JOURNAL OF RESEARCH IN SCIENCE TEACHING VOL. 39, NO. 1, PP. 63–78 (2002)

Teacher Communication Behavior and its Association With Students' Cognitive and Attitudinal Outcomes in Science in Taiwan

Hsiao-Ching She,[1] Darrell Fisher[2]

[1]*Institute of Education, National Chiao Tung University, 1001 Ta-Hsueh Rd., Hsin-Chu City, Taiwan, Republic of China*

[2]*National Key Center for School Science and Mathematics, Curtin University of Technology, GPO Box U1987, Perth 6845, Australia*

Received 21 August 1999; Accepted 7 December 2000

Abstract: In the study described in this article a questionnaire was employed that can be used to assess students' and teachers' perceptions of science teachers' interpersonal communication behaviors in their classroom learning environments. The Teacher Communication Behavior Questionnaire (TCBQ) has five scales: Challenging, Encouragement and Praise, Non-Verbal Support, Understanding and Friendly, and Controlling. The TCBQ was used with a large sample of secondary science students in Taiwan, which provided additional validation data for the TCBQ for use in Taiwan and cross-validation data for its use in English-speaking countries. Girls perceived their teachers as more understanding and friendly than did boys, and teachers in biological science classrooms exhibited more favorable behavior toward their students than did those in physical science classrooms. Differences were also noted between the perceptions of the students and their teachers. Positive relationships were found between students' perceptions of their teachers' communication behaviors and their attitudes toward science. Students' cognitive achievement scores were higher when students perceived their teacher as using more challenging questions, as giving more nonverbal support, and as being more understanding and friendly. The development of both teacher and student versions of the TCBQ enhances the possibility of the use of the instrument by teachers. © 2002 John Wiley & Sons, Inc. J Res Sci Teach 39: 63–78, 2002

Classroom interactions between teachers and students occur rapidly in a classroom. Good and Brophy (1991) indicated that teachers in secondary schools may have interactions with 150 different students in a single day. However, teachers are usually not aware or are not able to describe or remember what happens in these interactions with their students. For example, Good and Brophy interviewed teachers and confirmed that teachers usually were not aware how many questions they asked students and what kind of feedback they provided. Thus, it could be

Correspondence to: Hsiao-Ching She; E-mail: hcshe@cc.nctu.edu.tw

Contract grant sponsor: National Science Council, Taiwan, Republic of China; Contract grant number: NSC87-2511-S-009-001.

DOI 10.1002/tea.10009

helpful to teachers if their behaviors and interactions in teaching were identified and recorded. The study described in this article used a questionnaire to assess students' and teachers' perceptions of science teachers' interpersonal communication behaviors in their classroom learning environments.

Theoretical Framework

Three common approaches to studying teachers and their classrooms are systematic observation, descriptive case studies, and using student and teacher perceptions. Systematic observation and case studies have been used frequently in the past; however, now perceptual measures often are used, particularly when investigating a large sample of classes. The advantages of using student perceptions as indicators of the quality of the classroom environment have been elucidated in a number of studies (e.g., Rosenshine, 1971; Walberg & Haertel, 1980; Stodolsky, 1984; Fraser, 1998a). Examples of past findings include: students are directly involved in classroom activities and observe more of the teacher's typical behavior than does an observer; students are more familiar with their teacher's idiosyncrasies, which might be interpreted differently by an observer; using trained observers over a period of time is more expensive and time consuming than the administration and scoring of questionnaires; and the presence of observers could alter what generally occurs in the classroom.

In the past three decades much attention has been given to the development and use of instruments to assess the qualities of the classroom learning environment from the perspective of the student (Fraser & Walberg, 1991; Fraser, 1998a, 1998b), and the association between learning-environment variables and student outcomes has provided a particular focus for the use of learning-environment instruments. In a meta-analysis that examined 823 classes in eight subject areas representing the perceptions of 17,805 students in four nations, Haertel, Walberg, and Haertel (1981) found enhanced student achievement in classes that students felt had greater cohesiveness, satisfaction, and goal direction and less disorganization and friction. Other literature reviews since then have supported the existence of associations between classroom environment variables and student affective and cognitive outcomes (Fraser, 1998a). Therefore, one purpose of the study was to establish a questionnaire that would allow a study of students' and teachers' perceptions of teacher communication behavior in a large number of science classes at the same time. The questionnaire could then be used to investigate associations between students' perceptions of their teacher's interpersonal communication behavior in classroom-learning environments and their cognitive outcomes in science.

Until about 20 years ago research involving science students' outcomes focused primarily on educational objectives in the cognitive domain, but in more recent times attention has been paid to outcomes in the affective domain; the study of student attitudes has formed a primary component of this research (Weinburgh, 1995). Shulman and Tamir (1972) suggested that affective outcomes of education are at least as important as cognitive outcomes and acknowledgment of the importance of affective outcomes is reflected in their increasing emphasis in curricula (Mathews, 1974; Hough & Piper, 1982; Gardner & Gauld, 1990).

When classroom environment perceptions have been used as predictor variables, associations between student cognitive and affective outcomes and the learning environment have been found. Fraser (1994) provided a broad overview of these results, which indicate that classroom environment perceptions can influence students' outcomes. In a study in middle secondary science classes in Korea, students' attitude scores were higher in classrooms in which students perceived greater leadership, helping/friendly, and understanding behaviors in their teachers (Kim, Fisher, & Fraser, in press-a). In a second study in Korea results indicated that

favorable student attitudes could be promoted in classes in which students perceived more personal relevance, shared control with their teachers, and negotiated their learning (Kim, Fisher, & Fraser, in press-b). These results were the same as those of the past research of Brekelmans, Wubbels, and Levy (1993) and of Fisher, Rickards, Goh, and Wong (1997). Wubbels, Brekelmans, and Hooymayers (1991) found that the communication style of physics teachers is the most important variable in explaining differences in the students' appreciation of the lessons and the subject being taught at the class level. Because of the importance of students' affective outcomes in education and because past studies frequently have reported statistically significant associations between students' perceptions of their learning environment and their affective learning outcomes (Fraser, 1998b), it was decided to examine associations between students' perceptions of their teachers' behaviors with students' attitude to their class.

Much of the research on science learning environments has focused on student perceptions of teacher–student interpersonal behavior; however, it is possible to ask teachers for their perceptions of their classrooms. In the few research studies in which this has been investigated, science teachers' perceptions of their own interpersonal behavior were found to differ in some respect from those of their students. For example, in two Australian studies, Wubbels and Levy (1993) and Fisher and Rickards (in press) used the Questionnaire on Teacher Interaction (QTI) with large samples of students and their teachers in science classrooms. They showed that there were differences in teachers' and students' perceptions of teacher–student interpersonal behavior and that teachers believed they were more cooperative and less oppositional in the classrooms than their students perceived them. Similar results have been reported elsewhere (Cooper & Good, 1983; Fraser, 1998a). For this study it was decided to focus on both student and teacher perceptions by developing a teacher's version of the questionnaire so that comparisons could be made between the perceptions of teachers and their students. Using both teacher and student versions of the questionnaire possibly could provide more information about the relationships of teachers with their students in science classrooms.

Of all school subjects, science probably has the greatest inequity between the sexes in participation, achievement, and attitudes (Young & Fraser, 1994; Parker, Rennie, & Fraser, 1996; Baker, 1997). Also, previous studies have reported sex-related differences in students' perceptions of the learning environment (Lawrenz, 1987; Fisher, Henderson, & Fraser, 1995; Fraser, Giddings, & McRobbie, 1995). Therefore, in line with this avenue of research, sex-related differences in students' perceptions of their learning environment were explored in this study. Other learning environment research in science classrooms has indicated differences in students' perceptions on other subjects in addition to sex differences (Fisher, Harrison, Henderson, & Hofstein, 1998). In this study differences between biological and physical sciences were examined. Furthermore, questionnaires like the TCBQ are of use to practicing science teachers if they are able to gain personal benefit from their use in their own classrooms. Thus, in this study we tried an application of the TCBQ with two classroom teachers.

Development of the TCBQ

Researchers in the Netherlands (Wubbels, Créton, & Holvast, 1988; Wubbels, Créton, & Hoomayers, 1992; Wubbels & Levy, 1993) investigated teacher behavior in a classroom from a systems perspective, adapting a theory on communications processes developed by Waltzlawick, Beavin, and Jackson (1967). Within the systems perspective of communication, it is assumed that the behaviors of participants mutually influence each other. The behavior of the teacher is influenced by the behavior of the students and in turn influences the student behavior. Thus, a circular communication process develops. This ''systems approach'' assumes that one cannot

''not communicate'' when in the presence of someone else. For example, if a teacher ignores students' questions because he or she does not hear them, then the students might infer that the teacher is too busy, that the teacher thinks the students are too dull to understand, or that the teacher considers the questions irrelevant. Based on this systems approach, the Questionnaire on Teacher Interaction (QTI; Wubbels & Levy, 1993) was developed. Research with the QTI in the Netherlands, America, and Australia clearly indicated that helpful, friendly, and understanding teacher behaviors were associated with higher cognitive outcomes scores and positive student attitudes (Wubbels & Levy, 1993; Fisher et al., 1995; Fisher & Rickards, 1997). Furthermore, it was demonstrated in these research studies that the teacher's strict or controlling behavior was associated with student cognitive gains, although not with their attitudes. It was thus decided to include in the questionnaire one scale to assess student perception of the teacher's understanding and friendly behavior and one to assess controlling behavior.

To gather data about teachers' nonverbal behavior, van Tartwijk (1993) developed a classroom-observation instrument. He found that 63% of the measured variance of the perceived influence teachers have on what happens in the class was explained by the nonverbal behavior of the teacher. For example, the teacher's facial expression, as perceived by the students, was an important aspect of nonverbal behavior for determining the level of the teacher's cooperative interpersonal behavior. The more the teachers smiled, the more helpful, friendly, and understanding the students perceived them to be. Van Tartwijk concluded that the nonverbal behavior of the teacher was related to students' perceptions of the interpersonal behavior of their teacher. Furthermore, systematic classroom observation research in Taiwan involving the use of nonverbal reinforcement in the teachers' behavior toward students supported the importance of this teacher behavior (She, 1998a, 2000, 2001). It was decided to include a scale that assessed the teacher's nonverbal support for the students in their classrooms.

Other research has shown that two teacher behaviors have had a considerable effect on students' achievement (e.g., Good & Brophy, 1974; Walberg, 1984). According to these research studies, questioning and the teachers' reactions to the students' answers are key factors in the interactions that occur between teachers and their students. Questions have been shown to be an important and integral part of learning, and questions asked by teachers can become indices of the quality of teaching (Carlsen, 1991; Smith, Blakeslee, & Anderson, 1993). Deal and Sterling (1997) suggested that effective classroom questions promote relevance, encourage ownership, help students interpret their observations, and link new learning to what students already know. In Taiwan, systematic classroom observation research involving the use of questioning and verbal reinforcement in the teachers' behavior toward students supported the importance of these two teacher behaviors (She, 1998a, 2000, 2001).

Thus, the development of this questionnaire was based on She's (1998a, 1998b, 1999, 2000, 2001; She & Barrow, 1997) studies of teacher–student interactions in science classrooms in Taiwan and on previous research with the QTI. Items for the questionnaire originally were written in Chinese and then translated into English. A back translation of the English version into Chinese by people not involved in the original translation was then completed. This resulted in modification of both the original Chinese version and the English translation. The initial version of the questionnaire, named the Teacher Communication Behavior Questionnaire (TCBQ), contained a total of 60 items, with 12 items in each of five scales: Challenging, Encouragement and Praise, Non-Verbal Support, Understanding and Friendly, and Controlling. Following item and factor analyses, the TCBQ was reduced to 40 items, with eight items in each scale. Each item is responded to on a 5-point scale, with the alternatives of *almost never, seldom, sometimes, often*, and *very often*. Table 1 contains a description of the meaning of each of the five scales and a sample item from each scale.

Table 1
Description of scales and a sample item for each scale of the TCBQ

Scale Name	Description of Scale	Sample Item
Challenging	Extent to which the teacher uses higher-order questions to challenge students in their learning	This teacher asks questions that require me to integrate in formation that I have learned
Encouragement and praise	Extent to which the teacher praises and encourages students	This teacher encourages me to discuss my ideas with other students
Non-verbal support	Extent to which the teacher uses non-verbal communication to interact positively with students	This teacher nods his/her head to show support while I am struggling to answer a question
Understanding and friendly	Extent to which the teacher is understanding and friendly towards the students	If I have something to say, this teacher will listen
Controlling	Extent to which the teacher controls and manages student behavior in the classroom	This teacher expects me to obey his/her instructions

In constructing the teachers' self-perception version of the questionnaire, slight changes were made to the wording to make it clear to the teachers that they were thinking about themselves. For example, an item like ''This teacher praises me for asking a good question'' in the students' version became ''I praise students for asking a good question'' in the teachers' version. In a second version teachers were asked to describe their ideal teacher, and again the wording was changed slightly. For example, the above item in the teacher ideal version became ''The teacher would praise students for asking a good question.''

Details of the development of the TCBQ have been provided elsewhere (She & Fisher, 1999, 2000). All five scales of the TCBQ were found to display satisfactory internal consistency reliability, discriminant validity, and factor validity. As well, additional analyses supported the ability of the TCBQ to differentiate between the perceptions of students in different classrooms. In the validation process the researchers used a combination of quantitative and qualitative analyses. The quantitative data provided numerical descriptions of the reliability and validity of the TCBQ, whereas student interviews provided verification of the content and construct validity of the scales.

Methodology

The objectives of the research described in this article were to: (a) provide further validation data for the TCBQ for use in Taiwan and cross-validation data for its use in English-speaking countries; (b) use the TCBQ to determine if there are any sex differences in students' perceptions of their teachers' communication behaviors; (c) use the TCBQ to determine if there are any differences between biological science students' and physical science students' perceptions of their teachers' communication behaviors; (d) investigate associations between students' perceptions of their teachers' communication behaviors and their attitudinal and cognitive outcomes; and (e) compare students' and teachers' perceptions of teachers' communication behaviors and use the TCBQ with two teachers.

To obtain an assessment of students' attitudinal outcomes, four scales from the Test of Science Related Attitudes (TOSRA; Fraser, 1981) were selected. These scales were Social

Implications of Science, Enjoyment of Science Lessons, Leisure Interest in Science, and Career Interest in Science. Students' first- and second-semester science academic scores were obtained to provide a measure of their cognitive achievement.

This research study was part of a larger cross-national study involving Australia and Taiwan. The sample of randomly selected schools participating in that larger study was available to the authors. The final sample consisted of 1,138 biological/physical science students from 28 classes in Grades 7–9 in Taiwan. Each student in the sample responded to the TCBQ and the four attitude scales. Twenty-eight of the teachers responded to both the self and ideal teachers' version of the TCBQ. In addition, to provide cross-validation information for use of the English-language version of the TCBQ, 307 students in 12 classrooms of Grades 7–9 science courses in Australia also responded to the questionnaire. Simple- and multiple-correlation data were used to examine whether there were any associations between students' perceptions of their teachers' communication behaviors and their attitude to class and cognitive achievement.

To help explain the results obtained, the researchers visited each of two of the classrooms on 10 occasions and compared their observations with the quantitative results obtained from the TCBQ. During the classroom observations the two observers (the authors) sat in the classroom, focusing on and describing interactions that were occurring between the teacher and the students. In addition, an observation checklist was used to code the frequency and types of teacher-initiated questions, the responses of the teachers to the students' responses and questions, and the teachers' understanding and controlling behaviors. Each of these 50-min class period observations was videotaped. This enabled the observers to view the session a second time and to check their original coding results as well as their written descriptions. This process also made it possible for the observers to compare both their coding results and their descriptions. It is noteworthy that this comparison showed the observations were very similar.

Results

Validation and Cross Validation of the TCBQ

Estimates of the internal consistency of the five scales of the questionnaire were calculated using Cronbach's alpha coefficient and are shown in Table 2. The alpha reliability coefficient for

Table 2
Internal consistency (cronbach alpha coefficient) discriminant validity (mean correlation with other scales) and ability to differentiate between classrooms for the TCBQ

Scale	Alpha Reliability		Mean Correlation with Other Scales		ANOVA Results (η^2)	
	Taiwan	Aust	Taiwan	Aust	Taiwan	Aust
Challenging	0.88	0.86	0.40	0.37	0.17^{**}	0.11^{**}
Encouragement and praise	0.91	0.87	0.50	0.44	0.19^{**}	0.15^{**}
Non-verbal support	0.93	0.92	0.50	0.44	0.21^{**}	0.09^{**}
Understanding and friendly	0.92	0.93	0.47	0.39	0.22^{**}	0.14^{**}
Controlling	0.87	0.87	0.14	0.05	0.21^{**}	0.05^{*}

$^{*}p < 0.05$.
$^{**}p < 0.001$.
Taiwan, n = 1138.
Australia, n = 307.

each scale, using the individual student as the unit of analysis, ranged between 0.87 and 0.93 in Taiwan and between 0.86 and 0.93 in Australia. The discriminant validity, the extent to which each scale measures a dimension different from that measured by any other scale, was examined using the mean correlation of one scale with the other four scales. These figures ranged from 0.14 to 0.50 in Taiwan and from 0.05 to 0.44 in Australia. These values can be regarded as small enough to confirm the discriminant validity of the TCBQ, indicating that each scale measures a distinct although somewhat overlapping aspect of a teacher's communication behavior.

The ability of a classroom questionnaire like this to differentiate between classes is considered important. Students within a class usually view the classroom learning environment similarly but view it differently from students in other classes. The instrument's ability to differentiate in this way was measured using a one-way analysis of variance (ANOVA), with class membership as the main effect. The results, depicted in Table 2, show that in fact each of the scales did significantly differentiate between classes ($p < 0.001$). The amount of variance explained by class membership is reflected in the η^2 scores, which ranged from 0.17 to 0.22 in the Taiwanese sample and from 0.05 to 0.15 in the Australian sample.

Estimates of the internal consistency of the five scales of the teacher's self and ideal versions of the TCBQ, calculated using Cronbach's alpha coefficient and shown in Table 3, were found to be generally satisfactory, particularly in light of the small sample. The reliability coefficient for each scale, using the individual teacher as the unit of analysis, ranged between 0.78 to 0.91 for the teacher's self version and from 0.76 to 0.95 for the teacher's ideal version. The mean correlation of one scale with the other four scales ranged from 0.12 to 0.35 for the teacher self version and from 0.18 to 0.48 for the ideal teacher version. Again, these values were small enough to be regarded as confirmation of the discriminant validity of the TCBQ, indicating that each scale measures a distinct but somewhat overlapping aspect of teacher communication behavior.

Sex Differences

The differences in scale means between males and females are indicated in Table 4. As determined by a *t* test, there were statistically significant differences between boys' and girls' perceptions of the learning environment ($p < 0.05$) on two of the five scales of the TCBQ. Girls perceived their teachers as more understanding and friendly than did the boys. On the other hand, the boys perceived their teachers as being more controlling than did the girls. These results are similar to those of previous studies showing that girls tend to perceive their learning environment

Table 3
Internal consistency (cronbach alpha coefficient) and discriminant validity (mean correlation with other scales) for teacher versions of TCBQ

Scale	Alpha Reliability		Mean Correlation With Other Scales	
	Self	Ideal	Self	Ideal
Challenging	0.79	0.86	0.26	0.48
Encouragement and praise	0.78	0.89	0.35	0.46
Non-verbal support	0.91	0.95	0.30	0.44
Understanding and friendly	0.82	0.91	0.26	0.38
Controlling	0.85	0.76	0.12	0.18

Taiwan teachers, n = 28.

Table 4
Sex differences in item mean scores for each scale of the TCBQ

Scale	Male		Female		Difference (F − M)	*T* test
	Mean	SD	Mean	SD		
Challenging	3.13	0.82	3.21	0.84	0.08	1.65
Encouragement & praise	2.65	0.94	2.73	0.95	0.08	1.32
Non-verbal support	2.49	0.96	2.63	1.02	0.14	2.34
Understanding & friendly	3.26	0.96	3.48	0.99	0.22	3.58*
Controlling	2.90	0.91	2.64	0.89	− 0.26	4.73**

*$p < 0.001$.
**$p < 0.0001$.
n = 500 (males).
n = 549 (females).

in a more positive way than do boys (Fisher, Fraser, & Rickards, 1997; Fraser et al., 1995; Rawnsley & Fisher, 1997).

Subject Differences

As depicted in Table 5, statistically significant differences were also found between biological science and physical science classrooms. On all five scales of the TCBQ, the students in the biological science classrooms perceived more of these communication behaviors in their teachers.

Association Between Teacher Communication Behavior and Students' Attitudes

Table 6 shows the associations found between the five TCBQ scales and student attitudes toward the science class. Multiple-regression analysis involving the entire set of TCBQ scales was conducted, in addition to a simple correlation analysis, to provide a more conservative test of associations between each TCBQ scale and attitude when all other TCBQ scales were mutually controlled. The internal consistency reliability figures for the attitude scales ranged from 0.73 to 0.88.

Table 5
Science subject differences in item mean scores for each scale of the TCBQ

Scale	Biological		Physical		Difference (B − P)	*T* test
	Mean	SD	Mean	SD		
Challenging	3.33	0.79	3.10	0.84	0.23	4.14*
Encouragement & praise	2.99	0.99	2.58	0.90	0.41	5.83*
Non-verbal support	2.84	1.04	2.44	0.94	0.40	5.90*
Understanding & friendly	3.61	0.97	3.26	0.96	0.35	5.26*
Controlling	3.04	0.88	2.65	0.89	0.39	6.45*

*$p < 0.0001$.
n = 309 (bio science).
n = 740 (phys science).

Table 6
Associations between TCBQ scales and students' attitudes in terms of simple (r) and multiple (R) correlations

	Strength of Environment-Outcome Association							
	Social Implic. of Science		Enjoyment of Science Lessons		Leisure Interest in Science		Career Interest in Science	
Scale	*r*	β	*r*	β	*r*	β	*r*	β
Challenging	0.36^{***}	0.33^{***}	0.38^{***}	0.31^{***}	0.33^{***}	0.25^{***}	0.26^{***}	0.18^{***}
Encouragement & praise	0.18^{***}	−0.06	0.27^{***}	0.01	0.25^{***}	0.05	0.22^{***}	0.06
Non-verbal support	0.19^{***}	−0.08	0.28^{***}	0.06	0.26^{***}	0.06	0.22^{***}	0.07
Understanding & friendly	0.29^{***}	0.23^{***}	0.30^{***}	0.12^{*}	0.26^{***}	0.06	0.20^{***}	0.02
Controlling	0.01	−0.07	0.02	-0.08^{*}	0.07^{*}	−0.02	0.06	−0.01
Multiple correlation, *R*	0.40^{***}		0.41^{***}		0.35^{***}		0.96^{***}	
R^2	0.16		0.17		0.13		0.08	

$^{*}p < 0.05$.
$^{***}p < 0.0001$.
n = 836.

An examination of the simple correlation coefficients shown in Table 6 indicates that there were statistically significant relationships ($p < 0.0001$) between students' perceptions of their teachers' communication behaviors for four of the scales of the TCBQ with all four scales of students' attitudes toward their science class. A weak association was found between the Controlling scale and Leisure Interest, but only at the $p < 0.05$ level. That is, students' attitude scores were higher when they perceived their teacher as using more challenging questions, as giving more encouragement and praise, more nonverbal support, and as being more understanding and friendly. However, using the more conservative standardized regression coefficient (β), which measures the association when the effect of the other scales is held constant, the regression coefficient of the Challenging scale is the only scale that showed significant correlation with all four of the attitude scales, confirming the importance of teachers using challenging questions. It is noteworthy that the students' perceptions of their teachers' communication behavior contributed between 8% and 17% of measured variance in students' attitudes toward science.

Association Between Teacher Communication Behavior and Students' Cognitive Outcomes

The associations between students' perceptions of their teachers' communication behaviors and their cognitive outcomes in science classes also were analyzed using simple correlation analyses and standardized regression. The students' scores in two examinations were used separately in these analyses. The simple correlation (*r*) figures reported in Table 7 indicate there were statistically significant ($p < 0.001$) associations between students' science achievement and four of the scales of the questionnaire: Challenging, Encouragement and Praise, Non-Verbal Support, and Understanding and Friendly. That is, students' cognitive achievement scores were higher when students perceived their teacher as using more challenging questions, as giving

Table 7
Associations between TCBQ scales and students cognitive outcomes in terms of simple (r) and multiple (R) correlations

Scale	First Semester Result		Second Semester Result	
	r	ß	*r*	ß
Challenging	0.37***	0.41***	0.33***	0.37***
Encouragement & praise	0.14*	− 0.13	0.12*	− 0.12
Non-verbal support	0.16**	− 0.03	0.14*	− 0.01
Understanding & friendly	0.23***	0.14*	0.19**	0.10
Controlling	− 0.05	0.13	− 0.06	− 0.13
Multiple correlation, *R*	0.40***		0.36***	
R^2	0.16		0.13	

*$p < 0.01$.
**$p < 0.001$.
***$p < 0.0001$.
n = 242.

more encouragement and praise and more nonverbal support, and as being more understanding and friendly. An examination of the standardized regression coefficients shows that the Challenging scale is the only factor that contributes to the students' cognitive outcomes and the only one that reached a statistically significant difference in level ($p < 0.0001$) regardless of first- or second-semester science achievement. Thus, the teachers' use of such questions is very important for improving students' cognitive outcomes in science. Students' perceptions of their teachers' communication behavior contributed about 15% to the measured variance in students' cognitive outcomes.

Application Using Students' and Teachers' Versions of TCBQ in Two Science Classrooms

When the means of the three versions of the TCBQ were compared, as shown in Table 8, it was apparent that teachers had a better perception of their communication behaviors on all scales of the TCBQ than did their students. The observation that the teachers perceived their behaviors more favorably than their students has been noted in previous research (Wubbels & Levy, 1993).

To help explain the results obtained from the TCBQ, the researchers visited each of two of the classrooms on 10 occasions and compared their observations with the quantitative results.

Table 8
Means and standard deviations for three versions of TCBQ in Taiwan

Scale	Teacher Actual		Teacher Ideal		Student Actual	
	Mean	SD	Mean	SD	Mean	SD
Challenging	3.59	0.47	3.80	0.54	3.33	0.76
Encouragement & praise	3.62	0.50	4.15	0.52	2.96	1.00
Non-verbal support	3.85	0.59	4.29	0.54	2.85	1.04
Understanding & friendly	3.99	0.64	4.46	0.49	3.61	0.97
Controlling	3.30	0.62	3.47	0.51	3.04	0.89

Teachers, n = 28, students, n = 1138.

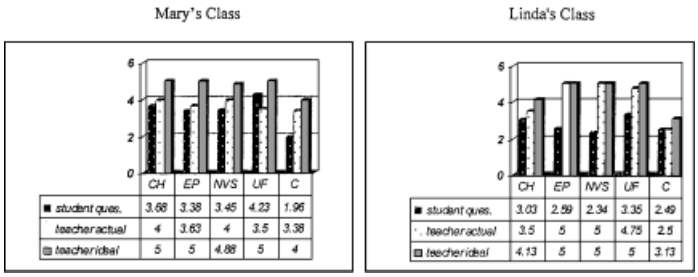

Figure 1. Using both of students' and teachers' versions of TCBQ in Science Classes Note: CH: Challenging, EP: Encouragement and Praise, NVS: Non-Verbal Support, UF: Understanding and Friendly, C: Controlling.

Figure 1 depicts the results obtained from these two classrooms. In Mary's classroom the students' perceptions were quite close to her perception, with the exception of controlling behavior. However, Linda's perception was quite different from her students' perceptions, particularly in encouragement and praise, nonverbal support, and understanding and friendly behavior. It was observed that in Linda's classroom her interaction with students occurred mostly with about 10 particular students, with the others having very little or no interaction with her. On closer examination of the students' TCBQ questionnaires, it was noted that the difference among individuals was high, with the responses of about 10 students to items in the first four scales ranging from 3 to 5. However, the scores of the rest of the students were quite low for these four scales, supporting the observations that the teacher may have little supportive communication with these students. The low scores suggest why the discrepancy existed in the perceptions of the students and their teacher about the teacher's communication behavior.

For Mary's class the student and teacher means of the first four scales — Challenging, Encouragement and Praise, Non-Verbal Support, and Understanding and Friendly — were quite close. The patterns of teacher–student interaction in Mary's classroom were much more evenly distributed among the students than what was observed in Linda's classroom. One of the ways Mary achieved this was her allocating a number to each student and then drawing a numbered stick to decide which student was to answer the question. Controlling behavior was an exception in which students perceived Mary to be much less controlling than she did. When classroom observations were made in Mary's class, very few controlling or managing-type behaviors occurred; thus, the observations confirmed the student perceptions. The results shown in Figure 1 suggest Mary's ideal teacher would be in control, and this may account for her self-perception being higher on this scale.

These results clearly demonstrate the value of using both teacher and student versions of the TCBQ, and they could inform science teachers about their science-classroom teacher communication patterns in a very short time. In these cases both Mary and Linda found the graphed results for their classes to be a source for reflection on their teaching practice. Moreover, the study shows the pattern of response to the TCBQ is close to the classroom observations, thus providing additional validation data for the TCBQ.

Discussion

This study attempted to facilitate future research and practical applications involving the interactions that occur between teachers and their students in science classrooms by describing the application of a new instrument, the Teacher Communication Behavior Questionnaire

(TCBQ). This instrument assesses five dimensions of a science teacher's communication behaviors with their students at the secondary school level from both the students' and teacher's viewpoints. Features of the TCBQ are its consistency with the literature, its specific relevance to the science classroom environment, and its salience to science teachers and their students. Validation data provided here and elsewhere (She & Fisher, 1999, 2000) have confirmed the reliability and validity of the TCBQ for use in Taiwan and in English-speaking countries.

The TCBQ was used with a large sample of students in Taiwan, where girls perceived their teachers as more understanding and friendly than did the boys. On the other hand, the boys perceived their teachers as being more controlling than did the girls. Thus, the girls in Taiwan generally were more favorable about their teachers' communication behaviors than were the boys. These findings are supported by previous observation studies of Taiwan science classrooms (She, 1998a, 2000). She found that in the Taiwan situation, boys usually were dominant in the science classroom, and some of them became actively involved in class discussions to get the teacher's attention. This often resulted in a negative response from the teacher. On the other hand, girls usually were perceived by their teachers as being more passive learners. Therefore, the teachers were less likely to give the girls a negative response. However, the results of this study are also similar to those of previous studies in other countries showing that girls tend to perceive their learning environment more positively than do boys (Fraser et al., 1995; Fisher et al., 1997; Rawnsley & Fisher, 1997). The TCBQ has the potential for use in future studies in which the effect of the student's sex of the is a variable of interest.

Subject differences were also apparent, with teachers in the biological science classrooms exhibiting more favorable behaviors toward their students than did those in physical science classrooms. In Taiwan physical science content tends to be perceived by many students as more abstract and harder to learn than biological science (She, 1998b). Conversely, the biology content is considered more relevant to the students' daily lives. Also, biology teaching appears to have a greater variety of approaches than does physical science teaching (She, 1998b). These might be the reasons why students perceived their biological science classrooms more favorably than did the physical science students. However, more research exploring the differentiation between biology and physical science classrooms is desirable.

Strong and consistent relationships were found between students' perceptions of their teachers' communication behaviors and their attitude toward science. Simple correlation results showed that students' attitude scores were higher when students perceived that their teacher used more challenging questions, gave more encouragement and praise, showed more nonverbal support, and was more understanding and friendly. The more conservative multiple regression analysis indicated that between 8% and 17% of the measured variance in students' attitudes toward science could be attributed to their perceptions of their teachers' communicating behavior. If teachers wish to develop better attitudes in their students toward science, then they should use challenging questions, give more encouragement and praise, show nonverbal support, and be understanding and friendly. Researchers consistently have reported that students' attitudinal outcomes improve when they perceive teacher behavior as more helping, friendly, and understanding (e.g., Henderson, Fisher, & Fraser, 2000; Kim, Fisher, & Fisher, in press-a). This study has provided additional evidence that students' attitudinal outcomes are positively associated with their teachers asking challenging questions, encouraging and praising, and providing more nonverbal support.

Associations with students' cognitive achievement scores were also found and were higher when students perceived their teacher as using more challenging questions, giving more encouragement and praise, showing more nonverbal support, and being more understanding and friendly, regardless of whether the first- or second-semester science achievement scores were

used. Other research has suggested that questions are an important and integral part of learning and that questions asked by teachers may be used as indicators of the quality of teaching (Carlsen, 1991; Smith, Blakeslee, & Anderson, 1993). According to Deal and Sterling (1997) and King (1994), effective classroom questions promote relevance, encourage ownership, help students interpret their observations, link new learning to what students already know, and promote students' thinking. Our findings add specific support to the ideas that the use of challenging questions and that being more understanding and friendly could increase students' science academic-learning outcomes, particularly on challenging questions.

Fisher and Rickards (in press) and Wubbels and Levy (1993) used the Questionnaire on Teacher Interaction (QTI) with students and teachers in Australia and showed that there are differences in teachers' and students' perceptions of teacher–student interpersonal behavior and that teachers tend to perceive their classes more positively than their students. Similarly, in this study differences between the perceptions of teachers and their students were observed.

The development of both teacher and student versions of the TCBQ enhances the possibility of the use of the instrument by teachers. Using both the teacher and student versions of TCBQ provides more information about the relationships of teacher and students in science classrooms. Examination of the differences between the teacher's and students' perceptions can provide a teacher with information for reflection on the meaning of these differences and, with a careful examination of individual student responses, an understanding of the reasons for them. Unless science teachers can understand what really happens between them and their students, it is possible they will not be able to change their behavior. Using a questionnaire like the TCBQ can help identify types of teacher behavior that could be improved. Consequently, this information could help science teachers promote an atmosphere of positive interaction in their classes and could improve students' science learning and achievement.

Many studies have reported that students' interest in learning science starts to decline in junior high school (Utmost, 1980; DeBoer, 1984; Erb, 1983; She, 1995a, 1995b, 1998b), with the teacher a major influence (She, 1995a, 1995b, 1998b). According to what is now called the Vygotskian perspective, teachers play a key role in mediating and passing on existing public knowledge to their students (Vygotsky, 1978). The Vygotskian perspective uses an analytical approach to examine how students develop a new understanding or new meanings in science classrooms. This approach recognizes the importance of interactions on an interpsychological plane — in particular, the nature of teacher–student interaction in the classroom. The TCBQ with its Challenging, Encouragement and Praise, Non-Verbal Support, Understanding and Friendly, and Controlling scales provides an additional way of exploring one aspect of teacher–student interactions in science classrooms, that is, the teacher's communication behavior.

The authors thank the participating schools, teachers, and students, with special thanks to Professor Jong-Hsiang Yang, National Taiwan Normal University, and Professor Barry Fraser, Curtin University of Technology.

References

Baker, D. (1997). Equity issues in science education. In Fraser B., & Tobin K. (Eds.), International handbook of science education. Dordrecht, the Netherlands: Kluwer.

Brekelmans, M., Wubbels, T., & Levy, J. (1993). Student performance, attitudes, instructional strategies and teacher-communication style. In Wubbels T., & Levy J. (Eds.), Do you know what you look like? Interpersonal relationships in education (pp. 56–63). London: Falmer Press.

Carlsen, W.S. (1991). Questioning in classrooms: A sociolinguistic perspective. Review of Educational Research, 61, 157–178.

Cooper, H., & Good, T. (1983). Pygmalion grows up: Studies in the expectation communication process. New York: Longman.

Deal, D., & Sterling, D. (1997). Kids ask the best questions. Educational Leadership, 54, 61–63.

DeBoer, G.E. (1984). A study of gender effects in the science and mathematics course-taking behavior of a group of students who graduated from college in the late 1970s. Journal of Research in Science Teaching, 21(1), 95–105.

Erb, T.O. (1983). Career preferences of early adolescents: Age and sex differences. Journal of Early Adolescence, 3, 349–359.

Fisher, D., & Rickards, T. (in press). Teacher–student interpersonal behaviour as perceived by science teachers and their students. In Fisher D.L., & Yang J.H. (Eds.), Proceedings of the Second International Conference on Science, Mathematics and Technology Education. Perth, Australia: Curtin University of Technology.

Fisher, D., & Rickards, T. (1997, April). A way of assessing teacher–student interpersonal relationships in science classes. Paper presented at the National Science Teachers Association annual National Convention, New Orleans, LA.

Fisher, D., Henderson, D., & Fraser, B. (1995). Interpersonal behaviour in senior high school biology classes. Research in Science Education, 25, 125–133.

Fisher, D., Fraser, B., & Rickards, T. (1997, March). Gender and cultural differences in teacher–student interpersonal behaviour. Paper presented at the annual meeting of the American Educational Research Association, Chicago.

Fisher, D., Rickards, T., Goh, S., & Wong, A. (1997). Perceptions of interpersonal teacher behaviour in secondary science classrooms: Comparisons between Australia and Singapore. In Fisher D., & Rickards T. (Eds.), Science, mathematics and technology education and national development. Proceedings of the International Conference on Science, Mathematics and Technology Education, Hanoi, Vietnam, (pp. 136–143). Perth: Curtin University of Technology.

Fisher, D., Harrison, A., Henderson, D., & Hofstein, A. (1998). Laboratory learning environments and practical tasks in senior secondary science classes. Research in Science Education, 28(3), 353–363.

Fraser, B.J. (1981). Test of Science-Related Attitudes (TOSRA). Melbourne, Australia: Australian Council for Educational Research.

Fraser, B.J. (1994). Research on classroom and school climate. In Gabel D. (Ed.), Handbook of research on science teaching and learning (pp. 493–541). New York: Macmillan.

Fraser, B.J. (1998a). Science learning environments: Assessment, effects and determinants. In Fraser B.J., & Tobin K.G. (Eds.), The international handbook of science education (pp. 527–564). Dordrecht, The Netherlands: Kluwer.

Fraser, B.J., (1998b). Classroom environment instruments: development, validity and applications. Learning Environments Research, 1, 7–33.

Fraser, B.J., & Walberg, H.J. (Eds.). (1991). Educational environments: Evaluation, antecedents and consequences. Oxford, England: Pergamon Press.

Fraser, B.J., Giddings, G.J., & McRobbie, C.R. (1995). Evolution and validation of a personal form of an instrument for assessing science laboratory classroom environments. Journal of Research in Science Teaching, 32, 399–422.

Gardner, P., & Gauld, C. (1990). Labwork and students' attitudes. In Hegarty-Hazel E. (Ed.), The student laboratory and the science curriculum (pp. 132–156). London: Routledge.

Good, T., & Brophy, J. (1974). Teacher–student relationships: Causes and consequences. New York: Holt.

Good, T., & Brophy, J. (1991). Looking in classrooms (5th ed.) New York: Harper Collins.

Haertel, G.D., Walberg, H.J., & Haertel, E.H. (1981). Socio-psychological environments and learning: A quantitative synthesis. British Educational Research Journal, 7, 27–36.

Henderson, D., Fisher, D., & Fraser, B. (2000). Interpersonal behavior, learning environments and student outcomes in senior biology classes. Journal of Research in Science Teaching, 37, 26–43.

Hough, L.W., & Piper, M.K. (1982). The relationship between attitudes toward science and science achievement. Journal of Research in Science Teaching, 19, 33–38.

Kim, H., Fisher, D., & Fraser, B. (in press-a). Classroom environment and teacher interpersonal behaviour in secondary science classes in Korea. Evaluation and Research in Education.

Kim, H., Fisher, D., & Fraser, B. (in press-b). Assessment and investigation of constructivist science learning environments in Korea. Research in Science and Technological Education.

King, A. (1994). Guiding knowledge construction in the classroom: Effects of teaching children how to question and how to explain. American Educational Research Journal, 31, 338–368.

Lawrenz, F. (1987). Gender effects for student perception of the classroom psychosocial environment. Journal of Research in Science Teaching, 24(8), 689–697.

Mathews, J.C. (1974). The assessment of attitudes. In Macintosh H.G. (Ed.), Techniques and problems of assessment (pp. 172–185). London: Arnold.

Parker, L., Rennie, L., & Fraser, B. (Eds.). (1996). Gender, science and mathematics: Shortening the shadow. Dordrecht, The Netherlands: Kluwer.

Rawnsley, D., & Fisher, D. (1997). Teacher–student relationships: Do they affect student outcomes? EQ Australia, 3, 34–35.

Rosenshine, B. (1971). Teaching behaviors and student achievement. Windsor, Berkshire, England: National Foundation for Educational Research in England and Wales.

She, H.C. (1995a). Elementary and middle school students' image of science and scientists related to current science textbooks in Taiwan. Journal of Science Education and Technology, 4(4), 283–294.

She, H.C. (1995b). Elementary and middle school students' perception of science, scientists, and their work. Proceedings of the National Science Council, Part D: Mathematics, Science, and Technology Education, 5(1), 19–28.

She, H.C. (1998a). Interaction between different gender students and their teacher in junior high school biology classes. Proceedings of the National Science Council, part D: Mathematics, Science, and Technology Education, 8, 16–21.

She, H.C. (1998b). The development and validation of the teacher–student interaction questionnaire in the secondary science classroom learning environment. Chinese Journal of Science Education, 6(4), 403–416.

She, H.C. (1999). Students' knowledge construction in small groups in the seventh grade biology laboratory: Verbal communication and physical engagement. International Journal of Science Education, 21(10), 1051–1066.

She, H.C. (2000). The interplay of a biology teacher's beliefs, teaching practices and gender-based student–teacher classroom interaction. Educational Research, 42(1), 28–39.

She, H.C. (2001). Different gender students' participation in the high- and low-achieving middle school questioning-oriented biology classrooms in Taiwan. Research in Science & Technological Education, 19(2), 147–158.

She, H.C., & Barrow, L.H. (1997). Gifted elementary students' interactions with female and male scientists in a biochemistry enrichment program. Journal of Elementary Science Education, 9(2), 45–66.

She, H.C., & Fisher, D. (1999, April). The validation and use of the TCBQ in studying secondary science classroom interaction and its association with students' attitudinal and cognitive outcomes in Taiwan. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Boston.

She, H., & Fisher, D. (2000). The development of a questionnaire to describe science teacher communication behavior in Taiwan and Australia. Science Education, 84, 706–726.

Shulman, L.S., & Tamir, P. (1972). Research on teaching in the natural sciences. In Travers R.M.W. (Ed.), Second handbook of research on teaching (pp. 1098–1148). Chicago: Rand McNally.

Smith, E.L., Blakeslee, T.D., & Anderson, C.W. (1993). Teaching strategies associated with conceptual change learning in science. Journal of Research in Science Teaching, 20, 111–126.

Stodolsky, S. (1984). Teacher evaluation: The limits of looking. Educational Researcher, 13, 11–18.

Utmost, M.E. (1980). Occupational sex-role liberality of third-, fifth-, and seventh-grade females. Sex Roles, 6(4), 611–617.

van Tartwijk, J. (1993). Sketches of teacher behavior (in Dutch). Docentgedrag in beeld. Utrecht, The Netherlands: W.C.C.

Vygotsky, L.S. (1978). Mind in society: The development of higher psychological processes. Cambridge, MA: Harvard University Press.

Walberg, H.J. (1984). Improving the productivity of American schools. Educational Leadership, 41, 19–27.

Walberg, H.J., & Haertel, G.D. (1980). Validity and use of educational environment assessments. Studies in Educational Evaluation, 6, 225–238.

Watzlawick, P., Beavin, J., & Jackson, D. (1967). The pragmatics of human communication. New York: Norton.

Weinburgh, M. (1995). Sex 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.

Wubbels, T., & Levy, J. (Eds.). (1993). Do you know what you look like? Interpersonal relationships in education. London: Falmer Press.

Wubbels, T., Créton, H.A., & Holvast, A.J. (1988). Undesirable classroom situations. Interchange, 19(2), 25–40.

Wubbels, T., Brekelmans, M., & Hooymayers, H.P. (1991). Interpersonal teacher behavior in the classroom. In Fraser B.J., & Walberg H.J. (Eds.), Educational environments: Antecedents, consequences and evaluation (pp. 141–160). Oxford, England: Pergamon Press.

Wubbels, T., Créton, H.A., & Hooymayers, H.P. (1992). Review of research on teacher communication styles with use of the Leary model. Journal of Classroom Interaction, 27, 1–12.

Young, D., & Fraser, B. (1994). A multilevel model of sex differences in science achievement: The Australian Second International Science Study. Journal of Research in Science Teaching, 31, 857–871.