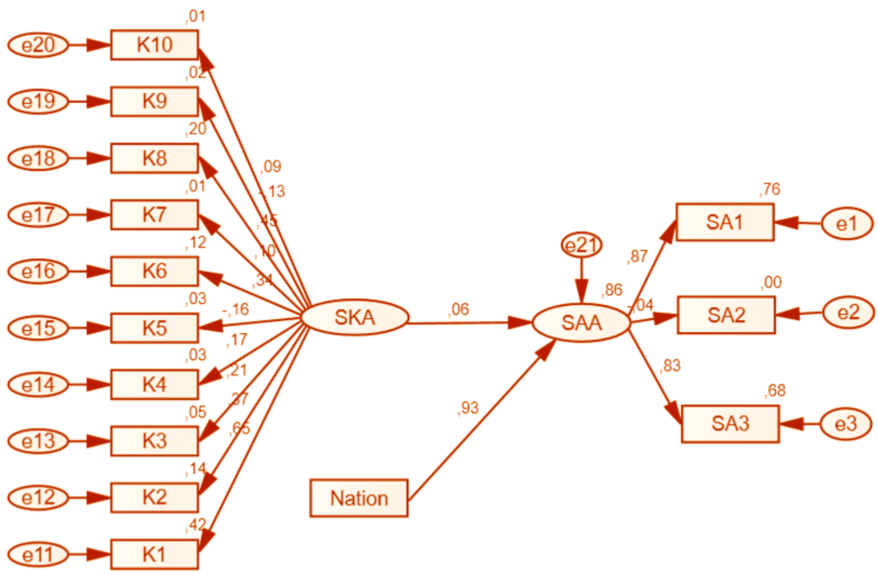

Figure 10. The Model of the Interrelationships between Sustainability Knowledge, Sustainability Attitude and Nation.

2006). As **Table 5** shows, all the goodness of fit indices are within the acceptable range; therefore, the validity of the model is acceptable.

The Relationship between Sustainability Knowledge (SK) and Sustainability Behavior (SB)

As indicated in **Figure 9** and **Table 6**, there is a positive and significant correlation between sustainability behavior (SB) and sustainability knowledge (SK) of the participants ($r = 0.084$; $p < 0.05$). On the other hand, there is no significant correlation between sustainability knowledge and SB1 (consumption pattern) ($r = - 0.003$; $p < 0.05$) and sustainability knowledge and SB2 (household use) ($r = 0.018$; $p < 0.05$). To check the model fit, goodness of fit indices (GFI) were used. Goodness of fit indices can be seen in **Table 7**.

In this study, χ^2/df, GFI, comparative fit index (CFI), normed fit index, (NFI) and root mean square error of approximation (RMSEA) were used. To have a fit model, χ^2/df should be less than 5, GFI, CFI and NFI should be above 0.85 and RMSEA should be less than 0.08 (Schreiber et al., 2006). As **Table 7** shows, all the goodness of fit indices are within the acceptable range; therefore, the validity of the model is acceptable.

The Relationships between Sustainability Knowledge (SK), Sustainability Attitude (SA) and Nationality

As indicated in **Figure 10**, the two independent variables of SK and nationality are strong predictors of attitude: SK ($\beta = 0.07$, $p < 0.05$) and nationality ($\beta = 0.93$, $p < 0.05$). As the **Figure 10** shows, nationality is the strongest predictor of attitude. In other words, the two independent variables predict attitudes of the participants in a positive and significant manner. To check the model fit, goodness of fit indices (GFI) were used. Goodness of fit indices can be seen in **Table 7**.

In this study, χ^2/df, GFI, comparative fit index (CFI), normed fit index, (NFI) and root mean square error of approximation (RMSEA) were used. To have a fit model, χ^2/df should be less than 5, GFI, CFI and NFI should be above 0.90, and RMSEA should be less than 0.08 (Schreiber et al., 2006).

As **Table 8** shows, all the goodness of fit indices are within the acceptable range; therefore, the validity of the model is acceptable.

As indicated in **Figure 11**, the two independent variables are strong predictors of behavior: SA ($\beta = 0.17$, $p < 0.05$) and nationality ($\beta = 0.23$, $p < 0.05$). As the figure shows, nationality is the strongest predictor of behavior. In other words, the two independent variables predict behaviors of the participants in a positive and significant manner. To check the model fit, good-

Table 8. Goodness of Fit Indices.

	χ^2/df	GFI	CFI	NFI	RMSEA
Acceptable fit	< 5	> 0.90	> 0.90	> 0.90	< 0.08
Model	3.856	0.955	0.934	0.913	0.053

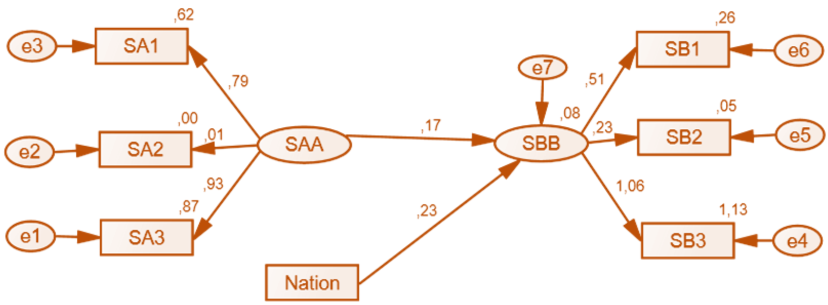

Figure 11. The Model of the Interrelationships between Sustainability Attitude, Sustainability Behavior and Nation.

Table 9. Goodness of Fit Indices.

	χ^2/df	GFI	CFI	NFI	RMSEA
Acceptable fit	< 5	> 0,90	> 0.90	> 0.90	< 0.08
Model	3.516	0.932	0.921	0.918	0.038

ness of fit indices (GFI) were used. Goodness of fit indices can be seen in **Table 9**.

In this study, χ^2/df, GFI, comparative fit index (CFI), normed fit index, (NFI) and root mean square error of approximation (RMSEA) were used. To have a fit model, χ^2/df should be less than 5, GFI, CFI and NFI should be above 0.90 and RMSEA should be less than 0.08 (Schreiber et al., 2006).

As **Table 9** shows, all the goodness of fit indices are within the acceptable range; therefore, the validity of the model is acceptable.

Discussion and Suggestions

Sustainable literacy seems to be a new competence framework that can pave the way for the transition to a sustainable future. When the relevant literature is reviewed, it is seen that the background of the subject consists mainly of studies investigating the emergence of environmental behavior. In this context, since the creation of the first model by Burgess et al. (1998) where they argued that environmental knowledge determines environmental attitudes, and in turn, environmental behavior, the emergence of environmental behavior has been attempted to be explained through various models. However, these models have focused on identifying the determinants of environmental behavior as the primary outcome, rather than explaining the mutual interaction between environmental knowledge, environmental attitude and environmental behavior. Unlike these models, Kollmuss & Agyeman (2002) have attempted to elucidate how environmental behavior is shaped more clearly on the basis the mutual interaction of the relevant determinants.

However, it is an undeniable fact that as environmental education has evolved into sustainability education, there is still insufficient clarity regarding what sustainable literacy is and how it is formed. Thus, the current study explored the mutual interaction between the dimensions of sustainable literacy through a comparative analysis of the scores of Turkish and British students.

When the findings of the study are generally evaluated, it is seen that there is a positive and significant correlation among all the dimensions of sustainability literacy (SK, SA and SB). At first glance, this situation suggests that there is a mutual and positive relationship between the dimensions of sustainability literacy. However, it is important to note that the correlation among the sub-dimensions of these dimensions varies. Indeed, some sub-dimensions have positive correlations while others show negative correlations and some show no correlation.

For instance, the absence of a significant and positive relationship between the SA (*sustainability attitude*) dimension and its SA1 (*concern/worried*) and SA2 (*social responsibility*) sub-dimensions with the SK (*sustainability knowledge*) dimension suggests that the positive relationship between these two dimensions may be driven by the SA3 (*locus of control*) sub-dimension. Similarly, the negative correlation between the SA1 (concern/worried) sub-dimension of the SA (*sustainability attitude*) dimension with the SB1 (*consumption pattern*) and SB2 (*household use*) sub-dimensions suggests that the positive correlation between these dimensions may be influenced by the SB3 (*participation*) sub-dimension.

Research findings show that there are mutual and quite complex interactions between the dimensions of sustainability literacy. This situation bears a significant similarity to the explanations regarding the nature of the mutual and complex interactions between environmental knowledge, environmental attitudes and environmental behavior since the 1970s. In the current study, the determination of mutual relationships between the dimensions of sustainability literacy and their sub-dimensions is parallel particularly with the model proposed by Kollmuss & Agyeman (2002). This is because the model proposed by Kollmuss & Agyeman (2002) specifically emphasizes that environmental behavior is shaped by a highly complex and cyclical interaction of numerous internal and external factors.

On the other hand, when examined more closely, the absence of a positive correlation among certain sub-dimensions of the sustainability literacy dimensions, which were found to be positively correlated with each other, also indicates a gap and mismatch between the relevant dimensions. This situation is supported by studies that particularly indicate that there is not always harmony and consistency between environmental knowledge, environmental attitudes, and environmental behaviors (Kollmus & Agyeman, 2002; Rajecki, 1982).

In the study, the understanding that the nationality variable plays an important role in the correlation between SA and SB highlights the necessity of international comparative studies in sustainable literacy research and education because the transition to a sustainable future can only be achieved through effective communication and cooperation at a global level.

As suggested by the “deficit model” put forward in the 1970s, it was envisaged that the gap between environmental knowledge, attitude and behavior would be closed through information and education. However, it is increasingly understood that in most cases, being informed about the environment is not enough to exhibit a corresponding attitude and act in this direction, and that environmental behavior is shaped within a complex process involving many factors.

Further research is needed on different target groups in order to better understand the interaction between the components of sustainability literacy and to gain sustainability literacy competencies through sustainability education. The detection of a negative correlation between some sub-dimensions of the dimensions of sustainability literacy as a result of the study suggests that different variables may be effective in the interaction between these dimensions. In this context, when the economic, psychological, social, cultural and other aspects of the subject are considered from a broader perspective, the nature of the complex interaction among the dimensions of sustainability literacy should be comprehensively elucidated.

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ORIGINAL ARTICLE

The Views of Students Regarding the Use of Virtual Reality Applications in Elementary Science Classes¶

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Abstract: *Recently, Virtual reality (VR) technologies have started to be used increasingly in the field of education, as in many other fields. With the widespread use of virtual reality applications, there is a need to investigate the effects of virtual reality applications in the field of education. The results obtained from these researches can contribute to the creation of effective and efficient virtual reality-supported learning environments. VR applications, one of the technology-supported learning environments, come to the forefront to help students learn concepts more easily and permanently. Since VR is very new and not a common practice in classrooms yet, it is necessary and important to investigate how VR can be used in science lessons and students' views on these practices. The main goals of this study were to develop the Virtual Reality Solar System Model (VRSSM) for the unit "Sun System and Eclipses" for the 6th grade students and to find out what the students think about using virtual reality applications in science classes. This is a qualitative study and 16 students participated in this study and used the VRSSM. The semi-structured interview form was used as a data collection tool. The data was analyzed using content and descriptive analysis. The results of this research revealed that the students want VR to be used not only in science lessons but also in other lessons, they think that the knowledge they have gained is permanent and that they believe that this application can increase their science achievement. Additionally, students think that the application increases their interest in science lessons and affects their learning positively. Therefore, it is expected that the results of this research will lead to the creation and implementation of three-dimensional virtual reality learning environments related to various subjects and levels of science teaching.*

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Introduction

PEOPLE'S habits of using technology change quickly due to the rapid advancement of technology, such as virtual reality (VR) and augmented reality (AR), and this development necessitates differentiation and change of learning environment. Virtual reality is a computer-generated environment that allows users to interact by activating their senses, creating the illusion that they are immersed in the created world (Okul & Şimşek, 2020).According to Tanrıkulu and Karagöl (2021), virtual reality is a growing field of study that is being investigated in both academic and business fields. In addition, the mobile technology and entertainment industries have made significant investments in virtual reality systems. Furthermore, major mobile device and phone manufacturers include virtual reality hardware in their products, and virtual reality glasses and hardware are increasingly being integrated into game consoles. Sezgin (2016) discusses Facebook's investment in virtual reality, foreseeing significant societal attention in the future. He highlights Facebook's pivotal role in this technology, suggesting it will become a major focus in the evolving landscape. There have been significant developments in the field of metaverse recently, and this field is now open to many sectors including education. Virtual reality systems, which are widely accepted and allow students to experience phenomena and concepts that are difficult to learn in a traditional educational setting, are also expected to bring new perspectives and benefits to educational processes. These systems, which were previously difficult to access due to their high cost and hardware shortcomings, are now developing rapidly in a variety of industries, most notably entertainment and medicine and these deficiencies are eliminated to a certain extent (Bayraktar & Kaleli, 2007). Gürsoy (2020) stated in his research that in business sectors with difficult and dangerous conditions, such as mining, virtual reality technology can be used to simulate very close to real-world conditions, while training can be conducted safely and without causing harm to the learners or their environment.

The importance of taking advantage of these opportunities in numerous disciplines grows with time, and it is critical to research issues that are difficult to learn or do in normal classrooms. At the same time, these systems are extremely effective at concretizing abstract concepts due to the much visual materials they have, integrating them into the education environment is essential (Aktamış & Arıcı, 2013). According to Kandemir and Demir (2020), virtual reality improves concept learning by providing learners with rich experiences that connect and varied feedback, correlating easily with real-world situations, allowing learners to engage with the virtual world, and amusing them as they study. Since the structure of the primary school science curriculum currently in practice in Turkey is based on constructivist learning theory and inquiry-based approach (Ministry of National Education, 2018), creating learning environments that allow students to actively participate in the learning process and enriching it with technology becomes even more important. In this context, learning environments enhanced with technology such as virtual reality, augmented reality, educational digital games, and gamification are thought to play an important role in ensuring active participation of students in lessons and inquiry-based learning. Virtual reality applications can improve and enhance the educational environment and other fields (Häfner et al., 2018). One of virtual reality's most significant contributions to education, according to Hamilton et al. (2021), is that it allows students to practice difficult and complex tasks repeatedly in a safe environment. In their study, Us and Aytıs (2009) define virtual reality as a system created in a computer environment that offers the user with a feeling of realism. Kuruüzümcü (2010) emphasizes how virtual reality helps the design of environments favorable to interdisciplinary learning employing multimedia technologies, as well as the investigation of concepts with actual accuracy and order. According to Aktamış and Arıcı (2013), using music, light, and interaction components in virtual reality settings engages all the students' sensory organs. The use of virtual reality in education has transformed it into an engaging and attractive framework (Öztürk & Sondaş (2020). Moreover, Heyselaar, Hagoort, and Segaert (2017) stated that the interactions with virtual avatars, are strikingly comparable to interactions with actual people. Moreover, the result of the study made by Liou, Yang, Chen and Tarng (2017) provides evidence that both AR and VR systems can improve students' knowledge structuring. In other words, both AR and VR systems are useful for knowledge construction. VR technology has been extensively presented in recent years as an innovative technology capable of creating extremely realistic, immersive, and interactive three-dimensional learning environments (Sarıtaş, 2015).

Because science courses cover a wide range of scientific concepts and principles, it is possible to visually present this knowledge to the students by utilizing computer-assisted teaching software. Many of the subjects or concepts mentioned in the science lesson are abstract. The difficulties that primary and secondary school students have in acquiring these abstract topics are frequently attempted to be solved via lectures delivered through the presentation. However, in some cases, learning through the presentation in this way may not be sufficient. For example, it has been determined that students have misconceptions or alternative concepts regarding the unit of solar system and eclipses, which is the subject of this study (Ekiz & Akbaş, 2005; Öztürk & Uçar, 2012). As a result, concretizing abstract events and concepts thanks to new technologies like VR can help students learn science concepts more easily and meaningfully (Dağdalan, 2019). In addition, when challenges and some learning problems arise, using computer simulations can help to solve this learning problems or offer new solutions especially when the subject involves three dimensions provide more attractive learning environment (Çekbaş et al., 2003). Today, virtual reality applications may be demonstrated as one of the most effective methods of benefiting from these simulations. So virtual reality applications are intended to improve learning settings, make students more involved in the learning process, and increase their interest in the subjects (Dağdalan, 2019; Öztürk & Sondaş, 2020). Furthermore, it is expected to contribute to the development of new possibilities and learning materials to make the same concepts more scientifically meaningful. In this context, it is thought that virtual reality learning environment would be effective in teaching abstract concepts or events that are difficult to learn and understand in science education such as solar systems which are the subject of this research, as well as in other concepts in order to make them easier and more understandable (Arıcı, 2013; Dağdalan, 2019; Liou et al., 2017).

In addition to the effect of virtual reality on the effective learning of concepts, it also enables an understanding and experience beyond the existing limits, as impossible phenomena can be fictionalized in the physical world (Kuruüzümcü, 2010). Because students have not yet had the opportunity to experience the "Solar System and Eclipses" unit of the 6th-grade science course in person or the classroom, the concepts in the "Solar System and Eclipses" unit remain abstract for them. Moreover, astronomy generally includes abstract scientific concepts and presents a significant cognitive learning challenge for primary school students (Liou et al., 2017). Moreover, elementary school students often find it challenging to grasp abstract astronomical concepts related to the relative positions and movements of the sun, moon, and earth (Sun et al., 2010). In addition, there is a need for innovative teaching methods that facilitate access to processes and structures that cannot be directly observed, such as atoms and the solar system. For this reason, instructors and teachers should use this technology to build virtual learning settings in which students engage with virtual real-like items connected to scientific concepts that can't be studied or observed at a macro or tangible level (Sarıtaş, 2015; Sun et al., 2010). Students can explore and interact with these concepts and phenomena on-site thanks to the tools and components created within the virtual reality opportunities. The review of the literature indicated that virtual reality applications for a wide range of disciplines in general, and scientific education in particular, are very limited, indicating the need for further research on the subject. Furtermore, as a result of their research study on Virtual Reality regarding Solar System, Eryanto and Prestiliano (2017) suggested to develop the materials by designing other animations (such as: comets, the planets' orbit) and improve the graphic quality of the planets and the space to make them more realistic. In spite of the fact that in learning science subject and concepts, especially the solar system, an interactive and interesting learning media is highly needed for the students

(Arıcı, 2013; Eryanto & Prestiliano, 2017; İneç, 2020), the using of the virtual reality in educaton has not been systematically studied yet (Lee, Park, Kim & Lee, 2005). At the same time, virtual reality technology needs to be studied on different topics, with different samples, at different grade levels (Dağdalan, 2019; Sarioglu & Girgin, 2020). Moreover, there is no doubt that investigating the reflections of VR-assisted science education practices is not only crucial for learners but also for educators who need to learn how to use new technologies effectively in their science classrooms (Artun et al., 2020). Considering all these factors, in this study, a virtual reality application was created for the "Solar System and Eclipses" unit in accordance with the science curriculum with the aim of allowing students to observe and learn the subjects and concepts interactively and visually. In this way, Virtual Reality about the Solar System can be effectively delivered knowledge in terms of the solar system lesson based on current curriculum (Eryanto & Prestiliano, 2017).

When the existing studies in the literature are examined in general, it has been concluded that only 23% of the existing applications are done in the field of education (Şimşek and Tuncer, 2019). The majority of studies which utilized ready-made applications conducted within the scope of virtual reality and investigated their effects on some discipline such as mathematics, medicine, languages and science education (Akaslan et al., 2018; Aktamış & Arıcı, 2013; Heyselaar, Hagoort & Segaert, 2017; Öztürk & Sondaş, 2020; Shih, 2015; Terzioğlu, et al., 2012; Şimşek & Tuncer, 2019). However, the number of studies regarding science education is very limited (Gündoğdu & Dikmen, 2017; Liou & Chang, 2018; Mintz et al., 2001) and some of these reseachers stated that the effects of virtual reality applications on different variables in learning environments should be studied by conducting new studies in this area (Aktamış & Arıcı, 2013; Dağdalan, 2019; Eryanto & Prestiliano, 2017; Lee et al., 2005; Sarıçam, 2019).

As stated above, the immersive virtual reality (IVRS) system offers many opportunities such as active participation and being there, as well as a new visual learning experience that has not been systematically studied yet and what's more ın previous studies on the solar system, which is the subject of this study, ready-made and publicly available virtual reality software which does not directly address the learning outcomes in the science curriculum was used on the computer screen or as a presentation tool, and its effect on the achievement of 6thgrade students was investigated (Aktamış & Arıcı,2013).

As previously stated, the immersive virtual reality (IVRS) system provides many opportunities such as active participation and being there, as well as a new visual learning experience that has not been systematically studied yet. Furthermore, in previous studies on the solar system, which is the subject of this study, ready-made and publicly available virtual reality software that does not directly address the learning outcomes in the science curriculum was used on the computer. The purpose of this study is to create virtual reality applications for "Sun System and Eclipses subjects" by taking into account learning outcomes in science curriculum, instructional design principles, and constructivist approaches, which are based on students learning and constructing their own knowledge through doing-living and active participation in the learning environment, as well as to determine students' views on the virtual reality application (VRSSM)).

The Main Problem of This Study

What are the students' views on virtual reality applications?

Methodology of Research

The methodology of this study consists of two stages. In the first stage, a virtual reality application was developed in accordance with the learning outcomes of the unit topic in this study. During the development of the application, the opinions of subject matter experts and science teachers were sought. In the second stage, voluntary 6th-grade students utilized this virtual reality application, and their feedback regarding the application was collected. At the commencement of the second stage, a science teacher was briefed on how to conduct the application by one of the authors of this study. In a school laboratory, 16 students were taught the topic by using virtual reality applications. Before each lesson, 5 virtual reality systems were prepared, and students were given preliminary information on how to use the application before being allowed to use the application (VRSSM) with the teacher's instructions. The one author of this study interviewed the teacher every week before the course and informed her about the use of the applications if needed.

Data Collection Tools and Analysis

Semi-Structured Interview Form for Virtual Reality Application

The Semi-Structured Interview Form was prepared by the researchers (the authors of this article) by taking the opinions of two experts experienced in virtual reality application and a science educator in order to determine the students' views about the VRSM developed in this study. The students participated voluntarily in this study, and also their parents' permission was obtained. The interview approach has significant characteristics in terms of being ideal for measuring features, offering the possibility to gather in-depth information, and being continually monitored (Teddlie & Tashakkori, 2009). The researcher conducted the interviews face to face and recorded them, giving each student a nickname such as Student A, B, C. The researcher has the opportunity to listen to the video recordings more than once while transcribing the interviews because the interviews were recorded. In additionally, to avoid any misunderstandings, a pilot research was conducted. The data obtained from the interview were analyzed as content and descriptive (Yıldırım & Şimşek, 2011). In the content analysis, first of all, codes, categories and themes were determined by two researchers (encoder) in this study by examining the interview texts. The researcher independently read and generated coding categories for each of the themes they encountered. After reviewing the results, the researchers recorded the data. Afterwards, an external expert's opinion was taken again regarding the determined codes and categories. Finally, the differences in category and coding were discussed and reached a consensus by the researchers together. The encoder reliability of the study was calculated as 89 %. Calculations of reliability greater than 70% are considered reliable for research (Miles & Huberman, 1994). In addition, the content analysis was supported by quoting the views of the students.

The virtual Reality: Design, Development, Application Process

In this study, the virtual reality environment and almost all the visual elements used in the application were designed and created by the researchers by considering learning outcomes in the science curriculum, instructional design principles, and constructivist approaches, which are based on students learning and constructing their own knowledge through doing-living and active participation in the learning environment. Furthermore, the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation), which is one of the best-known examples of instructional design models (Dick & Carey, 2000) was utilized to design the virtual reality environment for the Solar System and eclipse unit in this study. During the development process of VR, the opinion of three science education experts, two science teachers, and two ICT experts about the VRA were obtained, and the VRA was updated in line with the experts' feedback. The main field of application for the planned three-dimensional education environment is virtual reality glasses and control devices. The preferred virtual reality (VR) device is computer-assisted hardware. The sensors in this hardware detect the location of the user and transfer the physical actions such as location and direction change into the application in real-time. In this way, the movement of the user, for example, who makes walking or bending movements in the real world, instantly finds a response within the VR application. Similarly, control devices enable users to see their hands as avatars in the VR program and interact with it by moving their hands. In addition to this hardware, the LEAP MOTION tool, which permits interaction with only one's hands without the use of a control device, was chosen to provide an alternative and a different experience. In addition to these features, the program has been designed to be suited for usage in a computer environment, allowing for the broader field. Furthermore, the way the application works can be carried out simultaneously on virtual reality equipment and computers. In this way, the application has been designed in such a way that it can be used interactively from the computer that is connected at the same time and can be observed from the outside via the computer screen or external monitors to which the image will be transferred. Moreover, it is designed to work with Android-based mobile devices that require additional hardware and software.

Virtual Reality Solar System Model (VRSSM)

The students started their journey at a cabin in the virtual reality environment in Virtual Reality Solar System Model (VRSSM). They can use a telescope to investigate the moon and space at the observatory located area. Then, they can travel into space by boarding a spacecraft in the area. Moving into space, they find themselves in a space station orbiting the Earth and can observe the Earth from Space and begin to examine miniature versions of objects such as the Moon, inner and outer planets in the solar system (**Figure 1**). Both verbal and written information about the characteristics of the objects is also given. Following that, students are expected to classify the inner and outer planets in an interactive way in the VRSSM. In this stage, the student moves the inner and outer planets to the appropriate areas by using the laser stick in his/her hand (**Figure 2**). So they can learn these planets' orders in the Solar System.

In the next steps, the students are expected to visit all planets in order to examine some information about the planets through multimedia support (audio, visual, and written forms). After this section, students return to the space station for learning the subject of eclipses. When the course on all subjects is completed, they are expected to travel to the Earth, Sun, and Moon positions by teleporting with the spacecraft and making observations from each position during the eclipse (**Figure 3**).

Software used in Application Development Phase

Despite the fact that the application mostly displays visual parameters, different software was utilized in the development phase and in the program's background. Adobe Photoshop software was used in the editing of the im-

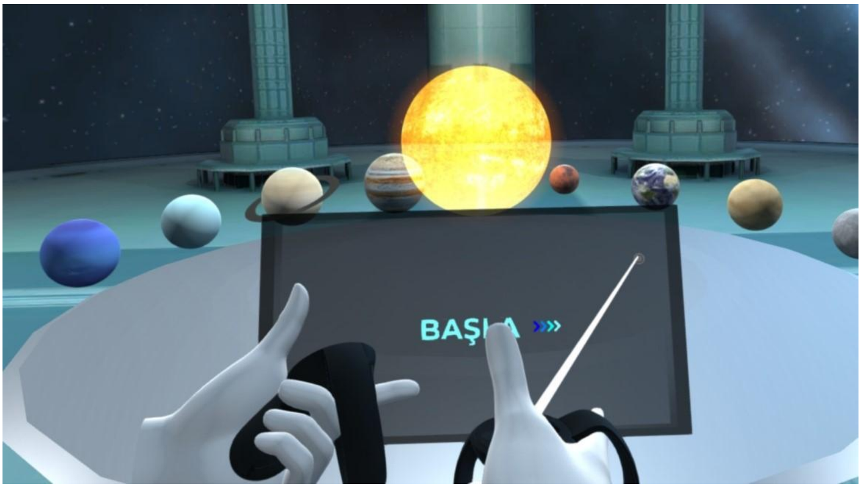

Figure 1. A Sample Image of Starting (BAŞLA in Turkish) Scene from Inside the Space.

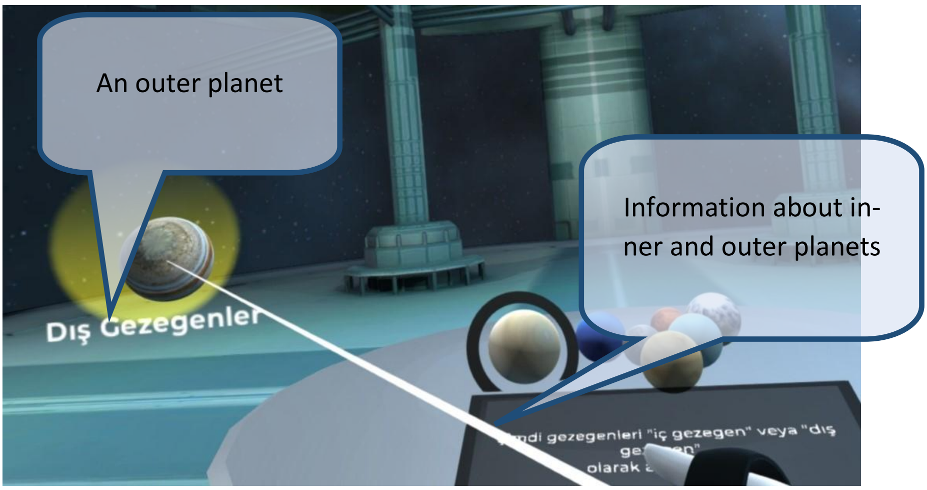

Figure 2. An Example Image from the Inner and Outer Planets Classification Application.

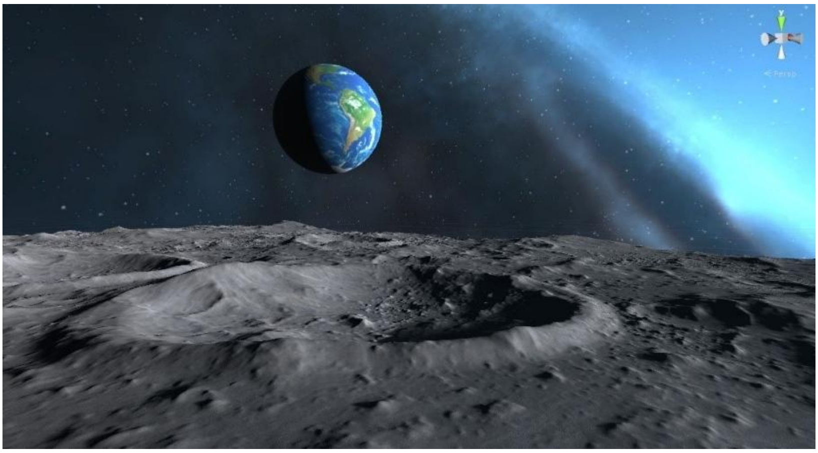

Figure 3. A Scene of the Virtual Solar System Model.

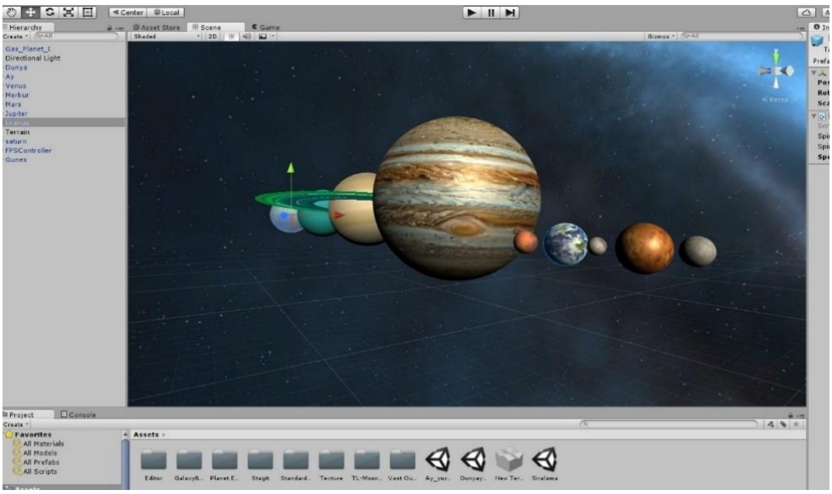

Figure 4. A Scene from the Developing Phase of the Application.

Figure 5. Sample Images from the Implementation Process.

ages after taking expert opinions, and Adobe Illustrator software was used in the design processes. The three-dimensional objects used throughout the program were created in Autodesk 3DS Max and combined with the edited visuals in this software. The process of making the created objects interactive was carried out in the Unity 3D software (**Figure 4**), which is the main software in the design of the application. While creating the interaction of objects, be-sides the use of CSHARP and Java programming languages on Unity 3D software, Microsoft Visual Studio was also preferred when needed. Leap Motion Controller software was used to provide interaction without an external device. Adobe After Effect and Premiere software were used in the design part of the application that needs to be edited in animations. The final version of the application was implemented with students in a classroom environment (**Figure 5**).

Findings

After the application, the students were asked the following question: “What do you think about whether the application affected your learning of the unit or not? If it did, how did this affect it?” The responses regarding the effect of virtual reality applications obtained from the interviews with students were classified under the themes “with effect” (13 students) and “without effect” (3 students) and three categories (funny, feeling reality, and no effect) within these themes, and these findings have been supported by sample quotations from students' responses here. First, almost all of the students who participated in the interview, except for three, think that the application is effective and funny. Moreover, some of the students thought that the VRA was very funny, while others stated that they experienced a sense of reality and felt as if they were walking in space. Some sample quotes from the students' opinions are given here: "*Yes, it (VRA) affected my learning .... If it wasn't for the virtual reality application, I wouldn't be able to understand anything about it....*(Student A)". Similarly, student B expressed her opinion as follows: "*Yes, it affected me, it made me feel like I was really next to the objects, I liked it very much*". Student G stated his opinion as follows: "*Yes, it did, I learned it while having fun.*" Student F stated as follows: "*Yes, it was impressive; it was like I was playing a game; I liked it very much*" and Student K stated that "*It was very fun; I was very impressed.*" Student J stated that he thought there was no difference between the two applications (VR and normal instruction) by saying, "*It didn't affect me much; I could understand the subject (in) anyway….*". These findings show that the virtual reality application has a positive effect on the emotion of students in general.

After the application, the students were asked, "*Did the virtual reality application affect your interest in the lesson in general? If so, did it affect it positively or negatively? Can you explain?*". During the interview, most of students stated that the virtual reality application positively affected their interest in the course, and three students said that "*we were already interested in science lessons*". For example, Student A expresses his views on the effect of virtual reality application on interest in the course as "It affected positively, it was memorable." Student F said "It affected my interest positively, it was a very good experience…". Student C stated that "…. *I already loved science, but I also saw the fun side of science again*". Student E stated that "*It affected me positively and increased my interest in the lesson*." On the other hand, student H expressed an opinion about virtual reality, as "*It did not affect my interest.*" ,"*Because there was not many thing that would affect my interest in the course*."

The third research question is, "Do you think that the virtual reality application makes the subject or concepts you have learned more permanent?", "Can you explain why?" With this question, it is aimed to reveal whether the virtual reality application provides the permanence of the knowledge (Due to the data limitations of this study, this finding reflects students' perceptions on the relevant subject). According to the content analysis of this question, three themes (e.g., interaction, memorableness, and exciting) and 25 codes (e.g., memorable, not forgettable, funny, interactively) within the themes have been reached in the coding of the responses that were collected through interviews. Thanks to this application, the student's knowledge becomes concrete, and they learn by doing and living in the virtual reality environment as if in a real one. All but one of the students stated that the virtual reality application was effective in ensuring the permanence of knowledge. For example, student A stated that "*yes, it was such a funny,… and beautiful application that I cannot forget the subject." Similarly, student E expressed his views as follows: "Yes, because we did it interactively, it was more memorable…." Student C stated that "it was much better to see with visuals such as life, and it was catchy." Student L said that "Yes, now when I take an exam,… I think that virtual reality helps me to remember what I learn so I will always be able to remember it…*"

During the interview, we asked the students, "Did you encounter any problems while using the application? Were there places you couldn't understand? If so, how did you fix these problems?" and then student responses were analyzed in a descriptive way. *While half of the students stated that they did not encounter any problems, others had some problems and needed the help of the teacher or the researcher. In terms of how the applications were used, student A stated, "No, I did not experience any difficulty, and there was no point that I did not understand." Student C explained, "No, it didn't happen, but I did get help from the teachers when I got a problem." Regarding the usage of the virtual reality application, student D said that, "No, I did not have any problems with the application, and there was no point that I could not understand." Another student stated as follows: "Sometimes it happened. In the button, there was a contact failure. I pressed a button, and the system was no longer able to function. I needed the teacher's help to solve it*."

The last research question is, "*Would you like to learn other lessons and topics with virtual reality applications? For which course or for which unit would you like to learn thanks to this application?*" With this question, it is aimed to reveal whether the student likes to use the application for other lessons or subjects. According to the content analysis of this question, one theme, "willingness" with four categories (e.g., all lessons, science, math), and 13 codes (e.g., all lessons, every lesson, all subjects, science, math, mathematics, sense organs, computer) have been reached in the coding of the responses that were collected through interviews. Most of the students who participated in the interview wanted the Virtual Reality Application to be used in all disciplines, two of them only in science lessons, two of them only in mathematics lessons, and three of them in other lessons. Some quotes from the students' responses are given below.

Student D said, "*I would like virtual reality applications to be used in all lessons and all subjects*." Student E expressed that "*Yes, I would like it to be used in math class*." Similar to Student D' views, Student F also stated that "*I would like it for every lesson and every unit because the virtual reality app was so much fun*". Student J stated that "*I would like to have this application in the sense organs (science) unit as well.*" Student K expressed that "*yes, I would like it to be used in math class*".

Conclusion, Discussion and Recommendations

The opinions of sixth-grade students about the virtual reality application were collected using a semi-structured interview form in this study. When the virtual reality application was used in the science course, the students thought that the virtual reality learning environment attracted their attention and interest and made the science lessons funnier and more interesting than normal teaching. This result was consistent with the findings of previous studies (Kandemir & Demir, 2020; İneç, 2020). For instance, Gedik (2020) took the students' thoughts on the virtual reality application and concluded that the students' interest, engagement, and motivation for climate lessons taught by using virtual reality technology increased. As mentioned above, similar results were found in this study. The following quotes from the students in this study show that they found the application effective and funny.

"Yes, it (VRA) affected my learning." "If it wasn't for the virtual reality application, I wouldn't be able to understand anything about it." "Yes, it affected me; it made me feel like I was really next to the objects, I liked it very much." "It affected my interest positively; it was a very good experience." "I already loved science, but I also saw the funny side of science again."

Interests are direct or indirect determiners of all essential components of science education, as they are in all fields of education (Kuhns, 1977), and help knowledge be retained for a much longer period of time. So, the fact that this virtual reality application has increased students' interest and helps them learns the lesson more easily. Similar to the results of this study, Dağdalan (2019) revealed in his research that the students found the virtual reality application interesting and that they learned while having fun thanks to this application. It was also observed that the students in the virtual reality experimental group had positive attitudes toward this technology. According to the results of the study by Kaleci et al. (2017), virtual reality environments are interesting, impressive, and intriguing, and provide a unique experience for users. In another study, it was concluded that virtual reality increased students' interests more than other materials (Lee, Park, Kim & Lee, 2005). Considering the results of both the current study on the solar system and eclipse and the above studies, it can be said that virtual reality applications positively affect students' interest in the course. Since the increase in students' interest in the lesson will allow them to listen and learn the lesson more carefully, virtual reality applications should be created for mostly all subjects in science lessons, and the effects of these applications on students' attitudes should be investigated. In this manner, understanding students' attitudes and views toward digital technology looks to be crucial in efforts to properly integrate them into instruction (Tsivitanidou et al., 2021).

Another result of this study's qualitative finding is that students believe the information they learn through virtual reality is more permanent. All but one of the students stated that the virtual reality application was effective in ensuring the permanence of knowledge. According to İneç (2020), the knowledge gained in a virtual reality environment is permanent because it contains multimedia and gives the impression of being there. These findings are supported by previous research (Gedik, 2020; Öztürk & Sondaş, 2020). In addition, thanks to this application, the students' knowledge becomes more concrete and memorable because they learn by doing and by living in the virtual reality environment as if in real one. This result should be tested in future studies since it was obtained based on interviews with students in the current study.

Regarding the problem faced by the students while performing the virtual reality application, half of the students stated that they did not encounter any problems, while some of them stated that they had some problems and needed the help of the researcher or the teacher. This may be due to the fact that they use virtual reality glasses for the first time, and it is also a new technology. Taking this conclusion into account in future studies can ensure the successful, healthful, and efficient use of virtual reality applications.

According to the results obtained from the research, the majority of the students who participated in the interview wanted the Virtual Reality Application to be used in all disciplines, while two of them wanted it to be used only in science courses, the other two wanted it to be used in mathematics courses, and three of them wanted it to be used in other courses. In the research conducted by Dağdalan (2019) on virtual reality, it was revealed that students want the use of virtual reality applications to continue in classes at the highest rate. Similar to this result, a study conducted by Dağdalan (2019) on Virtual Reality Applications revealed that students want such applications to be used in higher grades as well.

In this study, the data revealing the effect of VR application on students' achievement has not been analyzed yet. However, many studies have been done on this subject. The application of virtual reality technologies in the lessons helps to improve students' academic achievement significantly. In the literature review, it is seen that this study shows similar results to the studies carried out on virtual reality (Aktamış & Arıcı 2013; Chung, 2012; Dağdalan, 2019; Eryanto & Prestiliano, 2017; ; Gedik, 2020; Hwang & Hu, 2013; İneç, 2020; Liou & Chang, 2018; Jou & Liu, 2012; Lee & Wong, 2014; Sarıçam, 2019; Sun, Lin & Wang, 2010; Tüzün et al., 2009). For example, according to the experimental research on virtual reality that was conducted by Sarıçam (2019), the students who used VRA believe that their imaginations developed during the virtual reality application process, and that they were constantly active throughout the process, resulting in more permanent knowledge.

Another study's results on virtual reality indicated that many students had positive opinions on Virtual Solar System (VSS) for using it in their class; and they thought this kind of teaching activities contributed their understanding more effectively (Lee et al. (2005). Avcı et al. (2019) have concluded as a result of their meta-analysis that virtual reality applications at the primary, secondary, high school, and undergraduate levels have a moderate effect on students' academic achievement. Due to the fact that virtual reality applications produced for the public or general use cannot fully satisfy the needs of students, it is critical to create learning environments that are specific to the subject to be taught and designed to the students' levels. So, in future studies, a virtual reality learning environment should be accompanied by appropriate pedagogical approaches on each subject and should include orientation and navigation tools in order to empower learners' perceptual and cognitive systems (Lee et al., 2005). In order to generalize the results of these studies and current study, it is thought that it is necessary to make new studies regarding VR on more and different student groups and also discipline in future studies. Similar suggestions have been expressed by other researchers (Liou & Chang, 2018; Sarioglu & Girgin, 2020).

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REVIEW

The Five-Level Education and Teaching Research System: A Distinctively Chinese Research Mechanism for Basic Education

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Abstract: *China's five-level education and teaching research system (ETRS) has been instrumental in advancing Chinese basic education. It includes the central-, provincial-, municipal-, and county-level education and teaching research institutions and school-based teaching research offices, which jointly contribute to the enhancement of the quality of education and teacher professional development. There is close collaboration as well as a clear division of responsibility among these institutions. This article expounds on the ETRS's functions and characteristics, shedding light on its significance for Chinese basic education with a view to providing implications for global education development.*

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EDUCATION and teaching research (ETR) plays a crucial role in enhancing the quality of education and promoting teacher development by driving curriculum reform, guiding teaching practice, serving teachers' needs for professional growth, and supporting educational decision-making (Mou, 2022). The Chinese government puts a great value on ETR work. Based on the actual situation of China's basic education, an education and teaching research system (ETRS) with distinctively Chinese characteristics was established after nearly 70 years of exploration and experimentation (Luan, 2022). China's ETRS at the basic education level consists of five levels of institutions: the central-, provincial-, municipal-, and county-level ETR institutions, and school-based teaching research offices. The system is distinctly hierarchical, but with intensive collaboration and coordination between various levels of agencies. With its research focus on instructional practice, the ETRS has made substantial contributions to the development of Chinese basic education (Yang, 2023). This study aims to present the functions of ETR institutions in the system and features of China's five-level ETRS, shedding light on its significance for education quality enhancement and teacher professional development.

The Evolution of China's ETRS

An ETRS is an integral part of a nation's educational system, entailing the ETR organizational framework, ETR activities, and applications of research results. It requires the active participation of all educators as well as backing from schools and education departments (Jiang, 2023). Each country runs the ETRS in its own way. In the United States, for instance, the ETRS is managed by the education departments of each state, emphasizing the autonomous development and professional growth of teachers (Jiang, 2021). The UK's ETRS is carried out by local education departments under the leadership of the central educational authorities, with a focus on the applicability and creativity of ETR (Wang, Q., 2022). Likewise, Japan's ETRS is led by the national education administrative department and implemented by local education departments. It places more emphasis on improving the professional competence and teaching skills of teachers (Wang, H., 2022).

China's ETRS has undergone progressive improvement amid its educational reform and development. On the founding of New China, the Ministry of Education (MoE) held a conference on the national education work at the end of 1949, seeking to advance the educational cause to guarantee the right of ordinary people to education. It was proposed at the conference that ETR institutions should be established at the provincial, municipal, and county levels, drawing on the useful experience of the prior education systems of China and the Soviet Union's education systems. The teaching research group first emerged with the reform of higher education curricula in

1950 and 1951, subsequently spreading to basic education (Mao, 1989). In 1952, the MoE released the Provisional Regulations for Secondary Education and the Provisional Regulations for Primary Education, affirming that the primary purpose of teaching research groups was to improve teaching outcomes. As a result, the primary and secondary teaching research groups were officially set up, with the majority of researchers being frontline teachers. In 1955, the MoE issued a series of papers through its official journal, People's Education, reaffirming that the role of ETR institutions was to improve the quality of instruction and declaring that all ETR activities were under the direct leadership of education departments. By the mid-1960s, the three-level ETR framework for basic education had been successfully established (Li & Jiang, 2022).

The ETRS in China was suspended during the ten-year Cultural Revolution. With the resumption of the college entrance examination (Gaokao) in 1977, China endeavored to restore order in education and launched ETR efforts regarding textbook compilation and curriculum program formulation. In those days, however, the ETRS only ran at the provincial, municipal, and county levels, lacking overall organization and regulation from the state (Li & Jiang, 2022). To address this issue, the National Education Science Planning Panel was established in 1983 for the across-the-board planning of nationwide ETR work. In the meantime, the MoE's Basic Education Curriculum and Teaching Materials Development Center were held responsible for guiding ETR at the basic education level (Wang & Hu, 2020). In 1990, the National Education Commission (the precursor of the present MoE) released "Several Opinions on Improving and Strengthening the Work of Teaching Research Offices," affirming the important position of teaching research offices in ETR. This paper not only clarifies the responsibilities of ETR institutions but also increases their functions, highlighting their roles in teaching research, instructional direction, and teaching management. Consequently, a five-level ETRS that constitutes central, provincial, municipal, county, and school-based ETR agencies was progressively developed.

In 2010's "Opinions on Intensifying the Reform of Basic Education Curricula and Advancing Competence-focused Education," the MoE called for improving the ETR work mechanism to innovate ETR patterns (Ministry of Education of China, 2010). "Opinions on Strengthening and Improving Educational Research for the New Era's Basic Education," released in 2019, emphasized that ETR should serve school education and instruction, teacher professional growth, student holistic development, and educational management and decision-making (Ministry of Education of China, 2019). In response to the calls in this paper, local ETR institutions accelerated the reform of the ETRS by innovating ETR mechanisms and diversifying ETR contents. New ETR experiments included online ETR, collaborative ETR, thematic ETR, instructional demonstrations, on-site mentoring, and project-based research, among other ETR practices (Li & Jiang, 2022). During this period, the ETRS underwent continuous improvement and a transition towards a service-oriented education and teaching research system.

Organizational Structure of the ETRS

The five levels of institutions in China's basic education ETRS include the central-, provincial-, municipal-, and county-level ETR institutions and school-based teaching research offices (Yang, 2023), with each level bearing its own special responsibilities.

The central ETR institutions are primarily responsible for macro-level educational research and decision-making, as well as for transmitting educational ideas from the government and directing the development of ETR through publishing government papers (Su & Liang, 2015). For example, the MoE released "Opinions on Strengthening Science Education in Primary and Secondary Schools in the New Era" in 2023, aiming to enhance science education at the basic education level and increase students' scientific literacy. The paper stresses the importance of basic science education and proposes specific measures such as improving the curriculum framework, advancing teacher professional development, and promoting practical science and technology activities (Ministry of Education, 2023). Through circulating and interpreting government papers like this, the central ETR institutions deliver the state's educational propositions and decisions to local ETR agencies to ensure their effective functioning.

The provincial-level ETR institution manages the ETR work and makes educational decisions within the provincial administrative region. They support educational reform by formulating developmental strategies, managing the implementation of major national and provincial scientific research projects, organizing professional training for staff in the provincial education community, undertaking basic education teaching research, and providing guidance to lower levels of ETR institutions (Zhou, 2021). For instance, while undertaking ETR, the Shanxi Academy of Educational Sciences also bears the responsibility for managing scientific research in education in Shanxi Province. The academy has its own research projects to fulfill and, at the same time, needs to manage the ETR of primary and secondary schools on behalf of the provincial education department (Li, 2018).

The municipal-level ETR institution is responsible for basic education and secondary vocational education research, ETR planning and ETR project management, disciplinary instruction evaluation and monitoring, teacher in-service training, curriculum design research, textbook and course resource construction, educational research, and ETR information exchange within the municipal region (Wang, 2022). Taiyuan Education Research Center, for example, has ten basic functions to fulfill: i) providing advisory services to education administration departments in their decision-making; ii) researching theories associated with education and teaching and classroom teaching reforms; iii) conducting surveys to serve grassroots education and teaching practices; iv) organizing forums on teaching and lesson demonstrations for subject teachers; v) implementing monitoring, evaluation, and feedback on student academic quality; vi) directing schools to carry out teaching research; vii) selecting outstanding teaching cases and promoting successful teaching experiences; viii) publishing the journal Taiyuan Education to present the city's educational dynamics; ix) providing professional counselling for schools and student parents as public goods; x) undertaking relevant work delegated by the municipal education bureau (Li, 2018).

The county-level ETR institution focuses on investigating and researching the most important and pressing practical issues arising in basic education, summarizing and popularizing excellent teaching practices, and guiding teachers to improve their instruction accordingly (Wang, 2022). For instance, Qingxu County's "Regulations of Instruction for Compulsory Education Schools" stipulate detailed provisions on how to direct teachers in teaching plan creation, classroom teaching implementation, lesson observation, teaching research, exam question setting, and academic evaluation. According to this paper, research staff with the county-level ETR institutions need to observe 60 lessons, organize seven ETR events, deliver one subject-specific lecture and one thematic research lecture, conduct three lesson studies, and give one demonstration lesson each semester as the minimum requirement (Li, 2018).

The school-based teaching research office has the responsibility to address the issues and challenges arising from day-to-day instruction. The teaching research groups of the school also encourage teachers to devote themselves to researching teaching materials, methods, and issues by means of self-study, teaching journals, thematic debate, lesson studies, lesson observations, teaching forums, professional training, etc. (Wang, 2022). For example, in order to advance the school's physical education (PE), the PE teaching research group of Shuanglou Vocational School in Hai'an City, Jiangsu Province, formulated a detailed work plan to direct all PE teachers to implement PE instruction in an effective and scientific way. Based on the seven modules of the new national course standards, it selected teaching contents that suited the special circumstances of the school and the needs of the students and created colorful sports culture-related activities for them to best support their physical and mental development. Additionally, in order to enhance the professional expertise and skills of PE teachers, it built platforms to facilitate their communication with external agencies by providing them with opportunities for off-campus education and training and inviting elite teachers from other schools to share successful teaching practices (Xu, 2011).

Advantages of the Five-Level ETRS

Close Collaboration between ETR Institutions at All Levels

Despite the stark division of responsibility within the system, China's ETRS is a highly cooperative and collaborative network, with the work of ETR institutions at various levels being closely intertwined (Chen, 2022). While working to fulfill their respective prescribed duties, all ETR institutions pay great attention to inter-level partnerships, which can take various forms, such as joint research projects, resource sharing, and information exchange (Bai, 2021). This collaborative mechanism is a guarantee of the overall effectiveness of the ETRS. First, it helps optimize the utilization of research resources. ETR institutions at various levels have their own advantages in research resources, which can be fully leveraged through cooperation (Tang, 2018). For instance, state-level ETR institutions, with their abundant academic resources and research achievements, can provide theoretical support for their provincial- and municipal-level counterparts; school-based ETR offices have a better understanding of the actual situations of basic education and the needs of frontline teachers, thus having the potential to support higher-level ETR institutions by presenting authentic information. Furthermore, the collaborative mechanism in the ETRS is beneficial for heightening the generalizability and applicability of ETR results. Issues with education and instruction are typically complicated and context-sensitive, requiring multifaceted research and exploration. Through collaborative research, ETR institutions at various levels can contribute their respective perspectives to overcoming common challenges in basic education (Huo & Yu, 2023). Using the subject-specific instructional reform as an example, the municipal-level ETR institution can initiate the program and then engage teaching research groups from concerned schools in it to reach an effective solution through collaborative research.

A successful practice of collaborative research under the ETRS took place in Pudong New District, Shanghai. The district's ETR office initiated a research project on "the effectiveness of primary English writing teaching," which was jointly undertaken by English teaching research groups from the district's primary schools and also involved higher-level ETR institutions. The district's ETR office invited researchers from municipal-level ETR institutions and university professors to give lectures on existing studies of English writing, giving participants a deeper and more comprehensive understanding of English writing instruction. Subsequently, the English teaching research groups from primary schools conducted practical research on the question based on the actual situations of their students and drew effective methods and strategies for primary English writing teaching from their investigations. The successful implementation of the project can serve as an exemplary experiment that combines theoretical and practical research (Liu, 2018).

Sharing Research Outcomes in the ETR Community

Sharing research outcomes is an important component of the ETRS. ETR institutions at all levels constantly produce research outcomes in various forms, including reports, papers, case studies, and more. They are valuable to the entire ETR community (Hao, 2021). ETR institutions share their research results through academic conferences, ETR achievement exhibitions, and other avenues. These events not only promote academic exchanges but also help enhance the research level of the ETRS as a whole.

The emphasis on the sharing of research outcomes leads to the common growth of the ETR community. Through the sharing of research results, all members of the ETRS are fully informed of the dynamics of ETR in China and around the world. This helps them spot their gaps in ETR and determine the direction of their future research. In his investigation of ETR activity in primary and secondary schools in Zhejiang Province, Hao (2021) discovered that the Chinese language teaching research group of W Primary School successfully stimulated their colleagues' interest and engagement in teaching research by hosting research activities that engaged researchers from the regional education community. Each teaching and research activity has as participants' regional elite teachers, full-time educational researchers, and academics from universities. Such activities facilitate information sharing and mutual support, resulting in the marked advancement of Chinese language teaching research in the region.

Information sharing among ETR institutions also has the potential to promote teacher professional development. Through inter-peer communication, teachers are exposed to more diverse educational and teaching concepts, significantly expanding their horizons and perspectives. Moreover, inter-peer communication stimulates self-reflection in teacher researchers, motivating them to improve their professional competence and teaching techniques. A research mechanism that focuses on mutual learning and common growth helps expand the pool of excellent teachers and improve the quality of education and teaching (Zheng, 2022).

Prioritizing Teaching Practice Research

Researching issues associated with practical instruction is the top priority of the ETRS's work (Yang, 2023). The system puts heavy emphasis on the applicability of its research results and the enhancement of teachers' instructional competence. By engaging teachers in ETR activities, such as lesson observations, teaching forums, case studies, etc., it leads teachers to combine theoretical knowledge with practice to improve teaching efficacy.

The ETRS pays great attention to the practical needs of teachers. ETR institutions at all levels conduct on-site, in-depth communication with teachers to understand the challenges and perplexities they encounter in teaching as well as their most compelling needs. Based on these practical issues, the ETRS makes its research contents closely connected to the teaching practice of teachers, meeting their expectations to improve their teaching ability and skills (Wang, 2022). In Li's investigation on the ETR activity of teachers in A Primary School in Kunming City, 64.9% of the school's teachers claimed that participating in ETR activities contributed to increasing teaching effects and enhancing their professional competence; 20.9% of them noted that participating in ETR activities is a criterion for professional title ratings and award applications; 9% declared that they participated in ETR activities because the school leaders asked them to do so; and the remaining 5.2% reported that they participated in ETR activities to develop interests and hobbies (Li, 2021).

The ETRS also encourages frontline teachers' involvement in the planning of research projects. As major education actors, teachers' involvement in this regard helps enhance the pertinence and applicability of ETR work. By soliciting the opinions and suggestions and combining the practical experiences of frontline teachers, the ETRS makes its work more intimately coupled to the actualities of teaching, providing more directive value to teachers (Jiang, 2023).

Institutional Guarantees for the ERTS

A sustained development of the five-level ETRS requires solid institutional guarantees. The orderly and efficient operation of the system has been supported by a series of policies and regulations. In the past several decades, the central and local governments have issued many papers to ensure the smooth operation and development of the ETRS. In 1990's "Several Opinions on Improving and Strengthening the Work of Teaching Research Offices," the National Education Commission (1990) set forth the nature, functions, and responsibilities of teaching research offices as well as the compensations, research funding, and working rules for research staff in the context of working conditions at that time, which marked the institutionalization and normalization of the work of teaching research offices. In 1993, the Basic Education Department of the National Education Commission held in Beijing a meeting of directors of provincial-level teaching research offices, which came up with opinions and suggestions for improving the work of teaching research offices (National Education Commission, 1993). "Opinions on

Strengthening and Improving Educational Research for the New Era's Basic Education," released by the MoE in 2019, highlighted "strengthening the construction of education and teaching research institutions" and "stipulating the duties of education and teaching research" (Ministry of Education of China, 2019). In response to this paper, 14 provincial governments published policies on regional ETR. Among them, the Department of Education of Shandong Province (2020) issued in March 2020 "Measures to Strengthen Education and Teaching Research for Basic Education in the New Era," putting forward stipulations on "the building of education and teaching research teams, training and incentives for education and teaching research staff, and evaluation of education and teaching research work." The Department of Education of Guangdong Province (2020) released in May 2020 "Opinions on Establishing and Improving the Education and Teaching Research System for Basic Education in the New Era." The paper was divided into several sections, including "optimizing researcher staffing, standardizing professional criteria, heightening key competencies, implementing across-the-board training, and stimulating team vitality."

In the long-term practice of the ETRS, ETR institutions at all levels have formulated effective rules, regulations, and work procedures to specify their respective responsibilities, rights, and obligations and optimize their research methods. With these rules and regulations, the stability and consistency of ETR work have been ensured, and the possible impact of disruptive factors, such as staff turnover and policy adjustments, on ETR work could be circumvented (Wang, 2021).

The institutionalized ETRS is effective in encouraging innovations among research staff and teachers. By establishing scientific evaluation and incentive mechanisms, the system has continuously kindled their enthusiasm for innovation, propelling them to explore new educational concepts, teaching methods, and assessment instruments (Wang, 2010). In addition, institutionalized ETR work increases social recognition of the system. With a transparent and credible system, the public has a better understanding of the roles of the ETR staff and trusts their research outcomes more (Wang & Hu, 2020).

Conclusion

The five-level ETRS has made remarkable contributions to the development of Chinese basic education. The system's hierarchical management has significantly boosted the efficiency and efficacy of ETR work. To look ahead, China's ETRS should continue to harness its strengths in education research, teacher training, and educational recourse integration to further the enhancement of the quality of basic education; in the meantime, it should fully leverage cutting-edge technologies to innovate ETR contents and methods to better serve the digital transformation of education in the new era. Also, in the context of educational globalization, it is important for China's ETR institutions to actively engage in international exchanges and cooperation in order to learn from worldwide experiences in educational practice and research and to support the sustainable development of education.

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REVIEW

The Implementation of Project-Based Learning in Chinese Basic Education: Challenges and Recommendations

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***Abstract**: Project-based learning is a form of student-centered and inquiry-based learning. It differs from traditional instructional approaches by emphasizing students' acquisition of transferable knowledge through active exploration of real-world problems and challenges. For China's basic education community, project-based learning is still a relatively novel notion, and its popularization is subject to a variety of challenges. This study aims to pinpoint the barriers to the successful implementation of this pedagogical method in Chinese basic education. Recommendations on how to enhance its application are also proposed.*

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PROJECT-BASED LEARNING (PBL), as a student-centered instructional strategy, has gained increasing popularity across the globe. The core idea of PBL is that students acquire a deeper understanding of knowledge by engaging in exploring real-world issues. It is believed that PBL has the potential to boost students' academic competence as well as promote their mastery of 21st-century skills such as critical thinking, teamwork, and problem-solving (Wei, 2023). The PBL method emphasizes the teacher's role as a guide and facilitator in encouraging student active engagement in learning. Nevertheless, Chinese basic education teachers encounter challenges in implementing effective PBL due to their insufficient PBL knowledge and teaching techniques, as well as the lack of necessary resources. This study seeks to identify the current barriers to the adoption of PBL and put forward relevant recommendations for promoting its application in Chinese basic education.

A Brief Overview of PBL

Dewey is recognized as one of the early proponents of project-based education, and his idea of "learning by doing" has been a key principle underlying PBL (Dewey, 1938). Later educational research has advanced this idea of teaching and learning into an instructional approach known as "project-based learning." Today, PBL has become a well-established method of active learning in which students learn about a subject by working for an extended period of time in teams to investigate and solve a complex real-world question or issue (Shen, 2023). It typically entails a series of steps, including identifying the issue, posing questions, researching relevant knowledge, investigating possible solutions, representing the chosen solution, and reviewing and reflecting on the inquiry process (Huang, 2022). Central to PBL is students' autonomous inquiry, during which they develop new knowledge in relation to actual life and integrate knowledge from multiple disciplines to address genuine challenges. Compared with traditional teacher-centered classroom instruction, PBL, with an emphasis on students' hands-on and collaborative experiences, is significantly more effective in developing students' problem-solving abilities.

In the *NMC Horizon Report: 2015 K–12 Edition*, a joint effort of the US's New Media Consortium (NMC) and Consortium for School Networking (CoSN), experts reached the agreement that future education would place a high premium on exploring deeper learning approaches, such as PBL and inquiry-based learning (Johnson, 2015). At present, countries, including the United States, the United Kingdom, France, Canada, Singapore, and more, have tried to infuse essential elements of PBL into curriculum development and teaching practices. PBL has been adopted at all levels of schooling, from preschool to higher education. Moreover, it is heavily employed by a group of emerging educational institutions such as Think Global Schools and Khan Lab Schools (Ye, 2022).

Since its introduction into China's education community, PBL has garnered growing attention among Chinese educational researchers and teachers, as well as policymakers. The "Opinion on Advancing Education and Teaching Reforms and Comprehensively Improving the Quality of Compulsory Education," issued in 2019, strongly advocates the exploration and implementation of PBL, among other collaborative learning strategies (State Council of China, 2019a). The "Guiding Opinions of the General Office of the State Council on Promoting the Reform of Education Methods in General Senior Secondary Education in the New Era" affirm the necessity of innovating classroom teaching modalities, particularly emphasizing situation-specific, problem-based learning activities, and project-based integrated study (State Council of China, 2019b). Both papers highlight PBL as a crucial device for transforming the traditional education paradigm to improve the quality of education. Driven by the intensifying educational reform and advancement of educational concepts, an increasing number of schools are starting to pay attention to the PBL model and introduce it into classroom teaching. In recent years, amid the accelerated development of information technology, PBL in Chinese schools has exhibited a tendency towards digitization and multi-disciplinary integration. Furthermore, some educational institutions have initiated collaboration with businesses and communities to provide students with richer, more authentic project-based learning experiences in an effort to support the holistic development of students (Liu, 2022).

Barriers to the Implementation of PBL in Chinese Basic Education

Despite its many advantages, PBL is a relatively new teaching model for Chinese teachers. Its implementation in Chinese basic education has been constrained by various factors, such as the established curricula, teacher PBL literacy, and resource availability.

Current Curricula's Focus on Knowledge Foundations

At the basic education level in China, subject-based curricula place heavy emphasis on students' attainment of a solid knowledge base. Nevertheless, PBL is a more competence-oriented, interdisciplinary approach, focusing on student all-round development. Under the current education context and evaluation system that focus on basic knowledge mastery, the teacher is faced with a dilemma in adopting PBL in day-to-day instruction (Yin, 2021). The subject-based curriculum is distinguished by its logical structure and independent content knowledge specific to each individual discipline. It prioritizes the efficiency of knowledge transmission. To a large extent, subject-specific training restricts the breadth of thinking in students, hindering their overall development of essential competences such as inquiry and problem-solving abilities (Qiao, 2021). Contrarily, PBL is often based on big ideas or compelling social topics, drawing on lessons from several disciplines and being implemented in the form of modules. It also stresses that the question of exploration must have real-world applications. Evidently, PBL will inevitably weaken the fulfillment of the subject-based curriculum by disrupting the established knowledge structure and student learning progression, thus not conforming to the requirements of the national basic education curriculum. Therefore, a remarkable challenge of PBL in basic education is how to balance students' building of complete knowledge bases with their needs for developing key competences (Yin, 2021).

Teachers' Inability to Change Their Roles in Education

In a traditional education paradigm, the teacher plays a dominant role in the whole process of instruction; the classroom's effectiveness depends on the teacher's instructional techniques (Kang, 1986). In contrast, PBL is a student-centered process, aiming to maximize the student's engagement and motivate them to become the owners of their learning. First, PBL requires the teacher to be a participant in student learning instead of a knowledge transmitter. As opposed to their traditional role as a lecturer, the teacher in a PBL classroom needs to be involved in every process of student learning, covertly mediating the objective, progress, and method of students' inquiry. They must relinquish their dominating, authoritative position to build an eqalitarian, democratic learning atmosphere for the students (Yang & Guan, 2012). Second, the teacher needs to experience a transition from a material user to a project initiator. Teaching according to the textbook is no longer acceptable; rather, the teacher must be a competent developer of learning projects (Lyu, 2022). PBL is typically driven by a real-world issue or challenge. That means the teacher must be sufficiently sensitive and perceptive in life to spot the appropriate issue as the theme of PBL. Also, the design of PBL practices requires that the teacher have both disciplinary expertise and interdisciplinary horizons (Yao, 2023). Third, PBl means a shift in the teacher's role from an executor of teaching plans to a manager and evaluator of learning projects. Traditional instruction is a step-by-step, linear process, following a prescribed teaching plan (Qiao, 2021), whereas PBL is an open, dynamic process without a definite pattern to follow, which necessitates project management on the part of the teacher throughout all procedures. In addition, PBL is mainly evaluated by formative assessments. It is necessary for the teacher to adopt multi-dimensional evaluation, including student self-assessment, peer assessment, and teacher evaluation, to cover diverse aspects of student PBL performance, such as engagement levels, collaborative skills, and creativity (Yang & Guan, 2012). All these transitions from the roles of a traditional educator are difficult to reach for the majority of teachers in the short term, which hinders the popularization of PBL in Chinese basic education.

Limitations of Fixed School Schedules and Reachable Resources

The allocation of school time and resources is contingent on the curriculum program and course standards. Traditionally, to successfully complete teaching content in time, the teacher needs to meticulously manage the periods allocated to their course according to the course plan (Ji, 1999). However, PBL entails a lot of project design, coordination, and evaluation work in the classroom, consuming far more classroom time than traditional teaching methods. Under the PBL teaching paradigm, the teacher is not only responsible for teaching students' disciplinary knowledge but also for creating learning projects and directing students in their implementation. Specific duties associated with PBL teaching, including determining the theme, developing detailed plans, organizing resources, and monitoring project progress, consume extra time and significantly increase the teacher's workloads (Hu &Tian, 2023).

Teachers under the traditional instruction paradigm select teaching resources, such as teaching materials, courseware, aids, and experimental apparatus, according to the course standards (Xia, 2011). PBL often requires more teaching resources regarding experimental materials and technical tools, which are not always available within the school; sometimes, it may need resource support from external experts. In situations where the school cannot provide adequate support, the teacher may have to seek out teaching materials and tools, as well as partnerships and financial support from outside the school. These factors may frighten teachers away from adopting PBL (Yang & Feng, 2007).

Causes Underlying the Challenges of PBL in Basic Education

Inflexible Curriculum Structure

The curriculum structure is concerned with the organization and planning of relevant courses and activities conducted at a certain level of education. A reasonable structure of curriculum is instrumental in achieving the efficacy and quality of PBL (Wu, 2022). Currently, the rigid structure of the Chinese basic education curriculum has become an impediment to the implementation of PBL in China.

The development of basic education curriculum in China has undergone five stages: the subject-focused "Soviet-style" curriculum, labor-focused "social practice" curriculum, politics-dominated "political education" curriculum, natural science-focused "natural science" curriculum, and decentralized and integrated curriculum. The "Nine-Year Compulsory Education Curriculum Program for Ordinary Primary and Junior Secondary Schools (Trial)" stipulates that the basic education curriculum framework should include both subject-based courses and activity courses. The principle of "one uniform curriculum, multiple choices of textbook" has been supportive to the development of elective courses and practical activity courses to a certain extent (Yin & Gong, 2020). Despite curricular reforms like these, the current curriculum structure based on the discipline-specific evaluation mechanism is still insufficiently flexible for popularizing PBL.

Pressures of High-Stakes Examinations

The pressure of high-stakes examinations is one of the primary factors confounding the adoption of PBL in basic education. Under an examination-oriented education system, student academic results are the main consideration in teacher and student evaluation. Teachers and students tend to work hard for ideal test scores, disregarding the significance of practical applications of knowledge. In this context, PBL is often viewed as a practice irrelevant to students' school progression (Zhao, 2023).

Other outdated notions of education also have negative impacts on the popularization of PBL. For example, learning is traditionally seen as a process of passive reception of knowledge on the part of students, where the teacher is responsible for imparting knowledge. This notion is directly related to the rejection of PBL by teachers and student parents, who believe that there is a lack of structured delivery of content knowledge by the teacher in PBL and that students are likely to become aimless in learning, unable to master essential information and skills (Wang, 2017).

Insufficient PBL Instruction Ability of Teachers

Student PBL learning outcomes largely depend on the PBL design and organizational capacities of the teacher. Currently, the majority of basic education teachers have not developed an in-depth, systematic understanding of PBL as a pedagogical method. That leads to them deviating from the spirit of PBL when designing learning projects, making it difficult to achieve its educational value. Also, teachers must possess certain amounts of interdisciplinary knowledge and integration ability to implement PBL instruction. However, some of them may only have single discipline-based knowledge, thus being unqualified to design proper teaching plans for PBL, an instructional strategy with interdisciplinary features. Furthermore, PBL requires enhanced skills in classroom management, resource integration, coaching and mentoring, etc. on the part of the teacher. Teachers without all-round skills may find it difficult to adopt PBL in their in-class instruction (Gao, 2023).

A Paucity of Organizational Support

In PBL, students and teachers need a far wider variety of resources than in the traditional learning mode. They could be additional learning materials, apparatus, opportunities for on-site investigations, or even financial support (Wei, 2022). The school's support is crucial for accessing these resources. Somehow, the reading materials that the school library can provide and the technical expertise that the majority of basic education schools possess cannot meet the requirements of PBL instruction (Yang & Feng, 2007).

In the meantime, the lack of evaluation mechanisms that pertain to PBL is also a discouragement to its practical applications. The traditional examination-based evaluation method is not suitable for PBL. Without effective evaluation instruments, teachers and students can hardly develop adequate motivations for implementing PBL (Zhao, 2023). In addition, some schools develop PBL lessons merely for public demonstration to showcase their advantages in educational methods. That poses negative impacts on teachers' attitudes towards PBL in that these projects are mainly for publicity purposes rather than genuine explorations, severely deviating from PBL's instructional value (Zheng, 2021).

Recommendations for Improving the Implementation of PBL in Basic Education

Modifying the Curriculum Structure

Revising the curriculum structure is crucial to the reform of basic education, involving the adjustment and upgrading of basic curricular components and their interrelationships (Wang & Liu, 2015). Current curricula implemented by all schools are based on the national basic education curriculum program, which represents the essential requirements of the state for the qualities and competences of its citizens. Hence, the fulfillment of the objectives of the national curriculum program should underlie all school-based curricula (Wang & Liu, 2015). However, the existing curricular arrangement is not favorable for the implementation of PBL. It is imperative to conduct some key revisions to make the curriculum more open and inclusive to facilitate integrated and interdisciplinary study and the association of knowledge with actual reality. Such a curriculum reform has the potential to transform the traditional instruction paradigm, fundamentally changing teaching and learning patterns (Yin & Gong, 2022).

Enhancing Teacher PBL Literacy

Heightening teachers' PBL instruction competence is critical to its successful implementation among basic education students, as teachers act as the organizers, participants, and supporters of PBL (Yang & Guan, 2012). First off, it is important for the school to provide PBL literacy training to teachers before its across-the-board adoption. Through the training program, the teacher has the chance to comprehend PBL's significance and value in basic education and to develop interest in and confidence in PBL instruction. Alongside the school-based training, cross-school exchange also gives the teacher the opportunity to observe and contemplate PBL in PBL teaching settings. This is helpful in increasing the teacher's exposure to excellent PBL practices and the possibilities of their learning from the successful experiences of peers. In addition, it is advisable to introduce the "mentoring system" into PBL literacy training, under which those "PBL activists" can receive intensive training first and then lead their colleagues at large in the PBL implementation (Wang, 2009).

At the same time, it is important for the teacher to continuously upgrade their knowledge repertoire and increase teaching design capacities in order to create challenging, deeper-learning-inciting PBL protocols for their students (Cui, 2022). To do so, the teacher should voluntarily read an extensive range of books and journal articles on PBL and study excellent PBL cases. They can also leverage abundant online resources to enrich their theoretical knowledge about PBL and PBL implementation skills so as to practice PBL instruction with more positive attitudes.

Strengthening Resource Backing for PBL

The implementation of PBL is a complex task involving extensive resources, including information, apparatus, technical support, specialized funding, and more (Feng & Zhu, 2003). The school should expand its collection of professional books and journals on education sciences to facilitate teachers' acquisition of PBL-related knowledge. As for those PBL projects that require external expert and funding support, the school should mobilize organizational resources to reach partnerships with relevant experts and businesses.

In the IT era, the use of digital technologies can significantly boost the outcomes of PBL (Zhang, 2022). The school should increase its investment in digital resources, which will bring substantial benefits to teachers' and students' PBL activities. Cutting-edge information technologies, such as the cloud collaboration platform, virtual reality, and augmented reality, can enhance the implementation of PBL by providing more diverse learning scenarios and richer, more interactive learning experiences. Teachers can adopt learning analytics to gain a better understanding of students' academic positions, thereby making more precise and targeted PBL instruction protocols. Educational technology will help teachers monitor students' progress and adjust teaching strategies accordingly to advance PBL in a more reasonable manner. With online learning platforms, students can access more technical tools and information for their PBL activities and enjoy more flexible and efficient PBL without temporal and spatial constraints.

Incorporating PBL in the Evaluation Framework

Teachers' and students' attitudes towards PBL are determined by the components of education evaluation in some way (Zhao, 2023). Based on their own special circumstances, schools should modify their teacher evaluation system to incorporate PBL competence as an indicator of teacher performance and establish a specialized incentive mechanism to activate teachers' interest in engaging in PBL instruction.

PBL is aimed at promoting student learning of essential concepts and principles and augmenting their key competences, such as innovative, exploratory, and collaborative abilities, through authentic problem solving. Accordingly, the student evaluation system should also be updated with the change in educational requirements. A multi-dimensional evaluation approach that is more focused on student holistic growth than merely on their exam results should be developed to facilitate the assessment of PBL's educational outcomes.

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