Chapter 18
Enhancing Science Teacher Professional Development: Lessons from a Study of Misconceptions of Junior Secondary Biology Teachers

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18.1 Introduction

Many research studies show that students have ideas about many scientific phenomena or scientific processes before they enter the science classroom. Most of these ideas come from children's daily lives, and many of them are incomplete ideas or misconceptions. It is not easy for students to give up these misconceptions (Abell and Lederman 2007; Vosniadou 2008). Misconceptions can be a substantial barrier for students in learning scientific concepts. If these ideas are not changed during the processes of school learning, they will remain in the student's mind for a long time.

Several theoretical frameworks of how students change their misconceptions about the natural world have been developed over the past three decades since 1982, when Posner and his colleagues proposed the conceptual change model (Posner et al. 1982). Within each of these frameworks, there are three essential perspectives of conceptual change learning related to epistemology, ontology, and affective/ social/learner characteristics. Although these perspectives have different explanations about conceptual change, there is a consensus that conceptual change approach always means science teachers use different ways to communicate ideas or concepts with students by presenting these ideas or concepts either externally—taking the form of spoken language (verbal), written symbols (textual), pictures, physical objects, or a combination of these forms—or internally when thinking about them. Usually researchers who use conceptual change approaches in their classroom-based studies report that their approach is more effective than traditional

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ones dominated by the transmissive view of teaching and learning (Tobin et al. 2012).

However, the research evidence shows that even though students receive science education in school, they might also retain their misconceptions, and the impact of conceptual change instructional practices in real classroom situations tends to be associated with various teacher factors. One of the most important factors is whether teachers hold scientific ideas or misconceptions that are similar to those of students (e.g., Fulmer 2013; Sadler et al. 2013). It is irrational to expect teachers who hold the same misconception as students to present scientific idea or concepts externally or internally in a proper way. Therefore, research on both students' and teachers' misconceptions is important and a prerequisite to improving the efficacy of conceptual change instructional practices in school education.

18.2 Research on Misconceptions and Teachers' Impact on Students' Misconceptions

Various terms have been used for students' misconceptions, such as misconceptions, preconceptions, and alternative conceptions. Driver and Easley (1978) believe that different terms reflect the viewpoint of the scholars. The term "misconception" is used in this chapter because the current study focuses on the students' ideas about science concepts after classroom learning.

To address students' misconceptions with conceptual change strategies, science teachers must have related knowledge and teaching skills. Helping students reconstruct their scientific concepts is not simply a task of using a concept-changing checklist. Teachers' content knowledge and understanding of students' misconceptions are the key elements in implementing conceptual change in the classroom (Diakidoy and Iordanou 2003; Gomez-Zweip 2008). Teachers' impacts on students' misconceptions are classified into the following four categories:

1. The teacher holds misconceptions. The teacher cannot be aware of students' misconceptions and unconsciously delivers misconceptions to students in the teaching process. Research shows that science teachers hold some misconceptions. Furthermore, there are similarities in teachers' and students' misconceptions (Burgoon et al. 2009; Kruger 1990; Yip 1998).
2. The teacher does not hold misconceptions but also does not fully understand the negative impact of misconceptions on teaching and learning. Because the teacher does not care about the students' misconceptions, the chance to reconstruct the students' ideas decreases during the classroom teaching. In this way, students may retain misconceptions after they complete the school education (Morrison and Lederman 2003).
3. The teacher realizes that the misconceptions have negative effects on students' learning. Due to limited knowledge and skills in diagnosing and changing

students' misconceptions, the teacher cannot effectively convert students' ideas to scientific conceptions. Related research studies show that teachers pay limited attention to students' misconceptions and know little about diagnosing children's ideas and concept-changing strategies (Gomez-Zweip 2008; Morrison and Lederman 2003; Li 2007).

4. If teachers do not hold misconceptions and students do not have misconceptions before they enter the science classroom, students may hold misconceptions after the learning process due to a teacher's deficits in pedagogy and teaching skills (Chi et al. 1994).

To date, most of the research studies have focused on diagnosing students' misconceptions, and much less research has examined teachers' misconceptions. One of the reasons may be that researchers had a hypothesis that most teachers are well prepared in content knowledge due to their pre-service education and have sound content knowledge before they start teaching (Yip 1998). However, some researchers had claimed that teachers' content knowledge is not sufficient (Li and Liu 2010).

Based on the literature review, the current research focuses on the following questions:

- After 30 years of related research studies, what is the current situation concerning teachers' misconceptions in the junior secondary biology teaching force?
- Is there a similarity in students' and teachers' misconceptions in mainland China, as the previous international research suggests?
- What type of relationship characterizes this similarity?

18.3 Methodology

18.3.1 Sampling

Samples were taken from a capital city of a northern province in mainland China. In general, the education level of this city is at the average position in China. There are 90 junior secondary schools located in this city. Based on the standardized entrance test scores, those schools can be classified into three levels: high-score, intermediate-score, and low-score levels. A total of 11 sample schools were randomly selected from each level. From each sample school, two or three biology teachers and their corresponding classes were selected as the sample. There are 40–50 students per class. Altogether, 30 biology teachers and 30 classes including 1442 students comprised the sample.

Table 18.1 Content knowledge detected by the questionnaire

Code	Aspects of the concept of photosynthesis and respiration
PR	Photosynthesis vs. respiration
FN	Factors necessary for respiration
MER	Matter transformation and energy transfer during respiration
MEP	Matter transformation and energy transfer during photosynthesis
IF	Factors impacting the rate of photosynthesis reaction
AT	Photosynthesis and autotrophy

18.3.2 Instrument

The instrument used in this survey is a questionnaire with two-tier test items about photosynthesis and respiration developed by Haslam and Treagust (1987). Translation and back translation of the two-tier items in questionnaire were done to make sure the Chinese version is accurate and understandable. The original reliability, using Cronbach's coefficient alpha, was 0.72 tested by Haslam and Treagust in 1987. The reliability based on the sample of this study is 0.84. There are 13 test items in the questionnaire, with 2 points for each item, resulting in a total of 26 points. Among the 13 items, the biology content knowledge refers to six aspects of the concept of photosynthesis and respiration based on the previous research (see Table 18.1) (Canal 1999; Haslam and Treagust 1987; NRC 1996; Waheed and Lucas 1992).

The questionnaire was first translated into Chinese. Then, six bilingual bio-educators and four biology teachers reviewed this questionnaire to check the translation's accuracy in both content and language. They also evaluated the instrument's content validity. Finally, the instrument was slightly modified based on the reviewers' suggestions for a better fit into the Chinese context.

One of the purposes of this study is to examine students' misconceptions after biology classroom teaching. The survey was administered after students learned about photosynthesis and respiration in their biology course. This arrangement fits Haslam and Treagust's (1987) recommendation for the use of the questionnaire. Following the survey, both the teachers' and students' questionnaires were collected for analysis.

18.4 Results

The data from the questionnaires were collected and analyzed using the statistics software SPSS. Based on their performance on the survey, teachers were divided into two groups, the misconception-free (TMF) group with 13 teachers, and the misconception-holding (TMH) group with 17 teachers. For detailed analysis of teacher's impact on student learning, numbers were used as codes for teachers based on their number of wrong answers on the questionnaire; namely, the teacher

Table 18.2 The rate of incorrect answers from teachers and their students

Item code	Measured content	Proportion of teachers' incorrect answers (%)	Proportion of students' incorrect answers (%)
1	Photosynthesis and respiration	13	53.6
2	Photosynthesis and respiration	30	79.9
3	Photosynthesis and respiration	20	48.7
4	Photosynthesis and respiration	16.6	39.9
5	Factors necessary for respiration	3.3	58.4
6	Matter transformation and energy transfer during respiration	6.6	41.6
7	Matter transformation and energy transfer during respiration	16.6	75.2
8	Factors necessary for respiration	10	51.3
9	Matter transformation and energy transfer during respiration	20	84.9
10	Matter transformation and energy transfer during photosynthesis	13.3	60.4
11	Factors impacting the rate of photosynthesis reaction	16.6	67.9
12	Photosynthesis and autotrophy	20	68.3
13	Photosynthesis and respiration	10	66.6

with the lowest score was given number 1 and the teacher with the second lowest score with number 2. Teachers coded with numbers 1–17 belonged to the TMH group, whereas those with numbers 18–30 belonged to the TMF group. The students were divided into two groups as well. Of the classes, the 13 taught by TMF teachers were grouped into the STMF group and the remaining 17 classes were grouped into the STMH group.

The data show that after students learned photosynthesis and respiration in the biology classroom, they retained misconceptions. Approximately 94.3 % of students had one or more misconceptions. With a total of 26 points for test items in the questionnaire, the students' mean score is 14.1, resulting in 54 % accuracy (14.1/26 = 0.54). Approximately 56.7 % of teachers held one or more misconceptions. Teachers' mean score is 22 points (of 26 total points) resulting in 85 % accuracy (22/26 = 0.85). Table 18.2 shows the percentage of teachers and students holding misconceptions for each test item.

As shown in Fig. 18.1, the distribution patterns of incorrect answers for most of the test items are similar for teachers and students, except items 5 and 13. As the questionnaire is a diagnostic instrument for misconceptions on photosynthesis and respiration, an incorrect answer demonstrates that the teacher or student holds a poor understanding or misconception. The result shows that for the items for which teachers hold a misconception, their students would have a greater chance of holding a misconception. This finding is consistent with the previous research studies that reflect the teacher's impact on student learning as the first category mentioned above. Items 5 and 13 seem to fit the second, third, or fourth categories

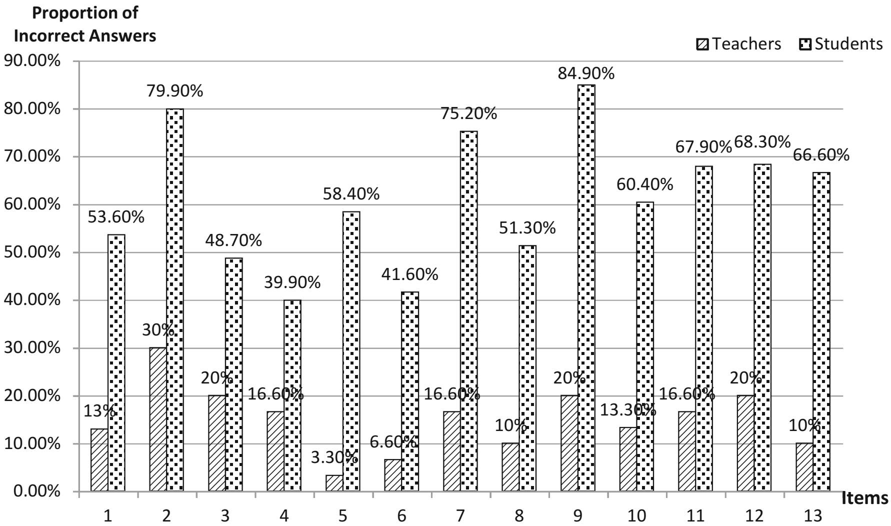

Fig. 18.1 Comparison of the rate of incorrect answers on each item among teachers and their students

Table 18.3 Comparison of scores between the two student groups taught by misconception-holding and misconception-free teachers

	Num.	Mean	Std. deviation	Std. error mean
STMF	13	12.33	6.18	1.71
STMH	17	8.22	4.36	1.06

of teachers' impact on students' misconceptions described above. To study the similarity in the misconceptions of teachers and their students, statistical analysis using SPSS was conducted on the data of 11 items, excluding test items 5 and 13. The results show that there is a significant positive correlation between teachers' misconceptions and those of students ($p = 0.035$; Pearson's $r = 0.64$).

As previously mentioned, 30 teachers were divided into the group of TMF or TMH, and their students were divided into two groups, STMF and STMH. Two-Sample t-Test was used to analyze the data of the two groups of students' performance. The result shows a significant difference in misconceptions between the STMF group and STMH group ($p = .042$; Cohen's $d = 0.77$). Table 18.3 shows the average scores and standard deviations of the two student groups.

A comparison of the ranks of a class's average score between the TMF and TMH groups also demonstrates the teacher's impact on student misconception. In Fig. 18.2, all of the 30 teachers' codes are displayed on the horizontal axis. The teachers' codes in this figure are consistent with the codes mentioned above, i.e., teachers in the TMH group are labeled from 1 to 17 (the teacher who received the lowest score is coded as 1 and the teacher who received the lowest number of wrong

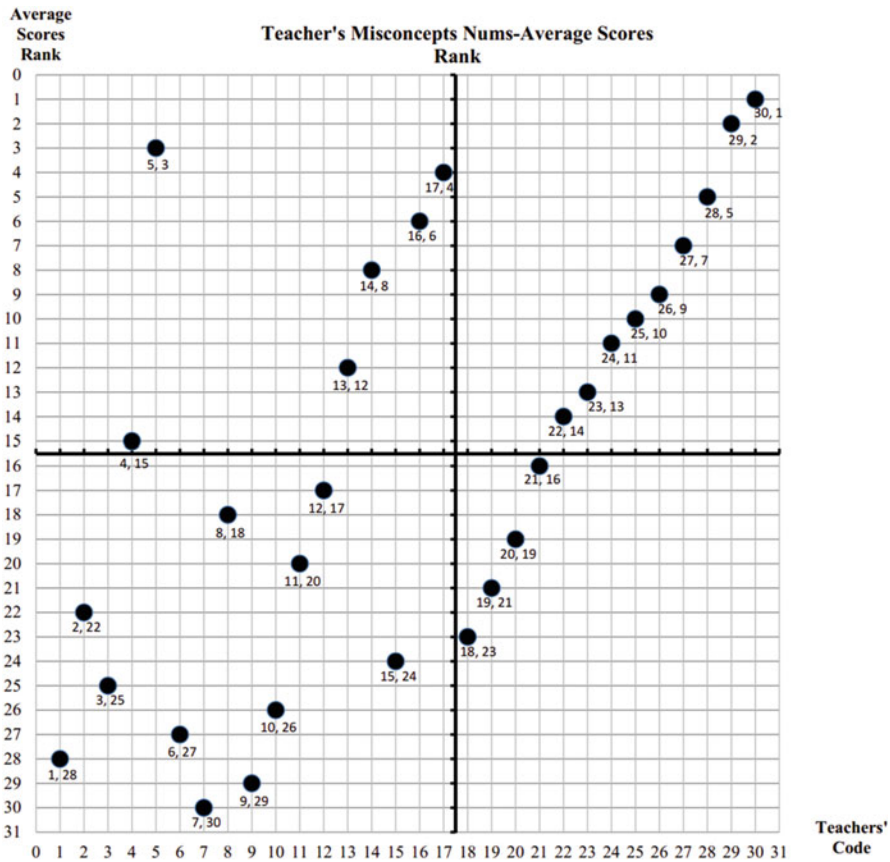

Fig. 18.2 The relationship between students' average score ranking and the number of misconceptions that teachers hold

answers is coded as 17), and the teachers in TMF group are labeled from 18 to 30 (none had a misconception diagnosed by this questionnaire). Therefore, in Fig. 18.2, spots that represent the TMH group fall on the left-hand side and spots that represent the TMF group fall on the right-hand side. The vertical axis shows the rank of the class's average score. For example, the spot "29,2" means that the class is taught by the teacher coded as 29, who is misconception free and the class's test score is at the second top position. The majority (69 %) of the STMF classes rank in the top 15. Furthermore, most of the STMH classes rank below the top 15. The data show that students taught by teachers without misconceptions displayed better performance than those taught by teachers who hold misconceptions. This could be a strong indicator of the impact of teachers' misconception on students' biology concept learning.

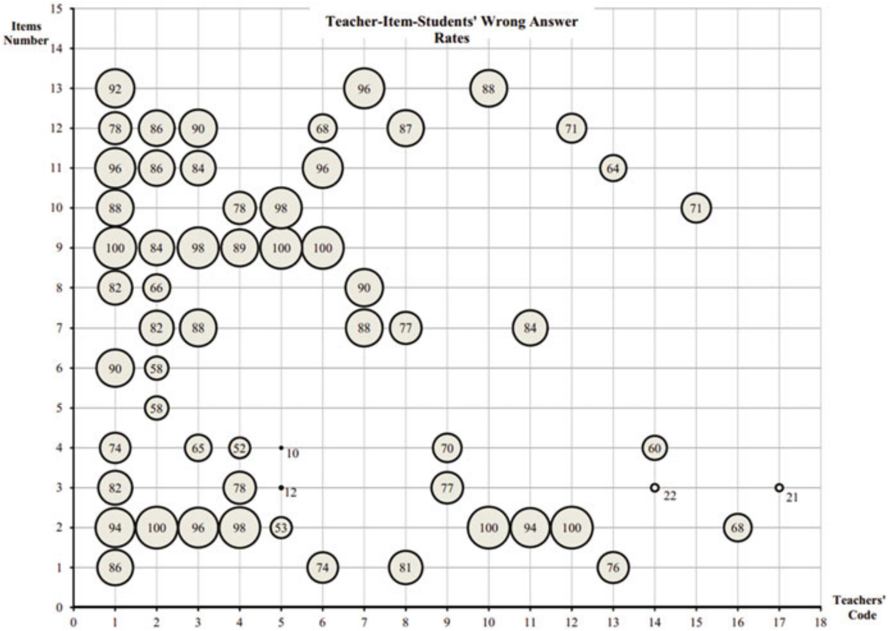

Fig. 18.3 The distribution and percentage of students' incorrect answers on the items for which their teachers held misconceptions

To analyze the relationship between teachers' misconceptions and those of their students in detail, the study also focused on individual teachers of the TMH group and their students. For the teachers with misconceptions, we matched teachers' performance on particular test items with those of their students, showing the relationship between them in a bubble diagram (see Fig. 18.3).

In Fig. 18.3, the horizontal axis refers to the teachers' codes and the vertical axis marks the test item number. Each bubble represents a teacher's incorrect answer (misconception) on a test item. The area of each bubble, i.e., the number inside each bubble, represents the percentage of students' incorrect answers on the corresponding item. Figure 18.3 shows that when teachers hold a misconception on a certain item, a high percentage of their students provides incorrect answers on the same item. For items 2, 7, 9, and 13, approximately 80 % of students answered incorrectly when their teacher held a misconception about the same item. For items 2, 3, 4, 9, and 12, there are at least six bubbles, indicating that these items are challenging for both teachers and their students. Among them, test items 2, 3, and 4 refer to the concept of "relationship between photosynthesis and respiration," item 9 refers to the concept of "matter transformation and energy transfer during respiration," and item 12 refers to the concept of "photosynthesis and autotrophy." Thus, the diagram details the type of similarities in teachers' misconceptions and those of their students. It also indicates the pitfalls in misconceptions about photosynthesis and autotrophy for both teachers and learners.

18.5 Conclusion and Discussion

18.5.1 Conclusion

Based on the survey, several conclusions can be made. First, after students learned photosynthesis and respiration in the biology classroom, many of them retained misconceptions. Approximately 94.3 % of students have one or more misconceptions. Some of their biology teachers also hold misconceptions on photosynthesis and respiration.

Second, there is a similarity in the teachers' misconceptions and those of their students. This result is consistent with the previous research in this area (Burgoon et al. 2009; Kruger 1990; Diakidoy and Iordanou 2003; Gomez-Zweip 2008; Yip 1998; Nancy et al. 2005). This finding does not indicate that students with teachers who have few misconceptions will hold few misconceptions. On the contrary, the data from test items 5 and 13 show that a high proportion of students maintain misconceptions, while more than 90 % of teachers hold scientific ideas. This finding is consistent with the previous research that the poor teaching strategies and skills of the teacher may result in student misconceptions (Morrison and Lederman 2003; Meyer 2004; Li 2007; Knuth et al. 2005). This indicates that students' conceptual understanding might be influenced by their teachers' general pedagogical knowledge or conceptual teaching knowledge and skills (i.e., the second, third, and fourth category), in addition to teachers' content knowledge or scientific understandings (i.e., the first category). The high correlation between the students' and their teachers' misconceptions, based on 11 of the 13 items, might suggest that teachers' misconceptions are a stronger source of students' misunderstandings of science in Chinese schools.

Third, further analysis of the similarity of teachers' misconceptions and those of their students reveals that: (a) There is a significant positive correlation between the teachers' misconceptions and those of their students for most of the test items ($p = 0.035$) except items 5 and 13, (b) The scores of students with misconception-free teachers are significantly higher than those of the students taught by a teacher with misconceptions ($p = 0.042$), and (c) The classes taught by the teachers with sound biology knowledge generally show better performance than those taught by teachers with misconceptions.

Based on detailed analyses of teachers' incorrect answers on a test item and their students' performance on the same item, it is clear that when teachers incorrectly answered an item, their students had a high chance of answering incorrectly. This provides a picture of the type of similarity in the misconceptions of teachers and those of their students. It also indicates that three aspects of photosynthesis and respiration are the most challenging for both biology learners and teachers, namely, the concepts of "photosynthesis and respiration," "matter transformation and energy transfer during respiration," and "photosynthesis and autotrophy."

18.5.2 Discussion

The survey results show that both biology teachers and their students in mainland China have misconceptions. Teachers' misconceptions might have a negative impact on students' learning of science concepts. The results also provide a detailed picture of the similarity in teachers' misconceptions and those of their students. This conclusion is consistent with previous research that found that teachers might be a factor in student misconceptions (Li and Liu 2010; Sanders 1993). After 30 years of research on misconception and conceptual change, the current research serves as a reminder that misconceptions held by science teachers remain a problem in junior secondary biology classrooms. More importantly, the problem found by this study is only representative for large cities such as those in the sampling area; it may be even worse in schools in rural areas.

Previous research studies revealed that students thought about science phenomena and held preconceptions before they entered the science classroom. The basic tenet of conceptual change instruction is that students' misconceptions are resistant to change, and explicit instruction that confronts student misconceptions is likely to be more successful. "Conceptual change approaches" are generally acknowledged as being more successful in classrooms (Duit and Treagust 2003). With these constructivist-based approaches, teachers need to explicitly connect with students' misconceptions, providing learning experience for students to actively explore and analyze evidence conflicting with their existing misconceptions. As advocated by the Chinese National High School Biology Curriculum Standards, inquiry-based teaching is seen as a promising strategy for teaching biology toward conceptual change. In the inquiry-oriented classroom, teachers are expected to engage students and directly challenge their misconceptions to promote conceptual change.

In future studies, we need to examine classroom practices have led to more successful student learning outcomes. One limitation of this research is that we did not distinguish the students who had misconceptions before they entered the biology class from those who developed misconceptions during the classroom teaching. That is to say, did some of the students develop misconceptions directly from their teacher during the classroom learning? If so, how many of the students developed misconceptions in this way? The current research provides new ideas and questions for further study. The current research evidenced another interesting phenomenon. In Fig. 18.3, there are some abnormal points, including the point labeled 10 for item 4 and points labeled 12, 22, and 21 for item 3, compared with other points. These points indicate that only approximately 10–20 % of students held misconceptions that their teacher also held. Therefore, 80–90 % of students had the correct scientific understanding. This result might be due to conceptual learning opportunities beyond the teachers' classroom teaching or other reasons that should be investigated.

The assumption that teachers obtained "perfect" content knowledge in pre-service education has been long-standing. The current survey demonstrated that this assumption is not accurate! The findings of this study provide some insights into teacher education, both pre-service and in-service. In the past decades, many efforts were made to enhance pre-service teachers' content knowledge by reviewing the latest development in biology and increasing lab experience (Chen et al. 2012). However, there is almost no emphasis on conceptual change in teacher training programs. Diagnosing student misconceptions and helping them to construct scientific concepts is not only the task of science teachers in general education but also the mission of the lecturers and professors involved in science teacher training programs. To rebuild the teacher training program with an emphasis on trainees' conceptual change, research on the following questions should be conducted to support the reform: What are the science teachers' perceptions, knowledge, and skills related to student misconception and conceptual change? What are the teacher candidates' perceptions and knowledge about misconception and conceptual change? To what extent are conceptual change theory and skills embedded in science teacher training programs? With the shift from the "top-down" decision-making model toward an "evidence-driven" decision-making model in curriculum development, such research will provide meaningful information for the design of preservice and in-service teacher training programs in China.

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