Chapter 4
Science Teaching Practices in Junior Secondary Schools

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4.1 Introduction

One of the most important Chinese science education reform efforts in the last decade has been the introduction of scientific inquiry and active learning into science teaching. In learning, the reform-oriented approach represents a shift in the focus of school science from a goal of "mastery of scientific knowledge" to the "development of student scientific literacy," while in teaching, reform-minded educators have been advocating a shift from the traditional teacher-centered approach to a more learner-centered, inquiry-oriented classroom (MOE 2001a). The curriculum standards issued by the Ministry of Education (MOE 2001b, c, d, 2011) clearly state that the success of a science program should produce student learning outcomes in three dimensions: scientific knowledge and skills, scientific processes and methods, and attitudes and values. However, as many people are aware, at secondary school levels, student learning is often driven by high-stakes standardized exams at gateways, and creative thinking and inquiry skills are not typically emphasized in these exams (e.g., Chen et al. 2010; Liang and Yuan 2008). Consequently, learner-centered and inquiry-oriented science instruction may not be

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L.L. Liang et al. (eds.), *Chinese Science Education in the 21st Century: Policy, Practice, and Research*, Contemporary Trends and Issues in Science Education 45, DOI 10.1007/978-94-017-9864-8_4

valued or implemented in classrooms by teachers despite the mandates of the national curriculum standards.

In this chapter, we first provide a brief overview of the reformed science curriculum in junior secondary schools. Then we describe an investigation into science classroom practices and report the findings of the study. Finally, we discuss the implications and make suggestions for future research.

4.1.1 Reformed Science Curriculum in Junior Secondary Schools

Between the establishment of the People's Republic of China in 1949 and the late 1980s, the Chinese basic and higher education systems, including the science curriculum and instruction, were largely influenced by the former Soviet Union model. In junior secondary schools, discipline-based science programs, including biology, physics, and chemistry, were offered. The release of curriculum standards (trial versions) on multiple subjects in 2001 signaled the beginning of the most recent systemic reform in basic science education in China (e.g., MOE 2001b, c, d). These curriculum standards were further revised in 2011.

As part of the reform effort, the required science courses in the junior secondary schools can be offered through either a discipline-based or integrated approach. Multiple textbook series have been published after they were approved by the National School Textbook Review Board and deemed as aligned with the respective curriculum standards. District science coordinators or curriculum leaders may choose either an integrated or separated, discipline-based textbook set for the schools under their oversight. In reality, however, the experiment involving integrated science programs has encountered serious challenges. Presently, Zhejiang province and Shanghai are the only places where integrated science programs are offered in junior high schools. School administrators, teachers, and parents fear that an integrated science program at junior secondary level may not be able to fully prepare the students for their discipline-based science courses in senior high schools and may negatively impact students' performance on college entrance exams. Other factors preventing the implementation of the integrated sciences may include a shortage of resources and quality science teacher training programs (Zhang and He 2012). For instance, in a study conducted by Zhang and He (2012), 27 preservice teacher candidates and 25 recently graduated in-service teachers majoring in science education from six normal universities were interviewed. It was found that the science teacher education curricula did not reflect the intended integration objectives of the major and that the science teacher educators were not competent in teaching integrated courses. The teacher candidates and recent graduates were least satisfied with their learning experiences related to the nature of science, scientific inquiry, and integration of subject matters.

Consequently, the majority of the junior secondary schools across the country continue offering science as separated, discipline-based subjects. Most frequently, students take biology in seventh grade, physics in eighth and ninth grades, and

Table 4.1 Content of physics curriculum in junior secondary school

Scientific inquiry	Theme/ topic	Subtheme/topic
Asking questions	Matter	Physical forms and changes; physical properties of matter; structure of matter, scale, and development; and application of new materials
Making hypotheses	Motion and interaction	Variety forms of motion, force and mechanical motion, sound and light, electricity and magnetism
Planning and designing investigations	Energy	Types of energy, the conversion and transfer of energy, the law of conservation of energy, sources of energy and sustainable development
Carrying out investigations and collecting data		
Analyzing data and engaging in argument from evidence		
Evaluating		
Communicating and collaboration		

Table 4.2 Content of chemistry curriculum in junior secondary school

Theme	Subtheme
Scientific inquiry	A better understanding of scientific inquiry, improving the ability of scientific inquiry, learning about the basic skills and ability to conduct experiments
Chemical substances around us	The atmosphere around the earth, water and common solution, metals and metallic minerals, common compounds in daily lives
Matter composition	Diversity of matter, particulate nature of matter, chemical elements, symbols of substance compositions
Chemical changes	Characteristics and classification of chemical changes, the law of conservation of mass
Chemistry and societal development	The relation between chemistry and energy resources, the usage of natural resources, common synthetic materials, chemicals and human health, environment protection

chemistry in ninth grade. Tables 4.1 and 4.2 present the content of physics and chemistry curriculum, as two examples (MOE 2001c, d, 2011). Three main themes addressed in the physics curriculum include matter, motion and interaction, and energy. In the chemistry curriculum, the main themes include chemical substances around us, matter composition, chemical changes, and chemistry and societal development. In both programs, "scientific inquiry" has been emphasized as both "content" and pedagogy.

Compared to the traditional teacher-centered instruction, the reformed science courses place more emphasis on learner-centered, hands-on/minds-on, inquiry-based, and constructivist-oriented practices. Inside the classrooms, students are encouraged to work in cooperative learning groups and communicate with the teacher and other peers orally and in writing, using diagrams, drawings, graphs, and mathematical equations. Teaching materials are designed with considerations of student diversity in development and learning styles. In general, instruction is expected to stimulate student interest and motivation and be built on student everyday life experiences. The development of student understanding is expected to connect with applications of the science content in the real world. Teachers are also expected to incorporate mass media and community resources (e.g., museums, parks, and libraries) in science learning and teaching.

4.1.2 The Need for Examining Classroom Practices and Their Potential Connections to Student Affective Learning Outcomes

To date, there have been only a few empirical studies that examined the degree of classroom implementation of inquiry-oriented learning based on teachers' or students' self-reports in schools that have been published inside China. Of these, one study reported middle school physics teachers' perceptions about inquiry and classroom implementation of inquiry teaching based on a teacher survey (Xie 2012). Xie found that the majority of the teacher participants did not implement the inquiry approach as required by the curriculum standards for various reasons, e.g., the exam-oriented education system, the teachers' limited understanding of the nature of scientific inquiry, and limited lab space and equipment. Another study used a teacher survey to investigate the characteristics and patterns of inquiry teaching practices in high school chemistry classrooms (Guo et al. 2011). According to the student reports, the majority of teachers implemented inquiry teaching less than one to two times per month. The inquiry teaching aspect was mainly implemented during designated chemistry experiment periods, and many of the experiments were confirmative in nature. In science classrooms, the majority of the teachers occasionally or rarely helped students develop scientific ways of thinking in teaching. Many teachers would implement inquiry when their classes were visited or observed by others. Overall, about 41 % of student participants perceived the inquiry approach as effective, while 31 % of students believed that inquiry teaching was a mere formality with little meaning. It was noted that both studies reported the findings based on individual survey items without including reliability and validity of instrumentation.

To further inform science teaching and policy-related decision making, it is important to obtain a more accurate picture of classroom practices and the relationship between a reform-oriented instructional approach and desirable learning outcomes. This study reports findings from an investigation into instructional practices in physics and chemistry classes from student perspectives based on a previously validated survey instrument (Juuti et al. 2010). It is among the first research studies that examine both the classroom practices and their potential connections to student affective learning outcomes in China. It certainly contributes to the overall body of knowledge about science learning and teaching in Chinese secondary schools, particularly from the student perspective.

4.2 Literature Related to Our Investigation

4.2.1 Theoretical Framework

This study draws upon the theoretical framework of the classroom learning environment, which emphasizes not only the role of teachers' actions but also of students' perceptions and interpretations of these actions (Shuell 1996). Such attention to the learning environment has proven valuable in science education as well (e.g., Fisher et al. 2011; Fraser 1998). The learning environment, and students' perceptions of their teachers' instruction within this environment, has been found to be an important predictor of student outcomes (den Brok et al. 2004). Drawing upon this theoretical framework highlights the importance of understanding teachers' actions from the students' perspective and, through this experience, the influence on students' attitudes and other learning outcomes.

4.2.2 Measurement of Science Classroom Teaching Practices

According to the science education research literature, there are multiple ways to examine teachers' instruction, including the use of classroom observations, teachers' self-reports, interviews, and student surveys (e.g., Adamson et al. 2003; Lawrenz et al. 2009; Fulmer 2008; Venville et al. 2008; Waight and Abd-el-Khalick 2007). While classroom observation methods have been found to be effective in understanding teachers' application of reformed instruction and relating this to students' outcomes (Judson and Lawson 2007; Park et al. 2011; Sawada et al. 2002), Chinese researchers have tended to avoid using these type of methods because training observers and repeated rating of classroom observations are usually costly and time consuming. Alternatively, survey methods using teachers' or students' self-reports have been frequently adopted by researchers in China. Regarding using teachers' self-reports for classroom practices research, however, some evidence has shown that teachers may give themselves higher marks on general surveys than should be expected (Centra 1973). More reliable results could be achieved by using instruments consisting of a larger number of action-specific items (Koziol and Burns 1986; Porter 2002). A good example of such instruments is the Survey of Enacted Curriculum (SEC) which includes a number of action-specific items and typically requires between 45 and 90 min to complete

(Porter 2002). As a result, teacher self-report surveys can be limited either by the participants' own bias or by the demanding time commitment of the participants.

Fulmer and Liang (2013) advocate the use of student survey as a measure of effective teaching and as direct evidence of student learning experiences in science classes and demonstrated a method for examining teachers' instruction by surveying US high school students. The main advantages of this type of approach include cost-efficiency and potentially reduced likelihood of self-confirmation bias, as the students may be less likely to over-report desirable actions than their teachers would. Furthermore, the large volume of data from students' responses allows the exploration of relationships in the data.

4.2.3 Student Attitudes Toward School Science

Student attitudes toward school science are affective in nature and involve student feelings, beliefs, and values with regard to school science (Osborne et al. 2003). Studies have revealed that there is a consistent interrelationship among the *cognitive* and *affective* factors (Beaton et al. 1996; Shrigley 1990; Simpson and Oliver 1990). Many studies have reported modest positive correlations between science attitude and science achievement (Schibeci and Riley 1986; Keeves and Morgenstern 1992; Weinburgh 1995). In a study conducted by Oliver and Simpson (1988), it was found that student achievement was strongly correlated with affective behaviors in the science classroom, particularly achievement motivation and student self-concept about their own ability in science. Research also reported that activity-based and/or issue-oriented instructional approaches had enhanced the development of positive attitudes toward science (Freedman 1997; McComas 1993; Siegel and Ranney 2003).

Whereas increasing student interest and retention in science is part of the goals of school science, research has repeatedly shown a decline in positive attitudes toward science as students move from lower grades to high school levels (Yager and Penick 1986; Catsambis 1995; Piburn and Baker 1993). Recent international studies also revealed that many students did not think that science was related to them personally, and a relatively small portion of students wanted to pursue a career involving science (OECD 2007). In a literature review of research on attitudes toward science, Osborne et al. (2003) suggested that ignoring the affective components of science education has led to the problem that many countries are currently experiencing: an alienation of youth from science. They therefore called for more research on the context of science classrooms to identify the nature and style of instruction and activities that engage students in learning science.

In order to develop student interest in science, Hidi and Renninger (2006) suggest that teaching should provide opportunities for interaction, cooperative group work, and challenges that lead to knowledge building and conceptual development. Researchers also argue that the use of student-preferred teaching methods in the science classroom supports positive social and emotional effects (Juuti et al. 2010). Thus, it is important to examine the interconnections among student interest in and attitude toward school science, enacted science teaching methods, and student-preferred instructional activities or practices.

4.2.4 Research Questions

In the present study, we attempt to investigate the following questions: (1) To what extent are students experiencing inquiry-oriented or direct teaching methods in physics or chemistry classrooms? (2) To what extent would students like to see changes of teaching practices in their physics or chemistry classrooms? (3) What are students' attitudes toward their learning of physics and chemistry in school? (4) What are the relative effects of the students' experiences of science classroom instruction on students' attitudes toward school science? (5) What are the relative effects of the discrepancy between students' *desired* and the *actual* science classroom experiences on the students' attitudes toward school science?

4.3 Methodology

This study examines students' attitudes toward science and their experience of classroom teaching practices in junior high school physics and chemistry classes. It is among the first studies that systematically explore interrelationships among student affective variables, perceived and desired classroom experiences, and other demographic characteristics. The following sections describe the instrument, the research sample and setting, and the analyses.

4.3.1 Instrument

The questionnaire used in this study was adapted from a study of science instruction in Finland (Juuti et al. 2010), first by translating the questionnaire into Chinese and then by modifying certain items to reflect the Chinese context. Both validity and reliability of the instrument were reexamined by the researchers of the study. Given the purpose of the study, we wanted to make certain that the survey items were understandable to Chinese students and reflected the Chinese context. We chose not to adopt the popular "back translation" procedure as described in other science education research literature. The questionnaire consisted of four parts: students' perceptions of classroom teaching methods and preferred instructional methods, students' attitudes about school science and science and technology in general, students' socioeconomic background information, and students' academic performance in physics and chemistry. In the teaching method section, student participants were asked to estimate the frequency (number of times over the course) that certain teaching methods actually occurred in classroom and the frequency they preferred or wished. There are 23 items in this section, using a 5-point Likert-type scale (1 = "never," 2 = "rarely, 1–5 times," 3 = "seldom, 6–10 times," 4 = "often, at least every other class," 5="very often, almost every class"). In the attitude section, students were asked to rate their perceptions and attitudes about school science on a 4-point Likert scale (1 = "disagree," "2 = mostly disagree," 3 = "mostly agree," and 4 = "agree").

4.3.2 Participants and Setting

The study involves 16 junior high schools of different levels of academic reputation or prestige in a well-developed city in Jiangsu province. The schools are of three types, A, B, and C, with the A schools being highest in academic standing and C schools being lowest in academic standing. A total of 1,334 questionnaires were distributed and collected by teachers appointed by school principals, with a survey return rate of 100 %. The study was conducted during December 2010 while the student participants (679 male and 655 female students) were taking physics and chemistry courses in 9th grade. During the survey, all participants were allowed to ask clarification questions and instructed to leave an item blank if they did not understand the question or were unsure about the answer. Five of the 1,334 returned questionnaires were fully blank, leaving 1,329 questionnaires with some data. Of these, five students completed the demographic questionnaire but did not respond to any of the other items, giving a final sample of 1,324 students (a nonresponse rate of approximately 1 %). Of these 1,324, the vast majority answered all items (almost 87 %), and there was no apparent pattern in the missing data (i.e., most items had a few students who skipped them and no item had nonresponse greater than 2 %).

4.3.3 Data Analyses

Analyses were conducted on the students' scores on measures of students' attitudes toward science and their actual versus preferred instruction. For attitude toward science, a score was calculated based on the eight attitude items, with a Cronbach's alpha of 0.68. Each student was assigned a score equal to the average of their response to all questions. For the instruction questionnaire, a factor analysis was conducted to identify subscales of items within the questionnaire based on students' responses about their teachers' instruction. Based on analysis of eigenvalues and a scree plot, a three-factor solution was found to fit the data well. The authors reviewed the content of the included items to identify any pattern or pedagogical principle connecting the practices addressed by the items and named the factor based on the form of teaching that reflected the items. Items that did not load to the

Table 4.3 Sample instructional practices survey items, by subscale

Item no.	Survey statement
Teaching with a cooperative orientation	
Q09	Students solve problems or complete tasks in small groups
Q10	Students conduct projects in small groups
Q15	Students learn cooperatively
Teaching with a constructivist orientation	
Q16	Students learn by writing essays, summaries, or stories about science
Q19	Students imagine or create various ideas (brainstorming)
Q22	Students hold a debate during the lesson
Traditional direct teaching	
Q06	Teacher leads discussion about difficult concepts and/or problems
Q12	Students learn by reading the textbook
Q14	Teacher describes phenomena and processes associated with experiments (instead of performing/demonstrating the experiments)

three main factors were removed. The first factor consisted of five items about *cooperative teaching*, such as having students work in pairs or small groups to conduct experiments or to discuss difficult problems. The second factor consisted of five items about *constructivist teaching*, such as having students draw concept maps, write stories about science, or hold a debate. The third factor consisted of eight items about *direct teaching*, such as writing content on the blackboard, having students read the textbook, or describing an experiment (rather than performing or demonstrating the experiment). The factors were examined separately for the actual versus preferred responses. The observed Cronbach's alpha values for cooperative teaching were 0.86 for actual and 0.85 for preferred; for conceptual teaching, 0.84 for actual and 0.85 for preferred; and, for direct teaching, 0.80 for actual and 0.87 for preferred. These values all indicate that the subscales had good internal consistency. For each subscale, a subscale score was computed based on the average response to the items in that factor. Table 4.3 presents a list of sample items within each subscale.

Next, to enable comparison of students' responses on the preferred and actual factors on the instruction questionnaire, a *discrepancy* score for each factor is calculated by subtracting the value for preferred from the actual score, similar to the method described by Juuti and colleagues (2010). Thus, positive values indicate that students experienced a form of instruction more than they preferred, and negative values indicate that students experienced a form of instruction less than they preferred.

After preparation into scales for attitude and for actual and preferred instruction, the data were analyzed in two ways to answer the five research questions posed. First, an analysis of variance was conducted to examine differences by school type for the attitudes, actual instruction, and discrepancies between actual and preferred instruction. Second, regression analyses were conducted to compare the relative effects of the instructional subscales on students' attitudes toward science.

4.4 Results and Discussion

Descriptive statistics for the students' attitude measures and their actual and preferred instruction are shown overall and by school type in Table 4.4. For attitudes, a higher number indicates more positive attitudes toward science. The average attitude score was near 3.0, indicating an overall positive attitude toward science (on a scale of 1–4). Because school types reflect different levels of previous academic performance and standing, we break down the findings according to school type where possible. There was a statistically significant difference in attitude among the school types ($F [2,1321] = 10.23$, $p < 0.01$), with students in the higher-ranked schools having lower attitude. However, this difference has an eta-squared value of 0.015, which is quite small from a practical standpoint.

The students' reports of actual instruction indicate that they often or very often experienced direct teaching, occasionally experienced cooperative teaching, and seldom or rarely experienced constructivist teaching. This pattern shown in Table 4.4 is consistent across all school types. The students in higher-ranked schools reported significantly lower cooperative teaching ($F [2,1326] = 6.17$, $p < 0.01$) and constructivist teaching ($F [2,1326] = 16.70$, $p < 0.01$) than did counterparts in the lower-ranked schools. However, while statistically significant, such school differences are small from a practical standpoint, with effect sizes (as eta-squared values) below 0.03 for all reports of actual instruction.

Table 4.5 presents the descriptive statistics on the differences between students' actual experience of instruction and preferred instruction. As can be seen, students

Table 4.4 Descriptive statistics for student attitude and instructional subscales

			Actual			Preferred		
School type	N	Attitude	Coop	Construct	Direct	Coop	Construct	Direct
Total	1,324	3.01	3.57	3.08	4.33	4.35	3.99	4.58
A	399	2.92	3.44	2.92	4.29	4.24	3.77	4.52
B	581	3.01	3.59	3.05	4.40	4.37	3.98	4.62
C	344	3.10	3.68	3.34	4.27	4.45	4.25	4.58

Coop cooperative teaching, *Construct* constructivist teaching, *Direct* direct teaching

Table 4.5 Descriptive statistics for the discrepancies between actual and preferred instructional subscales

	Discrepancies		
School type	Coop	Construct	Direct
Total	−0.78	−0.91	−0.25
A	−0.80	−0.85	−0.23
B	−0.78	−0.94	−0.22
C	−0.76	−0.92	−0.31

Coop cooperative teaching, *Construct* constructivist teaching, *Direct* direct teaching. Negative values indicate that students experienced a form of instruction less than preferred in all schools reported experiencing less of each type of instruction than was preferred. In particular, the constructivist teaching shows the greatest discrepancy between actual and preferred, across all school types. In addition, there are no statistically significant differences in the discrepancies among schools in the students' ratings for either cooperative teaching (F [2,1326] = 0.20, $p > 0.50$) or constructivist teaching (F [2,1326] = 1.21, $p > 0.25$). Only type C schools have slightly higher discrepancy for direct teaching (F [2,1326] = 4.98, $p < 0.05$), although the direction is consistent with the higher-ranked B and A schools.

To look deeper at the differences between scales, discrepancies on sample items are informative. As shown in Fig. 4.1, the sample items demonstrate that there are consistent discrepancies across all items, regardless of school type. Additionally, it is clear that some items have particularly large discrepancies for both cooperative (e.g., Q10) and constructivist teaching (e.g., Q16 and Q22).

Next, regression analyses were conducted to examine the relationship among the instructional variables and students' attitudes toward science. The first regression analysis focused on the relationship of attitude with students' actual instructional experience. Results indicate that there are small, positive relationships between students' attitudes and their experiences of cooperative teaching ($b = 0.206$, $p < 0.001$) and of constructivist teaching ($b = 0.14$, $p < 0.001$). By contrast, there is a small, negative relationship between attitude and the experience of direct teaching ($b = -0.088$, $p < 0.01$).

The second regression analysis examined the relationships between students' attitudes and any discrepancies between actual and preferred instruction. Because earlier ANOVA results indicated that students differed in actual versus preferred instruction by school type, analyses were conducted separately for each school type. Results indicate that across all school types there was a consistent, positive relationship for cooperative teaching (for type A, $b = 0.19$, $p < 0.01$; for type B, $b = 0.206$, $p < 0.01$; for type C, $b = 0.23$, $p < 0.01$). That is, in all school types, students had higher attitudes toward science when the difference between actual and preferred instruction was positive. On the other hand, there are no significant relationships between attitude and the discrepancies for constructivist teaching or direct teaching for any of the school types.

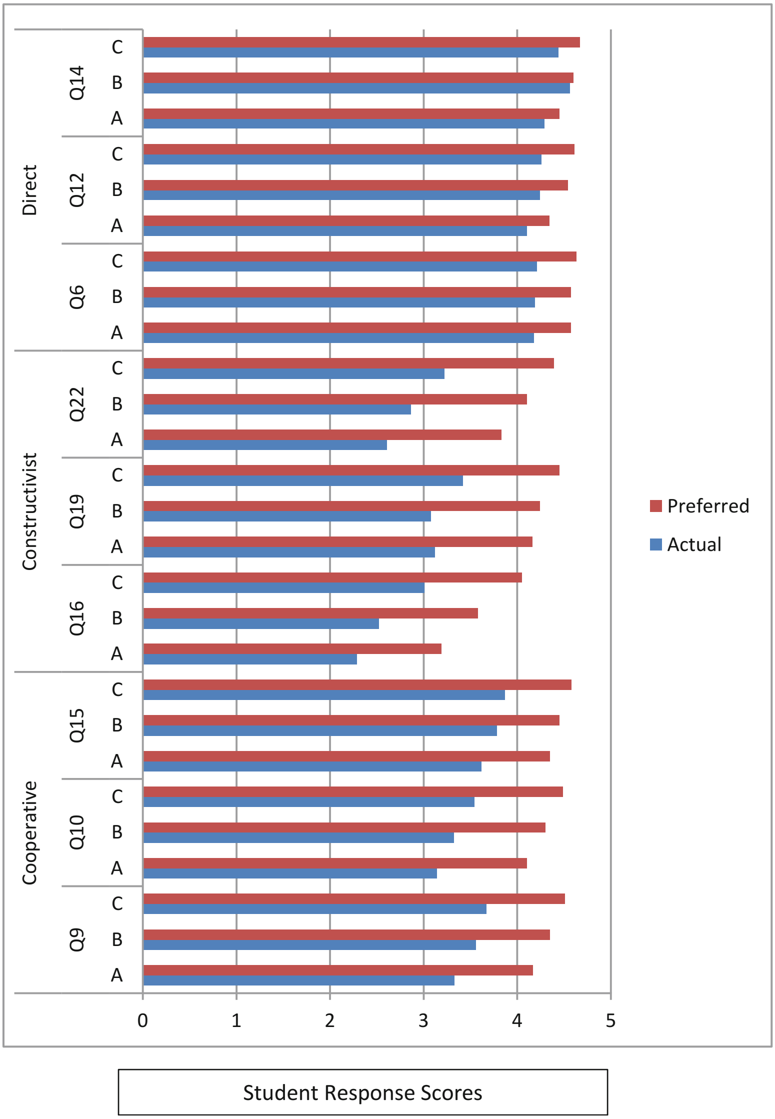

Fig. 4.1 Student responses to sample instructional practice survey items, by school type. Note that *A*, *B*, and *C* represent three types of participating schools: *A* = schools with the highest academic standing; *C* = schools with the lowest academic standing; *B* = schools with academic standing between *A* and *C*. The selected survey items are presented in Table 4.4

4.5 Conclusions

In the present study, we examined the relationships among students' attitudes toward science and their actual versus preferred forms of instruction. The findings revealed that students experience cooperative teaching and constructivist teaching occasionally (between seldom and often), whereas direct teaching occurs very often. This reflects prior work carried out in other countries (e.g., Juuti et al. 2010). Additionally, findings indicate that students would prefer to experience much more constructivist teaching than they currently do. Students would particularly welcome more instructional practices incorporating writing, brainstorming, debating, and science field trips.

We also examined the students' attitudes toward science according to their school background and the types of instruction they experience. Our finding that students from better-performing schools (i.e., "A" schools) have lower attitudes toward science was unexpected. In this education system, admission to the higher-ranked schools is competitive, and there is greater pressure for academic success and examination performance in such schools. So, it is possible that students in the higher-ranked schools have lower attitudes toward science because of the greater academic pressure they have in this subject. On a separate point, our findings regarding forms of instruction showed that students have more positive attitudes toward science when they report more frequently experiencing cooperative teaching and constructivist teaching and less frequently experiencing direct teaching. Furthermore, there is a consistent, positive relationship between students' attitudes toward science and their preference for instruction—when students' actual experience of cooperative teaching is closer to their preferred amount, they have more positive attitudes.

The findings reveal that students in the Jiangsu province report experiencing cooperative and constructivist teaching only occasionally and at a lower rate than desired. Furthermore, these students' attitudes toward science are positively related to the incidence of both cooperative and constructivist teaching, suggesting the potential importance of using cooperative and constructivist teaching strategies to raise students' attitudes toward science. Our results are consistent with the findings of Juuti and colleagues (2010), in that the students reported experiencing very high rates of direct teaching and would prefer to experience more cooperative and conceptual instruction. Furthermore, the results underscore the value of cooperative and constructivist teaching for supporting students' engagement with the class (e.g., Treagust 2007), thus supporting students' satisfaction with the classroom experience and potentially improving their performance in the subject (Nolen 2003).

4.5.1 Implications

The findings have implications for future research and for the understanding and planning of teaching. Firstly, the findings demonstrate that there are meaningful ways to measure students' experiences of instruction through a student survey of their instructional experiences and to use this information in the evaluation and planning of instruction. Much as Fulmer and Liang (2013) showed in their study of US students' experiences of science instruction, drawing on students' reports of their classroom experience can be influential in understanding instruction and may be informative for teachers and curriculum developers in planning for instruction. Such findings have been supported in other topic areas as well (e.g., Juuti et al. 2010; Nolen 2003).

Secondly, the findings show that students' attitudes are significantly higher when they experience instructional strategies that encourage student cooperation and conceptual development, as has been recommended for science education in the West (e.g., Treagust 2007). Drawing on these findings, if increased attitudes toward science are a desirable outcome of science teaching in China, then one possible avenue is to increase the use of cooperative and conceptual instructional strategies in class. However, the present study did not experimentally manipulate the extent of cooperative, conceptual, or direct teaching. Thus, additional research is needed to test such a conjecture about the potential mechanism through which cooperative and constructivist teaching can raise students' attitudes toward science.

Acknowledgments The authors thank Dr. Xiufeng Liu, Dr. Bing Wei, and two anonymous reviewers for their insightful comments.

References

Adamson, S. L., Banks, D., Burtch, M., Cox, F., III, Judson, E., Turley, J. B., Benford, R., & Lawson, A. E. (2003). Reformed undergraduate instruction and its subsequent impact on secondary school teaching practice and student achievement. *Journal of Research in Science Teaching, 40*(10), 939–957.

Beaton, A., Martin, M. O., Mullis, I., Gonzalez, E. J., Smith, T. A., & Kelley, D. L. (1996). *Science achievement in the middle school years: IEA's Third International Mathematics and Science Study*. Chestnut Hill: Boston College.

Catsambis, S. (1995). Gender, race, ethnicity, and science education in the middle grades. *Journal of Research in Science Teaching, 32*(3), 243–257.

Centra, J. A. (1973). Self-ratings of college teachers: A comparison with student ratings. *Journal of Educational Measurement, 10*(4), 287–295.

Chen, X., Jia, C. C., & Chen, N. (2010). Alignment between the physics content standard and the exam（物理内容标准与考试之间的一致性研究）. *Curriculum, Teaching Material and Method (课程.教材.教法), 30*(7), 67–71. (In Chinese).

den Brok, P., Brekelmans, M., & Wubbels, T. (2004). Interpersonal teacher behaviour and student outcomes. *School Effectiveness & School Improvement, 15*(3/4), 407–442.

Fisher, D., den Brok, P., Waldrip, B., & Dorman, J. (2011). Interpersonal behaviour styles of primary education teachers during science lessons. *Learning Environments Research, 14*(3), 187–204. doi:10.1007/s10984-011-9093-z.

Fraser, B. J. (1998). Science learning environments: Assessment, effects and determinants. In B. J. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (Vol. 1, pp. 527–564). London: Kluwer.

Freedman, M. P. (1997). Relationship among laboratory instruction, attitude toward science, and achievement in science knowledge. *Journal of Research in Science Teaching, 34*, 343–357.

Fulmer, G. W. (2008). *Successes and setbacks in collaboration for science instruction: Connecting teacher practices to contextual pressures and student learning outcomes*. Saarbru¨cken: VDM Publishing.

Fulmer, G. W., & Liang, L. L. (2013). Measuring model-based high school science instruction: Development and application of a student survey. *Journal of Science Education and Technology, 22*(1), 37–46. doi:10.1007/s10956-012-9374-z.

Guo, Y., Lu, Y. & Shi, J. (2011). Investigating inquiry teaching in high school chemistry classrooms: Status analysis and reflections (高中化学科学探究教学现状调查及常态化思考). *Teaching Chemistry in Secondary Schools* (中学化学教学参考) (4), 3–5. (In Chinese).

Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist, 4*(2), 111–127.

Judson, E., & Lawson, A. E. (2007). What is the role of constructivist teachers within faculty communication networks? *Journal of Research in Science Teaching, 44*(3), 490–505. doi:10.1002/tea.20117.

Juuti, K., Lavonen, J., Uitto, A., Byman, R., & Meisalo, V. (2010). Science teaching methods preferred by grade 9 students in Finland. *International Journal of Science and Mathematics Education, 8*(4), 611–632.

Keeves, J. P., & Morgenstern, C. (1992). Attitudes towards science: Measures and effects. In J. P. Keeves (Ed.), *The IEA study of science III: Changes in science education and achievement: 1970 to 1984* (pp. 122–142). New York: Pergamon.

Koziol, S. M., Jr., & Burns, P. (1986). Teachers' accuracy in self-reporting about instructional practices using a focused self-report inventory. *Journal of Educational Research, 79*(4), 205–209.

Lawrenz, F., Wood, N. B., Kirchhoff, A., Kim, N. K., & Eisenkraft, A. (2009). Variables affecting physics achievement. *Journal of Research in Science Teaching, 46*(9), 961–976.

Liang, L. L., & Yuan, H. (2008). Examining the alignment of Chinese national physics curriculum guidelines and 12th-grade exit examinations: A case study. *International Journal of Science Education, 30*(13), 1823–1835. doi:10.1080/09500690701689766.

McComas, W. F. (1993). STS education and the affective domain. In R. E. Yager (Ed.), *What research says to the science teacher, volume 7: The science, technology and society movement* (pp. 161–168). Washington, DC: National Science Teachers Association.

Ministry of Education (MOE). (2001a). An *outline for the basic education curriculum reform* (基础教育课程改革纲要). (official document). (In Chinese).

Ministry of Education (MOE). (2001b, 2011). National Science Curriculum Standards for the Full-Time Compulsory Education (Gr. 7–9). *(Trial Version, Revised Version)*. (义务教育科学课程标准). Beijing: Beijing Normal University Press. (In Chinese).

Ministry of Education (MOE). (2001c, 2011). National Physics Curriculum Standards for the Full-Time Compulsory Education (Gr. 7–9). *(Trial Version, Revised Version)*. (义务教育物理课程标准). Beijing: Beijing Normal University Press. (In Chinese).

Ministry of Education (MOE). (2001d, 2011). National Chemistry Curriculum Standards for the Full-Time Compulsory Education (Gr. 7–9). *(Trial Version, Revised Version)*. (义务教育化学课程标准). Beijing: Beijing Normal University Press. (In Chinese).

Nolen, S. B. (2003). Learning environment, motivation, and achievement in high school science. *Journal of Research in Science Teaching, 40*(4), 347–368. doi:10.1002/tea.10080.

OECD. (2007). *PISA 2006: Science competencies for tomorrow's world*. Retrieved July 8, 2008, from http://www.pisa.oecd.org/document/2/0,3343,en_32252351_32236191_39718850_1_1_1_1,00.html

Oliver, J. S., & Simpson, R. D. (1988). Influences of attitude toward science, achievement motivation, and science self concept on achievement in science: A longitudinal study. *Science Education, 72*(2), 143–155.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education, 25*(9), 1049–1079.

Park, S., Jang, J.-Y., Chen, Y.-C., & Jung, J. (2011). Is pedagogical content knowledge (PCK) necessary for reformed science teaching? Evidence from an empirical study. *Research in Science Education, 41*(2), 245–260. doi:10.1007/s11165-009-9163-8.

Piburn, M. D., & Baker, D. R. (1993). If I were the teacher . . . Qualitative study of attitude toward science. *Science Education, 77*, 393–406.

Porter, A. C. (2002). Measuring the content of instruction: Uses in research and practice. *Educational Researcher, 31*(7), 3–14.

Sawada, D., Piburn, M., Judson, E., Turley, J., Falconer, K., Benford, R., & Bloom, I. (2002). Measuring reform practices in science and mathematics classrooms: The reformed teaching observation protocol. *School Science and Mathematics, 102*(6), 245–253.

Schibeci, R. A., & Riley, J. P., Jr. (1986). Influence of students' background and perceptions on science attitudes and achievement. *Journal of Research in Science Teaching, 23*, 177–187.

Shrigley, R. L. (1990). Attitude and behavior are correlates. *Journal of Research in Science Teaching, 27*, 97–113.

Shuell, T. J. (1996). Teaching and learning in a classroom context. In D. C. Berliner & R. C. Caffee (Eds.), *Handbook of educational psychology* (pp. 726–764). New York: Macmillan.

Siegel, M. A., & Ranney, M. A. (2003). Developing the changes in attitude about the relevance of science (CARS) questionnaire and assessing two high school science classes. *Journal of Research in Science Teaching, 40*, 757–775.

Simpson, R. D., & Oliver, J. S. (1990). A summary of the major influences on attitude toward and achievement in science among adolescent students. *Science Education, 74*, 1–18.

Treagust, D. F. (2007). General instructional methods and strategies. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education*. Mahwah: Lawrence Erlbaum Associates.

Venville, G., Sheffield, R., Rennie, L. J., & Wallace, J. (2008). The writing on the wall: classroom context, curriculum implementation, and student learning in integrated, community-based science projects. *Journal of Research in Science Teaching, 45*(8), 857–880.

Waight, N., & Abd-El-Khalick, F. (2007). The impact of technology on the enactment of "inquiry" in a technology enthusiast's sixth grade science classroom. *Journal of Research in Science Teaching, 44*(1), 154–182.

Weinburgh, M. (1995). Gender differences in student attitudes toward science: A meta-analysis of the literature from 1970 to 1991. *Journal of Research in Science Teaching, 32*, 387–398.

Xie, S. (2012). Investigating inquiry teaching in middle school physics classrooms within minority ethnic groups (民族地区初中物理教师开展科学探究教学情况的调查), *Research in Continuing Education* (继续教育研究), Issue 4, 86–89. (In Chinese).

Yager, R. E., & Penick, J. E. (1986). Perception of four age groups toward science classes, teachers, and the value of science. *Science and Education, 70*, 355–363.

Zhang, H., & He, H. (2012). Student perceptions of the integrated 'science education' major in some Chinese universities. *International Journal of Science Education, 34*, 1991–2013.