JOURNAL OF BALTIC SCIENCE EDUCATION

ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

AN EXPLORATION ON CONCEPT TEACHING KNOWLEDGE OF BIOLOGY TEACHERS IN LOWER-SECONDARY SCHOOLS

Mingyu Li

Abstract. *The topic 'photosynthesis' contains many intangible and abstract scientific concepts, regarding which students hold many preconceptions. Conceptual learning is a process of co-creation and flow that requires the teachers' higher educational level on conceptual teaching. The present research considers photosynthesis as an example. Results of Ball's 2008 research on teachers' content knowledge for teaching served as the theoretical framework. In total, 30 biology teachers from 11 lower-middle schools in a medium-sized city in China were selected as the research objects. The conceptual learning achievements of 1442 students taught by those teachers were used as a yardstick, and two sets of self-designed questionnaires were used to demonstrate, describe, and discuss these elements and their current state in the teachers' mind and determine influencing factors. According to the results, except for the knowledge of concept and student element, all the other three elements attained the passing level. Specifically, the level of common concept knowledge was relatively high, but this element had not attained the perfect level. A scope for improvement was observed for the other three conceptual knowledge elements. No significant difference in the knowledge elements level was observed among the teachers from different schools.*

Keywords: *concept teaching, teachers' concept teaching knowledge, teacher education, teacher knowledge*

Mingyu Li
Capital Normal University, China

Introduction

Scientific content knowledge plays a crucial role in teaching and can promote scientific thinking in students. Scientific development is closely related to the formation of scientific concepts, and the achievements of science are mainly presented in a conceptual form. On the one hand, scientific concepts have formed gradually and improved with the development of science, revealing the objective laws of things, and reflecting the results of scientific understanding. On the other hand, as the basic unit of scientific thinking operations, scientific concepts can deepen scientific thinking and promote scientific understanding and practice. China's new 'Compulsory Education Biology Curriculum Standards', which was released in 2011, highlighted in implementation recommendations that standards claimed 'focus on the study of important concepts' and pointed out that important biological concepts are at the centre of the discipline (China, 2011). Based on the development of students' core literacy, The Biology Curriculum Standard of General High School of China introduced in 2017 further clarified the four core literacy elements, namely life concept, scientific thinking, scientific inquiry, and social responsibility, emphasizing the need for the construction of students' biological concepts, acquisition of life concept, and development of scientific thinking. Concept teaching has become the core content of biology teaching (China, 2017).

Therefore, possessing the corresponding concept teaching knowledge has become the premise and foundation for biology teachers to carry out effective concept teaching. Unfortunately, at present, our teacher training has not specially set up concept teaching courses, and there are a few studies on concept teaching. Thus, it is unclear what type of knowledge do biology teachers need to possess in concept teaching. This problem cannot be avoided for our teacher training institutions and teachers themselves. Thus, the present research aims to address this core issue.

https://doi.org/10.33225/jbse/22.21.121

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

First, the research position of this study needs to be clarified, and the key concepts need to be defined. According to the constructivist view of learning, learners have formed their own ideas and views on scientific phenomena and processes before receiving formal education, which has led to the formation of many concepts in their brains, some of which are correct, and some are wrong; some are complete, and some are incomplete. Because these prior concepts are stubborn and often difficult to change, if they are not paid timely and sufficient attention in the early teaching process, they are likely to be held by learners for a lifetime (Treagust, 2006).

Academic circles have different names for learners' original views and viewpoints, or prior- concepts. At present, there are three terms that are widely used: misconception, alternative conception, and preconception. Different terms represent different philosophical views of scholars. Scholars such as Ausubel (1963) have advocated the use of "pre-scientific conception", referred to as "preconception". They believe that the negative implication of preconception is much less than that of misconception. Preconception is an incomplete understanding of concept and may not be wrong, and it best expresses what the researcher wants to express.

This study considers the term "preconception" because what affects students' follow-up learning is not only the misconceptions in students' minds but also the incomplete understanding of scientific conceptions, which are also the objects that remain to be explored. Therefore, the term "preconception" is used uniformly in this paper (for the use of terms in the cited literature, the author's original text shall be followed).

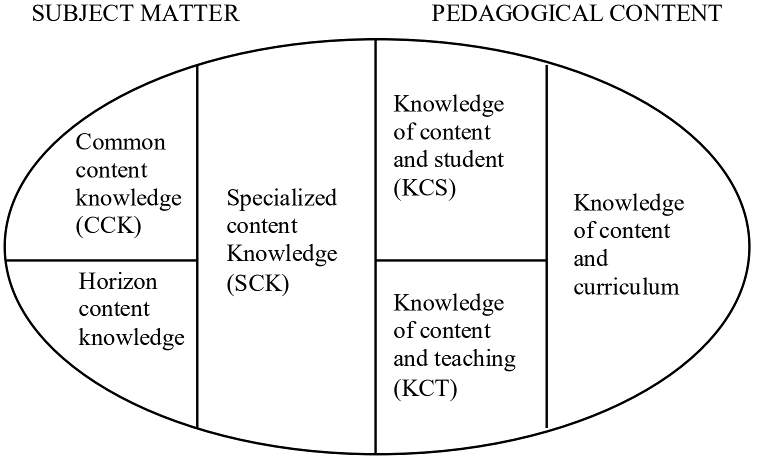
As early as the 1980s, Shulman and his colleagues have begun paying attention to this problem. They initially have divided teachers' content knowledge (CK) into subject matter knowledge, teaching content knowledge, and curriculum knowledge (Shulman,1986). Later, the teacher's CK has been put into the teacher knowledge, and the teacher's knowledge has been divided into seven elements, and the PCK that originally belonged to CK has been independent, becoming an element that belonged to the teacher's knowledge and juxtaposed with the teacher's CK (Shulman,1987). At that time, the academic circles generally believed that the level of teachers' PCK had closely related to the quality of teachers' teaching effect. Therefore, many scholars further have defined PCK and carried out research on teachers' PCK based on the work of Shulman and his colleagues (e.g., Leinhardt, 1990; Grossman, 1991; Cochran, 1993; Morine-Dershimer & Kent, 1999). However, they had ignored a very important element of teacher knowledge other than teacher PCK, that is, the teacher CK that Shulman and his colleagues initially paid attention to and have been continuously engaged in research on this aspect. PCK can be said to be teaching practical knowledge based on teaching situation. To effectively use PCK, teachers should first have corresponding CK in their minds, that is, in their conceptual system, there should be corresponding CK concept nodes for them to temporarily call the combination to deal with the problems encountered in teaching.

Ball et al. (2008) Based on Shulman and his colleagues' main views on teacher knowledge research in 1986 (lack of paradigm and PCK concept), the importance of promoting content knowledge for teaching (CKT) had been emphasized again, and on the basis of Schumann's definition and essential attribute positioning of PCK at that time, the constituent elements, types and essence of content knowledge used by mathematics teachers for teaching had been further revealed through practical investigation. The authors emphasize that PCK is a special form of content knowledge.

Through normal observation and summary of the teaching process, based on the collective wisdom of a group of experts with extensive experience and subject background, and the research accumulation of Ball and other scholars in recent decades, the authors have summarised the necessary content knowledge of mathematics teachers. According to them, the induction of this knowledge element originates from the excavation of teachers' essential knowledge. This research result has strong popularisation significance and can be successfully applied to other disciplines, such as history, biology, and music. It is proposed that the elements contained in CKT are as follows: Common content knowledge (CCK); Special content knowledge (SCK); Knowledge of content and students (KCS); Knowledge of content and teaching (KCT). (As shown in Figure 1)

https://doi.org/10.33225/jbse/22.21.121

Figure 1
Domains of Mathematical Knowledge for Teaching (Ball et al., 2008)



Based on this CKT framework, this study constructs the concept teaching knowledge framework of biology teachers, which is in line with the existing relevant research views and conclusions, then the content of each element was divided and defined (Burgoon et al., 2009; Gomez-Zwiep, 2008; Kruger, 1990; Yip, 1998; Iordanou, 2003; Morrison & Lederman, 2003; Meyer, 2004).

This research collected, summarized, and internalized the results of previous studies and inferred that the concept teaching knowledge of lower-secondary school biology teachers should include four elements: CCK, SCK, KCS, and KCT. These four elements can respectively identify the teachers' general and professional mastery level on scientific concepts and maturity level on misconception, diagnostic methods, and changing strategies. It is considered that the four elements of teacher concept teaching (CCK, SCK, KCS and KCT) exhibit a recursive logical relationship.

CCK (Common Concept Knowledge) reflects the degree of mastering scientific concepts for teachers. Related studies have demonstrated that a vital source of students' preconceptions is teachers' preconceptions. Consequently, this element fundamentally promotes students' learning about concepts, which belongs to the scope of CCK.

SCK (Special Concept Knowledge) explains the essence of differences between preconceptions and scientific concepts. It could be distinguished from CCK because it forms the basis for teachers to understand students' preconceptions. At the same time, SCK includes teachers' understanding about the definition, characteristics, and functions of preconceptions. To a certain extent, SCK reflects teachers' essential understanding of preconceptions that can potentially impact teachers' teaching orientation. Moreover, SCK determines whether teachers will notice the hindrance caused by preconceptions in students' learning, which will seriously influence students' learning achievement. Simultaneously, it affects the teachers' meta-cognition level about their preconceptions, as well as their professional development. This knowledge element belongs to the scope of SCK.

Knowledge about students and concepts is the teacher's knowledge of the students' preconception level. For example, based on the existing knowledge and cognitive level of students from different backgrounds and grades, how to define the difficulty degree of a topic? Students hold preconceptions on which subjects? What types of preconceptions do students usually have? What methods can be used to explore students' preconceptions? This knowledge element belongs to the scope of KCS (Knowledge of Concept and Student).

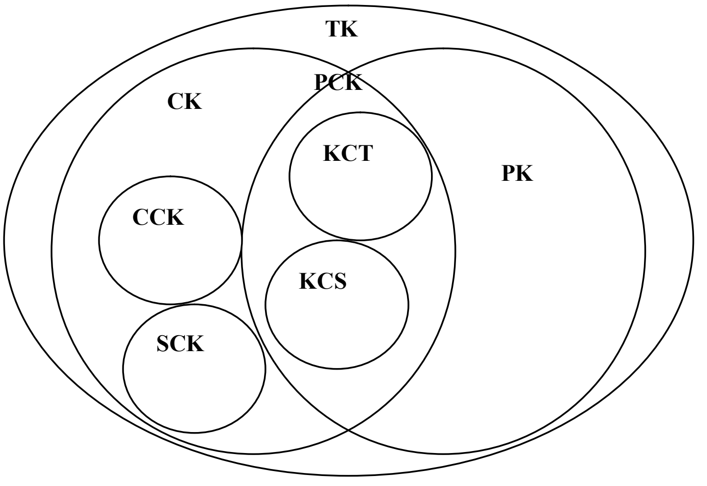
Knowledge about students and pedagogy is the teachers' knowledge of students' conceptual change strategies. It refers to teachers' mastery and the condition for applying conceptual change strategies under specific situations. This knowledge element belongs to the scope of KCT (Knowledge of Concept and Teaching).

Here, based on the main views of previous studies, especially the academic positions of Shulman (1986) and Ball et al. (2008), these four elements were returned to the teacher's subject content knowledge to express the relationship among these elements, teacher's content knowledge, and PCK.

https://doi.org/10.33225/jbse/22.21.121

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Figure 2
The Relationship among Various Elements of Concept Teaching Knowledge and PCK



As shown in Figure 2, this research highlights the following points: first, the four elements (namely CCK, SCK, KCS, and KCT) constitute the teacher's content knowledge. Second, KCS and KCT are also located at the intersection of content knowledge and pedagogy knowledge—PCK. Because CCK and SCK indicate the extent of misconceptions among teachers and their understanding of the essential attributes about misconceptions, they are all theoretical knowledge. KCS and KCT are teachers' knowledge about students and content and about students and teaching, respectively. On the one hand, teachers should have an understanding and mastery of these two aspects of knowledge at the theoretical level; on the other hand, they should also be able to apply the theoretical knowledge related to these two elements or the knowledge in their minds to the teaching practice depending on a specific teaching situation. Thus, the last two elements should belong to the PCK knowledge domain. The present research focuses on exploring the level of these four elements in the teacher's mind.

Since the concept teaching knowledge of biology teachers is put forward for the first time, this study uses the achievements of students' concept learning as the yardstick to confirm the rationality of these elements in statistical sense. The research idea is mainly inspired by three research paradigms of teachers' CK and students' learning achievements. 1)The "process product" research paradigm that studies the relationship between teachers' teaching behaviour and students' learning achievements, which has been proposed by the scholars (e.g., Brophy & Good, 1986; Doyle, 1977; Gage, 1978) 2) The research paradigm of "educational production function", which studies the relationship between educational resources and students' learning achievements (Greenwald et al., 1996; Hanushek, 1981). 3) The research paradigm of "teacher knowledge" has been raised by Ball team (Ball et al., 2008).

Definition of photosynthesis: synthesis of complex carbon compounds out of carbonic acid, in the presence of chlorophyll, under the influence of light' should be designated as either 'photo syntax' or 'photosynthesis' (Gest, 2002). Photosynthesis is the key concept to be learned by students from primary schools and even college or university. However, as a complex biological subject, photosynthesis covers several conceptual contents. Students find it difficult to understand the relationship among these conceptual contents. Extensive research has been conducted to study students' preconceptions regarding photosynthesis (Dolenc Orbanić et al., 2016). Relatively small number of studies have focused on teachers' preconceptions about photosynthesis, and many biology teachers have been reported to hold misconceptions similar to their students (Burgoon et al., 2011). However, little attention has been paid to the relevance of preconceptions between teachers and students about this topic. Therefore, this research considered the theme of 'photosynthesis' as an example and students' academic performance as a yardstick to delineate the elements of biology teachers' concept teaching knowledge from the perspective of quantitative research and analysed the concept teaching knowledge of science teachers.

Considering the crucial role of concept teaching in the construction of scientific concepts and the formation of scientific literacy, this research attempted to extend Ball's research on teacher's content knowledge for teaching. The present research also attempted to quantitatively demonstrate the connotation, boundary, and relation-

https://doi.org/10.33225/jbse/22.21.121

ship among the four elements of Ball's framework and to interpret them from the content knowledge base for conceptual teaching, which is essential for teacher's concept teaching. Hopefully, this research can be promoted and expanded to further deepen previous research results; more importantly, the slogan 'teaching for conceptual change' has been appealing for almost 40 years. Several studies have suggested that the construction of 'missing paradigm' must be grasped. Teachers' understanding and teaching level of scientific concepts need continuous attention. However, teacher education has grabbed considerable attention and should remain the prime focus in future. First, the present research determines the basic knowledge elements necessary for the concept teaching of science teachers and discusses how well the teachers master this knowledge.

Research Aim and Research Questions

The research aimed to delineate the elements of teachers' concept teaching knowledge, evaluate the potential relationship between the elements, and explore the current state of Chinese lower-middle school biology teachers' conceptual teaching knowledge by using the theme of photosynthesis. A reliable and valid questionnaire was developed in this research to test teachers' concept teaching knowledge. The following three questions were addressed during the research period.

RQ #1: Statistically, are CCK, SCK, KCS and KCT the necessary knowledge elements for the concept teaching of lower-secondary school biology teachers?

RQ #2: In practice, starting from the survey sample, how about the status quo of CCK, SCK, KCS and KCT of biology teachers in lower-middle schools?

RQ #3: Are there any possible influencing factors of concept teaching knowledge?

Research Methodology

Research Design

In terms of concept teaching, combined with previous research results, this research first defined the connotation of the four elements mentioned in the Ball's research framework: CCK, SCK, KCS, and KCT. Based on the two-tier diagnostic test of this topic compiled by Treagusts (Peterson et al., 1986), a set of diagnostic tests compatible with the study's objective and subjective questions was independently developed in the present research. Two versions of a two-tier diagnostic test questionnaire were used to explore the level of four knowledge elements for conceptual teaching of 30 teachers and to determine the learning achievement of the students of these teachers. By analysing the relationship between the level of knowledge elements for teachers' conceptual teaching and students' learning achievement, this research demonstrated the importance of these four elements through quantitative research, explored the relationship between these elements, and assessed the teachers' knowledge level for conceptual teaching.

Based on the research standpoints of Shulman, Ball, and other scholars on subject-oriented teacher knowledge, the present research explored the necessary content knowledge of science teachers for conceptual teaching. Based on previous research results and the perspective of conceptual teaching, the four knowledge elements mentioned in the Ball's model were specifically studied. The constructivist teaching view emphasizes the commitment to students' preconceptions. However, the existing research shows that teachers' preconceptions are also somewhat similar to students' preconceptions (Liu & Li, 2016). Teachers' preconceptions are likely to be one of the main sources of students' preconceptions (Li & Liu, 2010). Therefore, there is an urgent need to return to the content knowledge level of conceptual teaching and explore content knowledge required by teachers for conceptual teaching.

Participants

Participants were from a second-tier city in China. The teaching level of this city is medium in China. This city has 90 lower-secondary schools, which can be divided into three types according to the school level. This research first adopted a stratified sampling approach. Eleven schools were randomly selected from these three types of schools, and an average of 2–3 teachers were selected from each school. Then, one class taught by each teacher was randomly selected, with each class consisting of an average of 40–50 students. A total of 30 teachers (all 30

https://doi.org/10.33225/jbse/22.21.121

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

questionnaires were valid) participated in the survey. Simultaneously, the conceptual learning achievements of 1,442 students (1416 valid questionnaires were collected) they taught were also investigated to bring out the research objectives.

Before collecting the questionnaire, all participating teachers in the study were informed that the questionnaire collection was anonymous, and the data obtained were only for research purposes and would not be obtained by others.

The teacher group comprised 12 men and 18 women, with age ranging from 28 to 50 years. Of the total, 11 teachers were from Grade 7, and 19 teachers were from Grade 8. The average teaching age was 8 years. The teacher ratio of the three types of schools is 9:12:11.

Research Tool

Types of the instrument used

Two versions of the questionnaire were used in the present research: student's version and teacher's version. The content of the questionnaire is based on the two-tier diagnostic test related to the subject of 'photosynthesis and respiration' compiled by Australian scholars (Treagust & Haslam, 1986).

The student's version of the questionnaire is based on a literal translation of the original English version, and by using this questionnaire, the sources of the students' preconceptions were analysed. It consisted of 13 five-choice (one right answer, three distractors, and one for other reasons) test items. The first draft of the questionnaire was tested, and feedback of at least six experts and four experienced in-service teachers was obtained. Based on the feedback, the questionnaire was continually revised, and the final draft was then created. Before testing for validity and reliability, a pilot test was implemented with 100 students to determine whether there was anything the students could not understand. The score range possible on the two-tier test is 0–26.

Some changes were made to the teacher's version questionnaire based on the student's version questionnaire; the teacher's version questionnaire covered the four elements of teachers' concept teaching knowledge mentioned in this research. For example, the first part of the teacher's questionnaire is mainly for the second element of teachers' concept teaching knowledge, that is, SCK. The completed teacher's version of the questionnaire was also tested by six experts. The two versions of the questionnaire met the structural requirements of the standard questionnaire, and the questionnaire involved a combination of open and closed questions.

Question setting of the instrument

The questionnaire for teachers' concept teaching knowledge can be divided into three parts. The first part consists of six items, including three single-choice questions, one short answer question, and two semi-open questions, and these items are mainly used to measure the second element of teacher's concept teaching knowledge (i.e., SCK). The second part consists of 13 items, all of which are single-choice questions that are mainly used to test the first element of teacher's concept teaching knowledge (i.e., CCK). The third part consists of six items including two single-choice questions, one short answer question, and three multiple-choice questions. These six items are mainly used to test the third and fourth elements of teachers' concept teaching knowledge (KCS and KCT, respectively). The students' questionnaire has 13 items, and each question has 3 three-tier diagnostic tests. The first test involves selecting the option for a question. The second test involves explaining the reason for selecting the option (i.e., why do I choose this option?). The third test involves explaining the source of the reason.

Scoring standard of the instrument

The teacher's version of the questionnaire comprised a total of 25 questions and three parts. The second part of the questionnaire is about the CCK element, which is same as that in the student's version of the questionnaire. The statistical scoring method is as follows. The answers for the original English questionnaire are used as the standard. Under the condition that each respondent chooses the right option and the right reason at the same time, each question is assigned 2 points, and no points are assigned to the situation of missing answer or no more than one error. The third part of the teacher's questionnaire is about the KCS element, which mainly compares the answers

https://doi.org/10.33225/jbse/22.21.121

between the teachers and their students, and then, points are assigned. For example, to determine whether the teacher's speculation regarding the students' error rate is accurate, we need to determine whether it matches the student's actual answering situation. The rest of the questionnaire is about the SCK and KCT elements. The scores of related questions are based on the existing research results and the academic position of the research. Accordingly, four grades, namely excellent, good, general, and poor, are assigned, with excellent being equivalent to 3 points, good equivalent to 2 points, general equivalent to 1 point, and poor equivalent to 0 point. The score range possible on the whole test is 0–65.

Reliability and validity test of the instrument

The 'quantitative analysis method' of expert review was used to conduct the validity test, and the questionnaire for the validity test was compiled. The test questions in the survey questionnaire were compared with every detail of the teachers' concept teaching knowledge. Then, the correlation between every question and knowledge point could be determined using a four-point scale.

The content validity coefficient was 24/0+0+1+24 = 0.96. According to the validity test requirement of the General Knowledge Survey Questionnaire, the acceptable range for the validity coefficient is >0.70. Thus, the test questions of the questionnaire could examine the teachers' concept teaching knowledge.

Because the questionnaire contains various questions, the scoring method does not involve marking a single answer as right or wrong but involves multiple scores. For example, the scoring method applied in the first and third parts of the questionnaire uses a range 0–3. Therefore, with the Cronbach alpha coefficient, a reliability coefficient of 0.843 was calculated for the questionnaire.

The aforementioned test of validity and reliability of the teacher's questionnaire revealed that the questionnaire is effective and stable.

Example of a test item on the teacher's version of the questionnaire (question about KCS)

Q1. In your opinion, the proportion of students who can't correctly answer the question... (In the student version questionnaire) in your class is about?
A 1%—25%
B 25%—50%
C 50%—75%
D 75%—100%

Q2. Which do you think is the easiest choice for students (A, B, C, D)____________________________
Or other____________________________

Q3. What are the possible reasons for their choice__________________ Or other____________________

Q4. Which scientific concept or aspect of the conception do they understand not deeply enough or even wrong?
(a short answer to this question is enough)

Procedure

The research was conducted in the fall semester of the 2019-2020 academic year and involved the unit of "Photosynthesis" in the 7th grade biology course. The duration of the research was a total of twelve weeks.

After learning the theme of photosynthesis, the teachers and students were asked to complete the questionnaire in one lesson, that is, 45 min and 45–60 min, respectively. The teachers and students were required to keep thinking independently and not to refer to any relevant materials or answers from others to ensure the reliability of data obtained from the questionnaires.

https://doi.org/10.33225/jbse/22.21.121

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Treatment in the students group

Once the questionnaires were distributed, the students were told that they were to follow the instructions on the sheets. After each student received a sheet, the researchers shared the following two points with the students. 1) There are 13 questions in the student questionnaire, and each question contains 3 small questions. First, make choices according to the questions; Secondly, explain the options made and why to choose this option; Finally, for this reason, explain the source of the reason. 2) In the second small question of each question, 1, 2, 3, 4, and other reasons, the five options are juxtaposed, that is, if you can't find the corresponding reason in 1, 2, 3, 4, fill in the other reasons by yourself. The researcher acted as a guide throughout the process who answered students' questions about the items and explained rules to ensure the effectiveness of the returned questionnaire.

Treatment in the teachers group

Considering teachers' professional awareness, researchers did not make rigid requirements for teachers' answer location. Teachers are only required to answer the questionnaire according to the guidance within a given period of time. To ensure the authenticity and validity of the questionnaire as much as possible, the researchers asked the teachers to write their initials in the name column, asked the teachers to fill in the information such as education background, teaching age, rank and major, and asked the teachers to leave a common email for follow-up research. At the same time, the mailbox of the research group was attached to answer the teachers' questions at any time.

Data Analysis

Accordingly, 30 teachers' questionnaires and 1,442 students' questionnaires were distributed. Then, the collected data were encoded, and SPSS *Version 18.* was used for data analysis. The total score of the conceptual knowledge for teaching (CKT); the scores of CCK, SCK, KCS, and KCT of the 30 teachers; and the academic scores of their students were analysed to delineate and corroborate the theoretical framework proposed in this research——the elements of teacher concept teaching knowledge. The teacher's questionnaire was used to test the status quo of concept teaching knowledge.

Data collected were analysed using SPSS *Version 18*. Descriptive statistics were used to obtain the situation about means, standard deviations (maximum and minimum) of the scores for each element of conceptual teaching knowledge (CKT). The means were used to determine the level of teachers' concept teaching knowledge. Correlation analysis was used to determine the elements of teachers' concept teaching knowledge by calculating the correlation between the scores of knowledge elements and students' concept learning achievements. The t-test (p <0 .05) (Tlala et al., 2014) was used to verify the influencing factors of teachers' conceptual teaching knowledge level, such as educational background, teaching age, gender, rank, age, and school. Regressive analysis was calculated among the knowledge elements to infer the logical relationship between the elements.

Research Results

Statistical Analyses for Teachers' Concept Teaching Knowledge

The academic achievement of students is a critical criterion for evaluating the teachers' teaching level, and this paper statistically analysed the relationship between the four elements of teachers' concept teaching knowledge (CCK, SCK, KCS, and KCT) and students' academic achievement by using SPSS Version 18. In this manner, the speculation that whether these four elements of concept knowledge are essential for lower-secondary school biology teachers can be verified.

Analysis of the Correlation between Four Elements on the Concept Teaching of Biology Teachers in Lower-secondary Schools and Students' Academic Achievement

First, the developed questionnaire of teachers' concept teaching knowledge was used to assess the concept teaching knowledge of lower-middle school biology teachers. Then, the correlation between teachers' score of

https://doi.org/10.33225/jbse/22.21.121

the four elements of concept teaching knowledge and the students' academic achievement was analysed using SPSS *Version 18*. The four elements were highly positively correlated with students' academic achievement ($p < .01$, $p < .01$, $p < .01$, and $p < .05$). The overall scores of the four elements on the teachers' questionnaire (content knowledge) and the students' academic achievement level also showed a high degree of positive correlation ($p < .01$). According to common sense, the impact of teachers' knowledge on students' academic achievement must be higher than that of students' academic achievement on the teachers' knowledge level. The results obtained using the students' questionnaire revealed that the prominent three sources of students' preconceptions were their reasoning and judgment, the teaching of lower-secondary school biology teachers, and lower-secondary school biology textbooks. Students' reasoning and judgment only indicated that they had a low level of understanding regarding the relevant scientific conceptions, which resulted in wrong answers. Only the other two causes of error truly reflected the source of students' preconceptions about scientific concepts. Hence, the four elements of teachers' concept teaching knowledge greatly influenced students' academic achievement and played a key role in concept teaching. The quantified results largely supported our initial assumptions about these elements of concept teaching knowledge, that was, the concept teaching knowledge of lower-middle school biology teachers must have four elements, namely CCK, SCK, KCS, and KCT.

Relevance Analysis of Four Elements of Junior Biology Teachers' Concept Teaching Knowledge

The present research analysed the correlation between the adjacent elements of the first to the fourth elements of teachers' concept teaching knowledge (CCK, SCK, KCS, and KCT) by using SPSS *Version 18.* A significant positive correlation was observed between the adjacent elements (($p < .01$). Then, the causal relationship between adjacent two elements was analysed through regression. Significant causal relationships were observed between the first and second factors ($p < .05$), second and third factors ($p < .01$), and third and fourth factors ($p < .01$). Therefore, this research suggested that these causal relationships may be a type of recursive logical relationship. The results showed that biology teachers' concept teaching knowledge needs four elements: CCK, SCK, KCS, and KCT. Quantitative results demonstrated that these four elements are likely to share a type of recursive logical relationship.

Influencing Factors about Lower-middle School Biology Teachers' Concept Teaching Knowledge

This research collected data on teachers' academic qualifications, majors, genders, teacher qualification levels, number of courses about teaching, and the level of their schools, which may affect the level of teachers' concept teaching knowledge. However, except for the level of their schools, other variables were similar. On considering the school level as a grouping variable and teachers' concept teaching knowledge scores and total scores as dependent variables, no significant difference was found in the dependent variables among different groups, that was, no significant difference was observed between the scores for the various elements and total scores for teacher's concept teaching knowledge among different levels of schools. The schools were grouped as follows: 1) the first-level middle schools in a city: WSS middle school, YLS middle school, CYSY middle school (3 schools); 2) Key middle schools in a city: WSE middle school, SSW middle school (2 schools); 3) Ordinary middle schools in a city: QSE middle school, SSS middle school, SB middle school, LSB middle school, BSE middle school, and SW middle school (6 schools).

Analysis of the Status Quo of Biology Teachers' CCK Level in Lower-middle Schools

Table 1 presents the basic statistical description of the CCK level of biology teachers in lower-secondary schools. In the first part of the questionnaire, 13 questions were set with 2 points for each question. The preconceptions of biology teachers regarding the subject of photosynthesis and respiration were explored, and the level of knowledge about common concept teaching (CCK) under this theme was also identified. The summarized statistics from the CCK-related questions for teachers are presented in Table 1 and Figure 3.

https://doi.org/10.33225/jbse/22.21.121

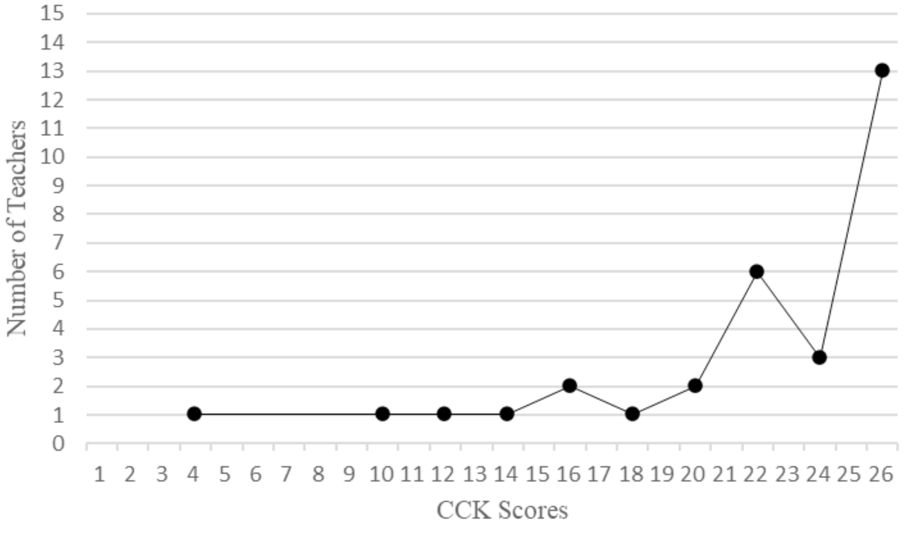
ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Table 1
Teacher CCK Level Basic Description Table

Scores	*N*	*M*	*SD*	Min	Max
Item1	30	1.73	0.69	0.00	2.00
Item2	30	1.40	0.93	0.00	2.00
Item3	30	1.67	0.76	0.00	2.00
Item4	30	1.67	0.76	0.00	2.00
Item5	30	1.87	0.51	0.00	2.00
Item6	30	1.87	0.51	0.00	2.00
Item7	30	1.60	0.81	0.00	2.00
Item8	30	1.80	0.61	0.00	2.00
Item9	30	1.60	0.81	0.00	2.00
Item10	30	1.80	0.61	0.00	2.00
Iem11	30	1.60	0.81	0.00	2.00
Item12	30	1.60	0.81	0.00	2.00
Item13	30	1.80	0.61	0.00	2.00
CCK total score	30	22.00	5.40	0.00	26.00

Note. M = Mean; SD = Standard Deviation

Figure 3
Teacher's CCK Score Distribution



As shown in the aforementioned table and figure, of the 30 teachers, 13 teachers obtain a full score of 26, whereas 17 teachers do not obtain a full score. While answering CCK-related questions, 56.7% (17/30) teachers exhibited different levels of misunderstandings. Of the 30 teachers, 20 teachers scored 20–24 points and 24–26 points. There were a certain number of teachers in other fractional segments. The teacher's average score was 22 (a full score of 26, 22/26 = 0.85). The standard deviation was 5.41, which was relatively high. Conclusively, the CCK level of most lower-secondary school biology teachers was relatively high; their CCK scores were generally higher than 20. However, some teachers were found to hold varying degrees of preconceptions. In addition, there were mistakes in each question. Only 43.3% of teachers achieved a full CCK score of 26.

https://doi.org/10.33225/jbse/22.21.121

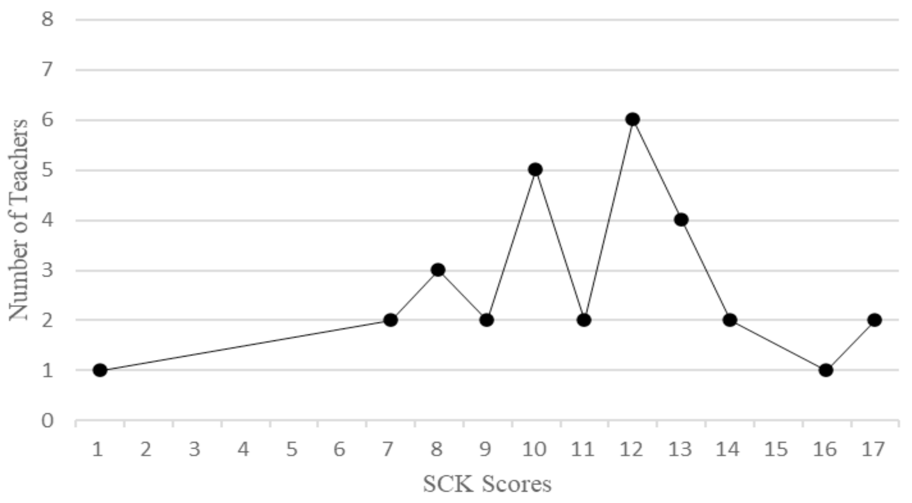
Status Quo of Biology Teachers' SCK Level in Lower-middle Schools

In the second part of the teacher's questionnaire, 6 questions were set with 3 points per question. These questions were used to explore the special concept teaching knowledge of lower-secondary school biology teachers. The special concept teaching knowledge reflects the teachers' understanding about the definition, terminology, and characteristics of preconceptions, as well as the negative effects of preconceptions on teaching. It also reflects the attitude of teacher's concept teaching. Because this knowledge element is unique to teacher's concept teaching, people with relevant scientific literacy do not have to master this knowledge, and therefore, this element is called SCK. The summarized statistics from the SCK related questions for teachers are presented in Table 2 and Figure 4.

Table 2
Teachers' SCK Level Description

Scores	*N*	*M*	*SD*	Min	Max
Item1	30	2.67	0.55	1.00	3.00
Item2	30	1.50	1.53	0.00	3.00
Item3	30	1.53	1.01	0.00	3.00
Item4	30	1.50	0.98	0.00	3.00
Item5	30	1.67	1.03	0.00	3.00
Item6	30	2.17	1.29	0.00	3.00
SCK total score	30	11.00	3.26	1.00	17.00

Figure 4
Teacher's SCK Score Distribution



As shown in the aforementioned table and figure, none of the 30 teachers obtain a full score of 18. Of the 30 teachers, 11 teachers score 10–12 points, and the remaining teachers score different points. The average teachers' score was 11 points (a full score of 18, 11/18 = 0.61), and the standard deviation was 3.26. The results indicated that the level of special concept knowledge of biology teachers in lower-secondary schools has reached the passing level, and the SCK level in lower-middle school biology teachers was uneven.

From the answers to each item, 30 teachers fully or partially recognized the existence of students' preconception. Among them, 50% of the teachers could correctly cite examples of students' preconception and tended to use the term "preconception". All 30 teachers had varying degrees of understanding of the characteristics of

https://doi.org/10.33225/jbse/22.21.121

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

preconception, and 83% of the teachers thought that preconception had an impact on students' learning of scientific concepts. In terms of preconception coping, 50% of teachers said they had paid attention to the impact of students' preconception on teaching, but they were unable to deal with it.

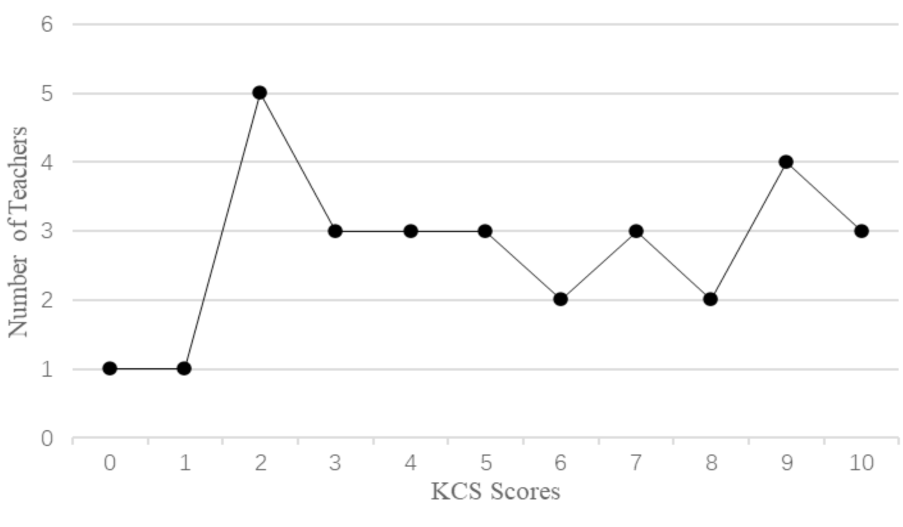
Analysis of the Status Quo of Biology Teachers' KCS Level in Lower-middle Schools

The third content examined belonged to the teacher's KCS. Regarding the analysis of KCS, the teachers' questionnaire had 5 questions that was used to examine teachers' knowledge of concepts and students. Some questions were asked to the teachers to predict the error rate of students' answers to a question, while other questions were related to the common preconceptions about a question, scientific conceptions related to the preconceptions about the question, probing methods that teachers tended to use for specific preconceptions, and teachers' understanding of the source of specific preconceptions. The summarized statistics from the KCS related questions for teachers are presented in Table 3 and Figure 5.

Table 3
Teacher's KCS Basic Description

Scores	*N*	*M*	*SD*	Min	Max
Item1	30	0.93	0.79	0.00	3.00
Item2	30	1.07	1.34	0.00	3.00
Item3	30	1.67	0.89	0.00	3.00
Item4	30	1.73	1.11	0.00	3.00
KCS total score	30	5.40	3.06	0.00	10.00

Figure 5
Teacher's KCS Score Distribution



As shown in the aforementioned table and figure, none of the teachers achieved a full score of 15. Of the 30 teachers, 9 teachers scored 2–9 points, and a certain number of teachers scored at all other points. The average score was 5.4 ($3 \times 5 = 15$, $5.4/15 = 0.36$), and the standard deviation was 3.03. From the results, it can be concluded that the KCS level is uneven among biology teachers in lower-secondary schools. Moreover, the difference between high and low scores was quite large, and the KCS level of biology teachers in lower-secondary schools was generally not high.

From the answers to each item, for specific teaching content, only 30% of teachers could correctly evaluate the students' error rate, while the remaining 70% of teachers overestimated the students' learning level. Only 13% of

https://doi.org/10.33225/jbse/22.21.121

the teachers were able to answer the preconceptions easily generated by students; 50% of teachers could provide correct or near correct explanations to the possible scientific reasons behind students' preconceptions. For the possible sources of students' preconceptions, 70% of teachers believed that they came from daily life experience, followed by social media misleading, weak grasp of basic concepts, inaccurate understanding of teaching materials, and teachers' misleading behaviour. The teachers considered the most used preconception diagnosis methods to be discussion and interview, followed by concept mapping, mapping, and questioning.

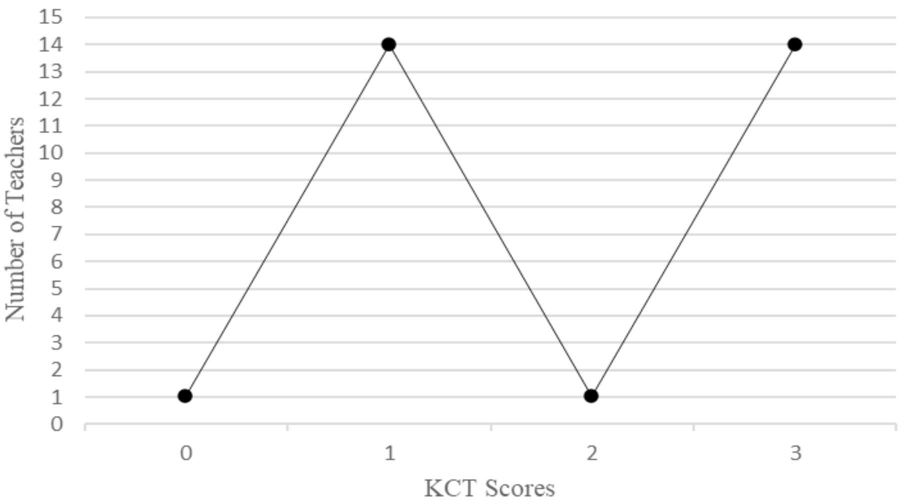
Analysis of the Status Quo of Biology Teachers' KCT Level in Lower-middle Schools

In the last part of the teacher's questionnaire, 1 question was used to examine teachers' tendency to use conceptual change strategies for specific preconceptions, which aimed to determine KCT (the fourth element of concept teaching knowledge, i.e., concept teaching knowledge about concepts and teaching methods). The summarized statistics from the KCT-related questions for teachers are presented in Table 4 and Figure 6.

Table 4
Teacher's KCT Basic Description

Contents	*N*	*M*	*SD*	Min	Max
Item1	30	1.9	1.05	0.0	3.0

Figure 6
Teacher's KCT Score Distribution



As shown in the aforementioned tables and figure, 28 of the 30 teachers scored 1–3 points, and a certain number of teachers scored at all other points. The standard deviation was 1.048. These results showed that 50% of teachers could name three conceptual change strategies. However, the difference between high and low was extremely large, which may be due to a very small number of questions in the questionnaire used.

According to specific answers, the conceptual change strategies commonly used by teachers in decreasing order of frequency were: intuitive teaching method, inquiry experiment method, cooperative learning method, comparative teaching method, for example teaching method, concept map method, and history of science method.

Discussion

In this study, the developed teacher questionnaire was used to measure the concept teaching knowledge of lower-secondary school biology teachers, and the CCK, SCK, KCS and KCT scores were determined. The two-

https://doi.org/10.33225/jbse/22.21.121

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

tier test questionnaire was used to measure the learning achievements of students in the corresponding classes taught by teachers; SPSS (Version 18) was used to analyse the correlation between teachers' CCK, SCK, KCS, KCT scores and students' learning achievements. The results indicate a significant positive correlation between the assessed variables. This finding is consistent with the research conclusions of scholars such as Brian Rowan, Robert J. Miller and Fang Shen Chiang (1997). According to the research conclusions of various scholars (e.g., Boardman et al., 1977; Harbison & Hanushek, 1992): "the impact of teachers' CK and teachers' teaching behaviour on students' learning effectiveness is positive." On the basis of the significant correlation between teachers' CCK, SCK, KCS, KCT scores and students' learning achievements, the present study suggests that a causal relationship exists between teachers' concept teaching knowledge and students' learning effectiveness, which is in line with common sense and previous research conclusions. Regarding the relationship among CCK, SCK, KCS and KCT, this study adopted the quantitative analysis method. By using SPSS (Version 18), the correlation between the four elements was analysed, and then, the causal relationship between adjacent elements was analysed. Therefore, this study suggests that the four elements comply with the initial relationship hypothesis, implying a recursive logical relationship (Li & Liu, 2019).

Accordingly, this study analyses the factors that may affect teachers' conceptual teaching knowledge according to the collected data and existing studies. The results show that the length of teaching experience or teaching experience of teachers and the level of teachers' schools have no significant impact on teachers' conceptual teaching knowledge. It can be seen that teaching experience cannot represent the amount of teachers' knowledge and skills. Furthermore, the level of school has no significant impact on teachers' concept teaching knowledge, probably because of the limited number of teachers or the slight difference in teachers' concept teaching knowledge at this stage, resulting in no great difference in the overall level. The later speculation is also in line with the existing research views (Knuth, 2005).

The present research discusses the current situation of concept teaching knowledge of biology teachers in lower-secondary schools. The first and foremost discussion concerns the common concept knowledge of biology teachers in lower-secondary schools, which is the level of teachers' preconceptions, as it reflects teachers' understanding of scientific conceptions. Studies have shown that teachers' preconceptions are a major source of students' preconceptions because teachers themselves hold certain preconceptions (Li & Liu, 2010; Sanders, 1993). These conclusions coincide with the results of this study.

As shown in Table 1 and Figure 3, 56.7% of the included teachers exhibited different levels of preconception. Li Gaofeng asserted that every teacher may hold a certain degree of preconception, and some teachers may have a certain degree of misunderstanding of each scientific concept. The standard deviation of the total score was large (5.41), and the average score of the teachers was 22, accounting for 85% of the full score of this knowledge element. Although the level of teachers' understanding about scientific conceptions was relatively high, considering the particularity of teachers' profession, it is essential to conduct research on teachers' preconceptions. Because teachers' preconceptions are likely to lead to students' preconceptions. Liu and Li (2017) sampled and analysed the preconceptions of nearly 1500 lower-middle school students and their 30 biology teachers in China. The authors found a significant positive correlation between the preconceptions of the teachers and students in the distribution trend. Simmie and Burgoon (2015) found a high level of preconceptions of pre-service teachers and an obvious connection between the preconceptions commonly held by pre-service teachers and students. Therefore, the level of teachers' mastery on scientific conceptions is especially important for students to acquire scientific conceptions. A qualified biology teacher should first have a solid knowledge base of the subject content, that is, they should have the ability to correctly understand and master the scientific concept, which is also the basic embodiment of the professionalism of teachers. Therefore, attention must be paid to the CCK of science teachers in teacher education. There may be three reasons for the imperfect teachers' CCK level. First, people generally believe that students rather than teachers have preconception; hence, they don't pay enough attention to teachers' preconceptions; Second, teachers have high self-confidence in their professional level and insufficient accurate metacognitive on the mastery level of their own scientific concepts; Third, the concealment, obstinacy, and universality of preconceptions are not conducive to the transformation of teachers' preconceptions.

Furthermore, the status quo of preconceptions of the lower-secondary school biology teachers was analysed in the present research. According to Table 2 and Figure 4, the lower-secondary school biology teacher's SCK level reached the pass level on average and was uneven.

As shown in the specific answer to this knowledge element, teachers are concerned about the existence of

https://doi.org/10.33225/jbse/22.21.121

preconceptions, while a half of the teachers are unable to give accurate examples, which shows that their understanding of preconceptions is not comprehensive. A half of the teachers prefer using the term 'preconceptions' instead of the terms such as misconceptions and different concepts. This may be because 'preconceptions' is a positive, good, suggestive, and more accurate term (Li, 2007). Teachers have noticed many characteristics of preconceptions. When supplementing, most teachers fill in "immutability" and "inaccuracy". It can be seen that teachers have a certain understanding of the essential characteristics of preconceptions. Most teachers agree that preconceptions have an impact on concept teaching. As for teachers' attitude toward students' preconceptions, a half of the teachers said they were unable to cope, and the other half said they could use some diagnostic methods and then use teaching strategies to change students' preconceptions. This finding is somewhat different from those of some studies (Li, 2007; Li, 2015). The scholars found that the teachers' metacognitive level of their preconceptions was low, and nearly 60% of teachers did not know much about the essence of preconceptions. On the one hand, it may be closely related to the increasing training of teachers' conceptual teaching in China's education reform in the past 14 years. Presently, teaching of scientific conceptions has attracted much attention; Teachers' understanding of the connotation, extension, essence, and characteristics of preconceptions, and the formation of relevant constructivist teaching conceptions have made remarkable progress. This finding is consistent with those of the research of Juhaevah et al. (2020), implying that the introduction of metacognitive improvement courses of teachers' preconceptions to the teachers' professional training plan can help teachers better identify and deal with students' preconceptions. On the other hand, for the other half of teachers who are unable to provide accurate examples and deal with students' preconceptions, in addition to the iterative renewal factors for teachers' own knowledge, teacher education institutions and academic communities need to further investigate the reasons and formulate corresponding plans to promote overall improvement of the teachers' concept teaching level.

The lower-secondary school biology teachers' knowledge about the level of students' preconceptions was also analysed in the present research. Five questions were used to examine the KCS of the lower-secondary school biology teachers. As shown in Table 3 and Figure 5, the concept level of biology teachers in lower-secondary schools and the level of their students' perceptions were uneven.

The difference between high and low scores was extremely large, and the lower-secondary school biology teacher's KCS level was generally not high. From the specific answer to this knowledge element, most teachers overestimated students' mastery of scientific concepts and mistakenly believed that students have correctly mastered relevant scientific concepts when they had not. Many teachers did not have a clear understanding of the common preconceptions of students. The common methods used by teachers to probe students' preconceptions were discussion and interview; For students' preconceptions, teachers were more likely to blame them on their daily life experience, but the main sources of students' feedback on their preconceptions were their own reasoning and judgment, teachers, and teaching materials. Therefore, teachers were unaware of their negative impact on students' learning scientific concepts or lacked metacognition on their mastery of scientific concepts. The results of this study are in line with the research conclusions of some scholars (Iordanou, 2003; Kruger et al., 1990; Yip, 1998). In addition, although the questions about preconception diagnosis methods were designated as multiple choices, many teachers often made a single choice. The same was true for the item about the source of students' preconception. This finding showed that teachers either did not carefully examine the questions or did not have a deep understanding of concept teaching knowledge and that the understanding of probing methods was not comprehensive enough (Diakidoy & Iordanou, 2003; Kruger et al., 1990; Yip, 1998).

Finally, the present research analysed the results of lower-secondary school biology teachers' knowledge about preconception change strategies. Table 4 and Figure 6 show that the lower-secondary school biology teachers' knowledge about concepts and teaching was uneven, and the difference between high and low scores was large.

This may be due to the small number of questions in this questionnaire. At the same time, this result was similar to the statistical results of KCS. It was speculated that it was probably related to the recursive logical relationship between the two knowledge elements. Teachers preferred using teaching strategies such as intuitive teaching, co-operative learning, and inquiry experiment to help students learn scientific concepts correctly. There are two reasons to explain this result. First, the teachers confirmed that these three teaching strategies were extremely effective in dealing with students' preconceptions. Second, the teachers did not know and use other teaching strategies very well. In addition, as in the answer to KCS elements, although multiple choices had been indicated in the process of answering this question, teachers often chose only one item. Thus, it is reasonable to believe that teachers did not know enough about concept teaching related knowledge from another perspective, especially the concept change strategy. We aim to address this issue in the future qualitative research. Findings of this study are in line with

https://doi.org/10.33225/jbse/22.21.121

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

the existing research conclusions and preferred the latter explanation, that is, the teachers were not very familiar with other less commonly used teaching strategies (Knuth et al., 2005; Morrison & Lederman, 2003; Meyer, 2004).

Conclusions and Implications

Over the past three decades, several studies on students' preconceptions have been conducted with the roaring slogan 'teaching for conceptual change'. However, there is a narrative in the NSES that 'In teacher professional development training, teachers' preconceptions are supposed to draw considerable public attention, similar to students' preconceptions, and attention should be paid to their original knowledge and teaching experience'. Some scholars believe that the main factors affecting the concept change strategy are the content knowledge of teachers and their understanding of the preconceptions. Therefore, the status quo of teachers' concept teaching knowledge has become the prime focus of concept teaching. The research results indicate that the concept teaching knowledge of biology teachers in lower-secondary schools requires four elements: CCK, SCK, KCS, and KCT. Regarding the concept teaching knowledge level, in addition to the third knowledge element (KCS), all other elements (CCK, SCK, and KCT) reached the passing level for the sample of lower-secondary school biology teachers. In terms of the level, the teachers exhibited a relatively high CCK but had not attained the full score, and room for improvement was observed for the other three concepts (SCK, KCS, and KCT). No significant difference in the level of teachers' concept teaching knowledge was observed among the different types of sampled schools. Therefore, the following three suggestions are proposed for design of the teacher professional development training course.

Focus on Science Teachers' Preconceptions

Studies have shown that both pre-service and on-the-job professional science teachers have different degrees of misunderstanding regarding scientific conceptions, which needs to be focused on during teacher professional development training. Training institutions in different disciplines should come together to establish a curriculum dedicated to the study of teachers' preconceptions. Even if the content varies, the basic framework can be achieved by the scientific community.

Efforts to Develop Diagnostic Methods to Probe Science Teachers' Preconceptions

For the diagnosis of preconceptions, various tools have been used to explore students' preconceptions, but only a few tools have been applied to explore teachers' preconceptions. The degree of teachers' preconceptions and students' preconceptions is similar. Therefore, the tools for diagnosing students' preconceptions in different disciplines should be adopted to develop diagnostic tools for teachers' preconceptions.

Attempts to Tap an Effective and Targeted Science Teacher Conceptual Change Strategy

The related research on conceptual change strategy and conceptual change teaching has been conducted for almost 40 years, but a certain gap still exists between the conclusion of academic research and the application of practical teaching. Extensive research has been conducted regarding the conceptual change strategy, for example, on topics such as bridging, concept change model, concept map, and other strategies. However, specific issues such as the classification and analysis of preconception types and the targeted application of corresponding change strategies warrant further research. While promoting and popularizing the change strategy and upgrading the protagonist of the application, breakthroughs in teacher professional development training require attention and focus.

Future Recommendations

The Necessity of Enriching Teachers' Concept Teaching Knowledge

The research breakthrough lies in the division of teachers' concept teaching knowledge and the identification of its influencing factors. However, prior to the initiation of research, the enrichment of various knowledge elements and the exploration of other knowledge elements also depended on the continuation of related research.

https://doi.org/10.33225/jbse/22.21.121

The Need for an Increase in the Sample Size of Teachers

Increasing the sample size of teachers is conducive to a more comprehensive examination of teachers' concept teaching knowledge, such as identification of possible influencing factors. The research results showed no significant difference in the teachers' concept teaching level across schools at different levels. Regarding students' academic achievement, the results indicated that higher the standard of the school, better is the student's academic achievement. Differences in the level of preconceptions of students from schools at different levels or an insufficient sample size of teachers may have made the difference not so obvious. The factors that may affect teacher's concept teaching knowledge remain to be further verified through subsequent research involving a larger sample size and the student sample pre-test.

Re-establishment of the Research Questionnaire

From 2011 to 2022, teachers have been developing concept teaching from the point it was unknown, and they have come a long way in terms of understanding and applying the concept. Although a large amount of research results has emerged, research questionnaires remain to be updated and reconstructed. Combining the content of the subject, exploring the teacher's concept teaching knowledge behind the content in depth, and updating the status quo of teacher's concept teaching are all necessary. Government, academia, training units, and teacher training departments first need to pay attention to the level of teacher's concept knowledge, that is, the level of mastery of scientific conceptions among teachers. The acquisition of scientific conceptions depends on the construction and application of scientific methods, and it finally constitutes a scientific way of thinking to achieve the cultivation and realization of biological literacy.

Acknowledgments

None.

Financial Disclosure

The author(s) received no specific funding for this work.

Competing Interests

There are no conflicts of interest in this manuscript.

References

AAFO, S. (1993). *Benchmarks for scientific literacy*. Language of Science Education.

Ausubel, D. P. (1963). *The Psychology of meaningful verbal learning*. Grune & Stratton. https://psycnet.apa.org/record/1964-10399-000

Ball, D. L. (1988). *Knowledge and reasoning in mathematical pedagogy: Examining what prospective teachers bring to teacher education* (Vol. 1). Michigan State University. Department of Teacher Education. https://deborahloewenbergball.com/s/Knowledge-and-reasoning-in-mathematical-pedagogy.pdf

Ball, D. L. (1999). Crossing boundaries to examine the mathematics entailed in elementary teaching. *Contemporary Mathematics*, *243*, 15-36. https://doi.org/10.1090/conm/243/3681

Ball, D. L. (2017). Uncovering the special mathematical work of teaching. In K. Gabriele (Ed.), *ICME-13 Monographs* (pp. 11-34). Springer. https://doi.org/10.1007/978-3-319-62597-3_2

Ball, D. L., & Bass, H. (2002). Toward a practice-based theory of mathematical knowledge for teaching. In E. Simmt & B. Davis (Eds.), *Proceedings of the 2002 annual meeting of the Canadian Mathematics Education Study Group* (pp.3-14). CMESG/GCEDM. http://www.cmesg.org/wp-content/uploads/2015/01/CMESG2002.pdf#page=13

Ball, D. L., Hill, H. C., & Bass, H. (2005). Knowing mathematics for teaching: Who knows mathematics well enough to teach third grade, and how can we decide? *American Educator*, *29*(1), 14-17, 20-22, 43-46. http://hdl.handle.net/2027.42/65072

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special. *Journal of Teacher Education*, *59*(5), 389-407. https://doi.org/10.1177/0022487108324554

Barker, M., & Carr, M. (1989). Teaching and learning about photosynthesis. Part 1: An assessment in terms of students' prior knowledge. *International Journal of Science Education*, *11*(1), 49-56. https://doi.org/10.1080/0950069890110105

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Boardman, A. D., Davis, O. A., & Sanday, P. R. (1977). A simultaneous equations model of the educational process. *Journal of Public Economics*, *7*(1): 23-49. https://doi.org/10.1016/0047-2727(77)90035-4

Brophy, J. & Good, T. L. (1986). Teacher behavior and student achievement. In M. C. Witt rock (Ed.), *Handbook of Research on Teaching* (3rd ed., pp. 328-375). Simon & Schuster McMillan.

Burgoon, J. N., Heddle, M. L., & Duran, E. (2011). Re-examining the similarities between teacher and student conceptions about physical science. *Journal of Science Teacher Education*, *22*(2), 101-114. https://doi.org/10.1007/s10972-010-9196-x

Butler, J., Simmie, G. M., & O'Grady, A. (2015). An investigation into the prevalence of ecological misconceptions in upper secondary students and implications for pre-service teacher education. *European Journal of Teacher Education*, *38*(3), 1-20. https://doi.org/10.1080/02619768.2014.943394

Cochran, K. F., DeRuiter, J. A., & King, R. A. (1993). Pedagogical content knowing: An integrative model for teacher preparation. *Journal of Teacher Education*, *44*(4), 263-272. https://doi.org/10.1177/0022487193044004004

Diakidoy, I. A. N., & Iordanou, K. (2003). Preservice teachers' and teachers' conceptions of energy and their ability to predict pupils' level of understanding. *European Journal of Psychology of Education*, *18*(4), 357-368. https://doi.org/10.1007/BF03173241

Driver, R., & Easley, J. (1978). Pupils and paradigms: A review of literature related to concept development in adolescent science students. *Studies in Science Education*, *5*(1), 61-84. https://doi.org/10.1080/03057267808559857

Doyle, W. (1977). Paradigms for research on teacher effectiveness. *Review of Research in Education*, (5), 163-198. https://doi.org/10.3102/0091732X005001163

Gest, H. (2002). History of the word photosynthesis and evolution of its definition. *Photosynthesis Research*, *73*(1-3), 7-10. https://doi.org/10.1023/A:1020419417954

Gage, N. (1978). *The scientific basis of the art of teaching*. Teachers College Press.

Gomez-Zwiep, S. (2008). Elementary teachers' understanding of students' science misconceptions: Implications for practice and teacher education. *Journal of Science Teacher Education*, *19*(5), 437-454. https://doi.org/10.1007/s10972-008-9102-y

Grossman, P. (1991). *The making of a teacher: Teacher knowledge and teacher education 1990 New York*. NY Teachers College Press.

Greenwald, R., Hedges, L. V., & Laine, R. D. (1996). The effect of school resources on student achievement. *Review of Educational Research*, (6), 361-396. https://doi.org/10.3102/00346543066003361

Harbison S. R., & Hanushek, E. (1992). *Educational Performance of the Poor: Lessons from Rural Northeast Brazil*. Oxford University Press.

Hanushek, E. A. (1981). Throwing money at schools. *Journal of Policy Analysis and Management*, (1), 19-41. https://doi.org/10.2307/3324107

Hoover, M., Mosvold, R., Ball, D. L., & Lai, Y. (2016). Making progress on mathematical knowledge for teaching. *The Mathematics Enthusiast*, *13*(1), 3-34. https://doi.org/10.54870/1551-3440.1363

Juhaevah, F., Sopamena, P., & Kaliky, S. (2020). Professional teacher program experience: teachers' knowledge on overcoming students' misconception. Kalamatika Jurnal Pendidikan Matematika, *5*(1), 19-34. https://doi.org/10.22236/KALAMATIKA.vol5no1.2020pp19-34

Kruger, C. (1990). Some primary teachers' ideas about energy. *Physics Education*, *25*(2), 86. https://doi.org/10.1088/0031-9120/25/2/002

Kruger, C., Summers, M., & Palacio, D. (1990). An investigation of some English primary school teachers' understanding of the concepts force and gravity. *British Educational Research Journal*, *16*(4), 383-397. https://doi.org/10.1080/0141192900160406

Knuth, E. J., Alibali, M. W., McNeil, N. M., Weinberg, A., & Stephens, A. C. (2005). Middle-school students' understanding of core algebraic concepts: Equality and variable. Zentralblatt fur Didaktikder Mathematik. *International Reviews on Mathematical Education*, *37*, 1-9. https://doi.org/10.1007/BF02655899

Leinhardt, G. (1990). Capturing craft knowledge in teaching. *Educational researcher*, *19*(2), 18-25. https://doi.org/10.3102/0013189X019002018

Lenin. (1985). *The Complete Works of Lenin* (E. Compilation Bureau of works of Marx, Lenin & Stalin of the CPC Central Committee Ed. 1 ed.). People's Publishing House.

Li, G. (2007). The investigation of the teaching situation of the teachers aiming at the prescription. *Journal of Qiqihar Junior Teachers' College*, (2), 120-121. https://doi.org/10.3969/j.issn.1009-3958.2007.02.048

Li, G. (2007). *Research on the concept of biology pre-school Science in junior high school.* [Doctoral Thesis, Beijing Normal University]. Beijing.

Li, G., & Liu, E. (2007). Research progress of pre-scientific concepts. *Inner Mongolia Normal University Journal of Fan University (Philosophy and Social Sciences Edition),* (4), 62-67. https://doi.org/10.3969/j.issn.1001-7623.2007.04.011

Li, G., & Liu, E. (2010). Research on the Origin of Pre-science Concepts in Biology for Junior High School Students. *Bulletin of Biology*, *45*(2), 37-39. https://doi.org/10.3969/j.issn.0006-3193.2010.02.014

Li, M., & Liu, E. (2019). Research on the knowledge elements of the concept teaching of biology teachers. *Biology Teaching*, *44*(4), 16-18. https://doi.org/10.3969/j.issn.1004-7549.2019.04.006

Li, X. (2015). *Investigation on prescientific concepts and improvement of diagnostic methods from the perspective of middle school biology teachers*. [Doctoral Thesis, Central China Normal University]. Wuhan.

Liang, L. L., Liu, X., & Fulmer, G. W. (2017). *Chinese science education in the 21st century: Policy, practice, and research*. Springer.

Liu, E., & Li, M. (2016). Enhancing science teacher professional development: Lessons from a study of misconceptions of junior secondary biology teachers. In *Chinese Science Education in the 21st Century: Policy, Practice, and Research* (Vol. 45). Springer, Dordrecht. https://doi.org/10.1007/978-94-017-9864-8_18

Liu, Q. (2004). *Research on the Model Construction of Teacher Knowledge.* [Doctoral Thesis, Southwest Normal University]. Chongqing.

https://doi.org/10.33225/jbse/22.21.121

Marmaroti, P., & Galanopoulou, D. (2006). Pupils' understanding of photosynthesis: A questionnaire for the simultaneous assessment of all aspects. *International Journal of Science Education*, *28*(4), 383-403. https://doi.org/10.1080/09500690500277805
Meyer, H. (2004). Novice and expert teachers' conceptions of learners' prior knowledge. *Science Education*, *88*(6), 970-983. https://doi.org/10.1002/sce.20006
Ministry of Education of the People's Republic of China. (2011). *Compulsory Education Biology Curriculum Standards* (C. Xiao, Ed. 2011 ed.). Higher Education Press.
Ministry of Education of the People's Republic of China. (2017). *Biology Curriculum Standard of Senior High School* (2017 ed.). People's Education Press.
Morine-Dershimer, G., & Kent, T. (1999). The complex nature and sources of teachers' pedagogical knowledge. In *Examining pedagogical content knowledge* (pp. 21-50). Springer.
Morrison, J. A., & Lederman, N. G. (2003). Science teachers' diagnosis and understanding of students' preconceptions. *Science Education*, *87*(6), 849-867. https://doi.org/10.1002/sce.10092
National Research Council. (1996). *National science education standards*. National Academies Press.
Ozkan, G., & Selcuk, G. S. (2015). The effectiveness of conceptual change texts and context-based learning on students' conceptual achievement. *Journal of Baltic Science Education*, *14*(6), 753-763. https://doi.org/10.33225/jbse/15.14.753
Peterson, R., Treagust, D., & Garnett, P. (1986). Identification of secondary students' misconceptions of covalent bonding and structure concepts using a diagnostic instrument. *Research in Science Education*, *16*, 40-48. https://doi.org/10.1007/BF02356816
Sanders, M. (1993). Erroneous ideas about respiration: The teacher factor. Journal of Research in Science Teaching, *30*(8): 919-934. https://doi.org/10.1002/tea.3660300809
Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, *57*(1), 1-23. https://doi.org/10.17763/haer.57.1.j463w79r56455411
Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4-14. https://doi.org/10.3102/0013189X015002004
Stavy, R. (1988). Students' understanding of photosynthesis. *The American Biology Teacher*, *50*(4), 208-212. https://doi.org/10.2307/4448710
Tlala, B., Kibirige, I., & Osodo, J. (2014). Investigating grade 10 learners' achievements in photosynthesis using conceptual change model. *Journal of Baltic Science Education*, *13*(2), 155-164. https://doi.org/10.33225/jbse/14.13.155
Tanner, K., & Allen, D. (2005). Approaches to biology teaching and learning: understanding the wrong answers—teaching toward conceptual change. *Cell Biology Education*, *4*(2), 112-117.
Treagust, D. F. (2006). *Diagnostic assessment in science as a means to improving teaching, learning and retention*. 2006 the Australian Conference on Science and Mathematics Education. UniServe. https://openjournals.library.sydney.edu.au/index.php/IISME/article/view/6375/7014
Treagust, D. F., & Haslam, F. (1986). Evaluating Secondary Students' Misconceptions of Photosynthesis and Respiration in Plants Using a Two-Tier Diagnostic Instrument. *Biology*, *21*(3), 203-211.
Wilson, S. M. (1987). "150 different ways" of knowing: Representations of knowledge in teaching. *Exploring Teachers' Thinking*, 104-124.
Xing, H., Physics, D. O., & University, C. N. (2016). The Deepened Research on Thinking Teaching in Primary and Middle Schools. *Curriculum, Teaching Material and Method,* (7), 33-39. https://en.cnki.com.cn/Article_en/CJFDTotal-KJJF201607006.htm
Yip, D. y. (1998). Identification of misconceptions in novice biology teachers and remedial strategies for improving biology learning. *International Journal of Science Education*, *20*(4), 461-477. https://doi.org/10.1080/0950069980200406

Received: *October 12, 2021* Revised: *December 16, 2021* Accepted: *January 24, 2022*

Cite as: Li, M. (2022). An exploration on concept teaching knowledge of biology teachers in lower-secondary schools. *Journal of Baltic Science Education*, *21*(1), 121-139. https://doi.org/10.33225/jbse/22.21.121

Mingyu Li PhD, Teacher Education College, Capital Normal University, No.23 Yard, Baiduizijia, Fucheng Road, Haidian District, Beijing, 100037, China.
E-mail: cnuli7027@163.com
Website: https://jsjy.cnu.edu.cn/
ORCID: https://orcid.org/0000-0002-3517-0363