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Students' knowledge construction in small groups in the seventh grade biology laboratory: Verbal communication and physical engagement

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RESEARCH REPORT

Students' knowledge construction in small groups in the seventh grade biology laboratory: Verbal communication and physical engagement

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Same- and mixed-gender small groups of middle school, seventh grade, students were observed gathering data on knowledge construction in terms of verbal communication and physical engagement in the biology laboratory. Video cameras with wireless receivers were used to record interactions between students in groups of four (36 target subjects in total). Both quantitative and qualitative methods were employed to examine how students exchange ideas, construct scientific concepts and perform laboratory work during laboratory sessions. Results indicated that gender differences exist in several verbal communication and physical engagement behaviour measures regardless of the same-gender or mixed-gender groups. However, one or two students in either all-boy or all-girl groups were dominant in their small groups' verbal communication and physical engagement, which suggested that individual differences also existed in the same-gender groups. It also showed girls working in the mixed-gender groups appeared to participate on a par with boys in the majority of engagement and verbal communication behaviours. However, more detailed analysis revealed that verbal communication and physical engagement patterns varied widely within the three mixed-gender groups. This study strongly suggested that girls have the potential to perform equally well as boys in the science laboratory and both individual and gender differences contribute to the students' differential verbal communication and laboratory engagement.

Introduction

Science laboratory activities play a unique role in science education since they are one of the few subject areas where students experience or observe physical examples of science concepts. According to Kempa and Ward (1975), laboratory projects encompass four broad activity phases: planning and design, performance, analysis and interpretation of results, and application. A large body of research exists suggesting that meaningful learning occurs in science laboratory classes when students are allowed to manipulate equipment and materials while working cooperatively in an environment where they feel free to tackle problems which interest them (Tobin 1990: 414). Lane (1993) argues that the cognitive goals of science laboratory work include promoting intellectual development, enhancing the learning of scientific concepts, developing problem-solving skills, developing creative thinking, and understanding science methodology. In addition, there are two practical goals involved in laboratory work: the development of investigative science skills in a cooperative setting, and providing a setting in which students can develop a deeper interest in science and perhaps consider it as a career choice (Collette and Chiapetta 1989).

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Solomon (1987) and Latour and Woolgar (1986) have suggested that the social construction of scientific knowledge entails a process of negotiation and consensus building, one which requires scientists or students to share, discuss and reach agreement on ideas. Solomon further points out that students socially construct context-dependent knowledge rather than general science theory. Hurd (1964) has mentioned that laboratory activities can provide students with concrete learning opportunities for investigating new ideas and understanding the results of experiments in light of generally accepted scientific concepts. In Lane's (1993) words, students in laboratory classes can learn how to construct meaningful knowledge, how to exchange personal ideas, and how to think collectively and reach consensus.

In the present study, how students verbally communicate ideas with partners in small groups was studied in the context of five domains: problem initiation, problem solving, reaching consensus, verification, and results reporting. Problem initiation and problem solving allow students to exchange information and manage group functioning; students with conflicting answers may agree on a single answer through reaching consensus and verification before reporting their results. Several researchers have attempted to show that providing (and, in some cases, receiving) explanations is positively linked to achievement (Peterson *et al*. 1981; Webb and Kenderski 1985); in addition, verbal conflict has been identified as a cognitive process directly affecting academic performance in learning groups (Wilkinson and Subkoviak 1985). Johnson and Johnson (1979) described a process in which incompatible opinions generate conceptual conflict among students, thus encouraging adversaries to find information in support of their positions, which leads to increased learning.

Many studies on gender-related differences in classrooms interaction state that boys receive more attention than girls from science teachers, e.g. they are given more opportunities to answer questions, given more freedom to call out answers, and receive more opportunities for teacher feedback (Greenfield 1997, Jones and Wheatley 1990, Sadker and Sadker 1994, She 1998, Tobin 1990). Jones and Wheatley (1989) have also noted that boys manipulate scientific instruments and give demonstrations more often than girls in laboratory settings, and She and Barrow (1997) have observed that gifted boys are most likely to use instruments and do experiments while their female laboratory partners either watch passively or talk about the experiment with other group members.

The current work extended the previous classroom interaction studies (She and Barrow 1997, She 1998, She in press) to a new setting: the seventh grade biology laboratory classroom. Several unique aspects were examined in the study. First, it focuses on learning in different gender composition (all-male all-female and mixed) small-groups in the middle school biology laboratory. Second, it emphasizes both of the students's verbal communication and laboratory physical engagement. It also provides a detailed account of the flow of verbal communication of students in different gender composition groups during their small group work from the viewpoint of the social construction of scientific knowledge.

Research questions

The present study has as its focus verbal communication and physical engagement within middle school biology laboratory groups having different gender compositions - all male, all female, and mixed. The first set of research questions explores the verbal communication and physical engagement behaviour of students in different gender composition groups. Do students participate equally in the different gender composition groups? Do students communicate with their partners equally in the different gender composition groups? It was hoped through quantitative analysis to be able to identify gender-based differences among same- and mixed-gender groups in terms of physical engagement and verbal communication - problem initiation, problem solving, verification, reaching consensus, and reporting results.

The second set of questions focused on the construction of scientific knowledge among different gender composition groups of students in the biology laboratory. How and what do they communicate with each other? What do they say in their small group? What questions do they initiate? Who initiates questions? Who provides a solution to partner's questions and what types of solution do they provide? How do they negotiate ideas, reach consensus, verify, and report the results? Therefore, this study used qualitative analysis of different gender composition groups' work to help explain the patterns that emerge from the substance and flow of the students' communication in the different gender composition groups (all-male, all-female, mixed).

Methods

The subjects

Three seventh grade classes (about 128 students) in a middle school located in northern Taiwan were involved in this study. Group composition was determined according to the willingness of students to work with partners of either the same or opposite sex. The researcher randomly selected a group of four boys, a group of four girls, a group of two boys and two girls from each individual class as target subjects. A total of 36 target students (18 boys, 18 girls) were examined carefully for their small group verbal communication and laboratory physical engagement during their laboratory work. Academic performance levels in all groups were determined as being average, with the exception of two boys in the excerpt C who were below average. One of the boys (B2) was more aggressive and dominant in most of the verbal communication and physical engagement, and the other boy (B1) usually did what B2 asks him to do.

Instruments and procedures

Observations of 100-minute laboratory sessions were made once per week for a full semester (five and half months) for each individual class. Student-student interactions in nine target groups were recorded with three video cameras equipped with wireless receivers. In order to explore the student-student interaction of different gender composition groups during their small group work and students' understanding of biology, both quantitative and qualitative analysis methods were employed in this study.

For the quantitative analysis, two coding systems were specifically designed for the systematic analysis of student-student interactions: the Laboratory

Physical Engagement Schedule (LPES) and Laboratory Verbal Communication Schedule (LVCS). Two coding systems were developed based upon the Small Group Coding Schedule (She and Barrow 1997), Rennies Activity Based Schedule (Rennie 1985) and Brophy-Good Dyadic Interaction system (Good and Brophy 1991). These two coding systems were piloted for a semester, and the percentage of agreement of code/re-code reliability was 0.83. The LPES was designed to quantify physical activity: for example, manipulating instruments, preparing an experiment, performing an experiment, recording results, reading associated material, attentively watching partners perform an experiment, attentively observing partner's discussion, observing an experiment, and not participating. The LVCS was developed to measure verbal behaviour in the following categories: problem initiation, problem solving, reaching consensus, verification, and reporting results. Problem initiation was categorized according to the level of complexity: process questions require an integration of prior knowledge, procedure questions require a description of how to approach a task, factual questions require brief factual answers, and request for input. Problem solving was categorized into six items: provide an answer, provide suggestion, provide direction how to approach problem, verbally describe what has been done, request others to perform laboratory tasks, and guide partner. Reaching consensus were further categorized into six items: accept other's idea, disagree with other's idea, argue, question partner's ideas/work, confirm data, and discuss an approach. Verification included three items: correct partner ideas/work, check textbook to make sure they are right, and remind partner to perform some task. Results reporting was categorized into five items: describe results/changes, discuss results/changes, question results, discuss how and what to report, tell partner what they should report.

After completing the classroom observation data collection, all the videotapes from the nine target groups student-student interaction for a semester were transcribed (a total of 63×100 minutes of videotape). A transcript of verbal interactions with detailed notes on non-verbal behaviour was created from the videotapes; all the 63 videotape transcripts were coded according to the LPES and LVCS coding systems. To ensure coding accuracy, a single, experienced observer was responsible for all coding data, which were analysed using the SAS statistical package. Individual students were identified by number. Mean frequencies of student-student interactions were calculated to represent average frequency per 100-minute laboratory period. Individual experience within each group was not considered independent of the behaviour of other group members; therefore, to account for intra-group dependence, standard deviations were calculated in addition to mean frequencies to reflect individual differences.

In addition to the quantitative analyses described above, the researcher analysed the verbal interaction transcripts in order to identify patterns which emerge from the substance and flow of students' learning and construction of science knowledge in the laboratory in different gender composition groups. In order to provide insight into how groups of different gender composition communicate with their partners, four groups of students were selected to represent boy-only, girl-only and mixed groups students' learning the laboratory work, respectively.

Results: Same-gender groups students interaction

Quantative analysis

The data of mean frequencies of physical engagement for same-gender groups, from the Laboratory Physical Engagement Schedule, are presented in table 1. Significant differences included the following:

- Girls in girl-only groups recorded experimental results more frequently than boys did in boy-only groups.
- Girls in girl-only groups read materials more frequently than boys did in boy-only groups.
- Boys in boy-only groups observed experiments more frequently than girls did in girl-only groups.

Table 2 presents verbal discussion mean frequencies for students working in same-gender laboratory groups. Significant differences included the following:

- Girls in girl-only groups initiated factual questions more often than boys did in boy-only groups.
- Girls in girl-only groups checked the textbook to make sure they did the experiment correctly more frequently than boys did in boy-only groups.
- Boys in boy-only groups corrected partner's ideas/work more often than girls did in girl-only groups.

In short, the results presented in table 3 show that, in same-gender groups, girls interacted more than boys on problem initiation, problem solving, and reaching consensus, but less on verification and reporting results. The difference in the category of problem initiation was found to be statistically significant ($F = 2.98$, $p = 0.1$), which implies that girls were more likely to ask for help.

Qualitative analysis

In order to examine how individual students within same-gender groups communicate with their partners, the qualitative analysis of the excerpts are presented. Examples of verbal interaction among groups of different gender composition are presented in the following transcript excerpt from a laboratory session on fish respiration. The primary objectives of this lab work were to help students understand the importance of control and experimental groups, as well as to understand the reasons for the change of colour in BTB (bromothymol blue). The following groups A (female-group) and B (male-group) were one of the typical same-sex groups observed for this study.

A case of all-girls group student-student interaction

Excerpt A (Group A): All-girl group (G: girl)

1 G1: You (points to G4) must go put some water into this bottle. You need to add water to this line (marks a line on the bottle)
2 G2: Do we need to put a cap on it?
3 G1: (caps bottle) I know why we need to cap the bottle.
4 G3: Why isn't it turning blue?
5 G2: Just wait a minute, it will change.
. . .

Table 1. Mean, standard deviation, and F test of male and female students' physical engagement items within their same-gender and mixed-gender groups.

	Same-gender groups							*Mixed-gender groups*						
	Female			*Male*				*Female*			*Male*			
Variable	*N*	*Mean*	*SD*	*N*	*Mean*	*SD*	*F*	*N*	*Mean*	*SD*	*N*	*Mean*	*SD*	*F*
Manipulate instrument/ do experiments	12	5.15	3.42	12	6.69	3.71	1.12	6	5.52	2.49	6	4.05	2.17	1.20
Record data/results	12	7.29	2.37	12	4.52	2.21	8.87*	6	5.85	0.97	6	4.79	1.18	2.86
Watch partner doing experiment	12	3.36	2.58	12	3.02	2.70	0.10	6	1.61	1.66	6	3.41	3.91	1.08
Non-participation	12	1.28	1.25	12	2.75	2.99	2.48	6	0.78	0.98	6	4.14	2.12	12.43**
Read materials	12	1.76	1.29	12	0.76	0.77	5.31*	6	1.62	0.63	6	0.70	0.70	5.74*
Prepare materials	12	2.19	1.32	12	2.69	2.19	0.46	6	2.10	1.07	6	1.75	1.36	0.24
Watch partner's discussion	12	0.29	0.54	12	0.17	0.30	0.45	6	0.06	0.14	6	0.20	0.23	1.67
Observe experiment	12	0.64	0.27	12	0.87	0.32	3.56*	6	0.32	0.42	6	0.33	0.41	0.00

Notes: $p*** < 0.01, p** < 0.05, p* < 0.1$

Table 2. Mean, standard deviation, and F test of male and female students' verbal communication items within their same-gender and mixed-gender groups.

	Same-gender groups							*Mixed-gender groups*						
	Female			*Male*				*Female*			*Male*			
Variable	*N*	*Mean*	*SD*	*N*	*Mean*	*SD*	*F*	*N*	*Mean*	*SD*	*N*	*Mean*	*SD*	*F*
Problem initiation														
process question	12	0.20	0.26	12	0.08	0.16	1.81	6	0.17	0.28	6	0.16	0.27	0.00
procedure question	12	0.38	0.48	12	0.50	0.48	0.36	6	1.49	0.30	6	1.22	1.07	0.35
factual question	12	1.84	1.20	12	0.94	0.71	5.02*	6	1.49	0.30	6	1.22	1.07	0.35
request input	12	0.93	0.61	12	0.63	0.62	1.47	6	0.44	0.46	6	0.14	0.20	2.12
Problem solving														
provide answer	12	2.27	2.40	12	1.69	1.07	0.60	6	2.40	1.57	6	1.23	0.85	2.58
provide suggestion	12	0.42	0.51	12	0.25	0.38	0.84	6	0.14	0.16	6	0.17	0.41	0.02
provide direction	12	2.29	1.92	12	1.99	1.11	0.22	6	3.25	3.23	6	1.84	1.43	0.95
request others to perform tasks	12	0.78	0.70	12	1.17	0.87	1.48	6	0.42	0.42	6	0.63	0.87	0.27
verbally describe what has been done	12	0.30	0.26	12	0.61	0.77	1.73	6	0.11	0.20	6	0.19	0.22	0.43
guide partner	12	0.29	0.45	12	0.28	0.29	0.00	6	0.13	0.15	6	0.17	0.28	0.08
Reaching consensus														
accept other's idea	12	0.14	0.13	12	0.16	0.18	0.14	6	0.10	0.16	6	0.07	0.17	0.11
disagree with other's idea	12	0.37	0.36	12	0.36	0.32	0.01	6	0.35	0.07	6	0.22	0.25	1.46
argue	12	0.20	0.22	12	0.24	0.25	0.14	6	0.21	0.18	6	0.07	0.17	1.80
question partner's ideas/work	12	1.10	0.66	12	0.99	0.80	0.12	6	1.09	0.42	6	0.66	0.63	1.93
confirm idea	12	0.45	0.41	12	0.24	0.25	2.39	6	0.27	0.27	6	0.11	0.14	1.65
discuss an approach	12	0.19	0.37	12	0.14	0.22	0.13	6	0.28	0.44	6	0.39	0.61	0.13
Verification														
remind partner to perform some task	12	0.52	0.48	12	0.65	0.57	0.38	6	0.52	0.46	6	0.58	0.72	0.03
correct partner's ideas/work	12	0.57	0.57	12	1.14	0.77	4.29*	6	0.29	0.26	6	0.24	0.28	0.13
check textbook	12	0.24	0.30	12	0.08	0.12	2.87*	6	0.08	0.12	6	0.06	0.14	0.07
Results reporting														
describe results/changes	12	1.93	1.37	12	2.24	1.17	0.36	6	1.39	0.80	6	1.03	0.75	0.65
discuss results/changes	12	0.39	0.59	12	0.26	0.21	0.53	6	0.06	0.14	6	0.00	-	1.00
question results	12	0.25	0.32	12	0.48	0.50	1.77	6	0.16	0.27	6	0.16	0.17	0.00
discuss how and what to report	12	0.08	0.12	12	0.06	0.15	0.00	6	0.00	-	6	0.13	0.20	2.44
tell what should be reported	12	0.22	0.32	12	0.12	0.21	0.73	6	0.17	0.41	6	0.21	0.27	0.06

Notes: $p^* < 0.1$ $p^{**} < 0.05$.

Table 3. Mean, standard deviation and F test of male and female students' verbal communication categories within their same-gender and mixed-gender groups.

	Same-gender groups							*Mixed-gender groups*						
	Female			*Male*				*Female*			*Male*			
Variable	*N*	*Mean*	*SD*	*N*	*Mean*	*SD*	*F*	*N*	*Mean*	*SD*	*N*	*Mean*	*SD*	*F*
Problem initiation	12	3.35	2.02	12	2.14	1.33	2.98*	6	2.79	0.74	6	1.86	1.59	1.70
Problem solving	12	6.47	5.16	12	6.03	3.13	0.06	6	6.61	4.43	6	4.21	2.74	1.27
Reaching consensus	12	2.45	1.21	12	2.18	1.06	0.45	6	2.31	1.16	6	1.53	0.94	1.64
Verification	12	1.32	0.94	12	1.87	1.14	1.65	6	0.89	0.66	6	0.87	0.78	0.00
Results reporting	12	2.86	1.62	12	3.18	1.50	0.24	6	1.77	1.19	6	1.53	0.68	0.18

Note: $p^* < 0.1$.

6 G4: What gets into the blood?
7 G1: The oxygen which is inhaled. (looks at bottle) The colour has changed.
8 G2: What colour is it?
9 G1: It's supposed to be yellow! Do we have white paper? (puts paper underneath the bottle) Bottle A does have a little bit of yellow colour.
. . .
10 G4: What is the purpose of having Bottle B?
11 G2: Which is the control? This one? This is the experimental group, the other is the control group. Are we doing the experiment?
12 G1: Yes.
13 G2: This is the control group!
14 G1: But our teacher will ask us about scientific method!
15 G2: This is the experiment, this is the experimental group, and this is the control group. I think that's it.
16 G2: It is the control group for the experiment.

In this group, G1 appears to be the only one who knows how to set up and perform the experiment; her actions and commands are therefore more systematic, as shown by the way she tells her lab partners what to do and how she gives solutions to problems raised by her partners. G2 occasionally provided answers and directions. G1 and G2 tended to be more dominant within their group than G3 and G4. The study found that girls in the all-girls group spent much more time on discussing the proper procedure and correct results for the experiment than scientific concepts. The only science concept they discussed was to identify the control and experiment group.

A case of all-boys group student-student interaction

Excerpt B (Group B): all-boy group (B: boy; T: teacher; BTB: bromothymol blue)

1 B1: (to teacher) Is it only CO_2?
T: Look at last week's notes. What colour should the BTB be?
2 B1: No! Even if you use the cap, it will still change to yellow, won't it? If you open the cap, then the air likes CO_2, or H_2O, or H_2CO_3 . . . the last time, the teacher said H_2CO_3 will make BTB change colour, so if you do open the cap then it might change colour because the air comes in with CO_2 or H_2O or H_2CO_3.
4 B1: I know, the fish will release H_2CO_3.
. . .
5 B2: What if it changes to yellow?
6 B3: Stop blowing air and see if there are any changes.
7 B1: Not yet! (B1 now blows air)
8 B3: It's changing!
9 B1: Yes! It's changing to yellow!
10 B3: Why do we need to add a cap?
11 B1: We don't want water vapour or carbon dioxide to get into the bottle . . . and to make it change colour. The water will react with . . .
12 B3: Because what?
13 B1: Because water vapour and carbon dioxide will become H_2CO_3.

B1 took a position of authority in the group based on his clear explanation of fish respiration and BTB colour change; he was thereafter expected to provide answers and direction for his partners. The majority of questions were asked by B2 and B3, who also provided descriptions of the experiment. This group had one student (B4) who did not participate in group discussions; he was frequently uninvolved in the work (talking to students in other group) or passively watching his partners work. In addition to the communication about proper procedure and product of the experiment, boys also spent time discussing science concepts about what would happen in the bottle with BTB (bromothymol blue) and fishes and why the BTB solution would change colour.

This excerpt underscores the point that same-sex groups are similar in that individuals play certain roles whether the composition is all-boys or all-girls. Some students are more controlling and thus dominate verbal and physical behaviour, while others remain dependent on their partners to provide information, answers and suggestion.

Results: Mixed-gender groups students interaction

Quantitative analysis

Table 1 also contains mean frequencies for mixed-gender students' physical engagement items. Significant differences included the following:

- Boys participated less than girls while they were in the mixed groups.
- Girls did more reading of materials than boys while they were in the mixed groups.

As shown in table 2, mean frequency measurements of boy-girl verbal communication within mixed-gender groups indicate girls had slightly more interaction in the majority of the items of verbal communication. However, none of the items reached statistic significant difference. In addition, girls working in mixed-gender groups had more verbal communication than boys did in all domains (table 3).

Qualitative analysis

The classroom observation data indicated that wide varied patterns of verbal discussion were observed across mixed-gender groups. In one group (group C), boys were more controlling than girls; they interacted more in the domains of problem solving, verification, and reporting results. Girls did more on problem initiation and reaching consensus. In the other two groups (both represented in excerpt D), girls were more dominant in problem initiation, problem solving, reaching consensus and reporting results; only in problem solving did the differences reach a statistically significant level. Therefore, transcript excerpts from two different mixed-gender groups will be presented in this section.

Excerpt C (Group C): mixed-gender group (B: boy; G: girl; BTB: bromothymol blue)

1 G1: Did you add the fish?
2 B2: He's doing it.
3 G2: Did you put a fish in this bottle?

4 B2: He said he added a fish in one, but not the other.
5 B2: You add the BTB.
6 B1: (brings two bottles containing fish and BTB)
. . .
7 G1: Neither one of the bottles has changed colour.
8 G2: (puts paper behind bottle) This bottle with fish did change to yellow.
9 B2: (blows air into the bottle containing fish)
10 B1: What are you doing?
11 B2: Making a faster reaction.
12 B1: Let me do it. (blows air into same bottle)
. . .
13 B1: Get a straw! (he finally gets a straw himself)
14 B2: Let me blow it.
15 G2: Let me blow into the one with the fish.
16 B2: The teacher said you should only blow air into this one, not that one.
17 B2: Let me blow into it. I want to blow into it!
18 G1: The colour is changing!
19 G2: They both changed to yellow.
20 B2: (speaks to other boy) You go clean the bottle.
21 B1: (goes to clean bottle)
22 G1: Why do we need to cap the bottle?
23 B2: Because otherwise the CO_2 will escape.

G1 and G2 used questions to check that their male partners did the experiment correctly; B2 tends to use commands in order to get B1 to perform tasks such as rinsing out one of the bottles. B1's and B2's academic achievements were the only two below average in this study, however, they appear to have taken the majority of responsibility for performing the experiment, and focused their attention on discussing the set-up. B2 in particular was more aggressive and controlling within their group. Only one question related to the science concepts was initiated by G1 and answered by B2. This was not the case, however, with the other two mixed-gender groups, as seen in the following excerpt D.

Excerpt D: mixed-gender group (B = boy, G = girl)
1 B1: Why do we need a control group?
2 G1: Because this bottle contains fish, and the other one doesn't.
3 B1: Oh.
(B2 and G2 write on their handouts and do not participate in the discussion.)
4 B1: (observes students in other groups) Aren't you supposed to blow air into the bottle?
5 G2: No! We don't need to do it. Ours has already changed colour.
6 B1: Is it changing?
7 G1: (observing other group) Theirs is changing more. It has almost changed into blue water.

This brief excerpt was presented to show that one boy actively participated in verbal communication with his two female partners, and that those two girls took turns responding to his questions or initiating discussion. The second male student did not participate at all. This constitutes one of two major interaction patterns observed within the mixed-gender groups. Both of the excerpts described above indicated that the discussions of science concepts appear to happen rarely in the mixed-gender small group work. In addition, it also demonstrated that the role of boys and girls within these two mixed-gender groups varied from group to group.

Discussion

Same-gender groups students' interaction

Girls in all-girl groups spent more time recording results and reading associated materials than boys in all-boy groups, boys in all-boy groups spent more time observing experiments than girls in same-sex groups, and all three items reached statistically significant difference levels. Similar studies have reported that girls tend to do more recording results than boys (She and Barrow 1997). The female student subjects in same-sex groups were more likely to initiate questions, which was found to be at a statistically difference level in comparison with all-boy groups. The item of factual question in particular also reached statistical significant difference level ($p < 0.1$). This result implies that girls are more likely to ask for help from their partners when necessary. In addition, girls in all-girls groups were more likely to check textbooks to make sure they were doing it correctly; and boys in all-boy groups did more correction of their partners ideas/work; and both of them reached significant difference level. The possible explanation for these differences were offered by Baird (1976), who argued that girls are not as interested as boys in problem solving, and therefore tend to ask more questions when they meet obstacles. He further described boys as receiving encouragement to be independent, aggressive, problem oriented, and willing to take risks in social interactions, whereas he describes girls as being more emotional, more sensitive to non-verbal indicators, less interested in problem solving, and unwilling to take risks.

In addition, the observation that each same-gender group had one or two students taking the lead in manipulating instruments/performing experiments and providing problem solution does not have any support in the previous literature. It does, however, point to the importance of individual students' characteristics and/or social status in determining physical engagement behaviour and verbal communication patterns.

Mixed-gender group students' interaction

In mixed-gender groups, girls were more active than boys in reading material; this item reached statistical significant difference. Boys spent more time than girls not participating while they were in the mixed-gender groups and this was also found to have statistical significance. These results were different to those of Eccles and Blumenfield (1985), for they reported that boys and girls did not differ in the frequency of non-participation and participation. Our findings also indicated that girls had slightly more verbal communication on the majority of the categories and items (tables 2 and 3), however, no statistical significant differences were found. These findings differ from a number of studies examining mixed-gender groups working on collaborative tasks - most of them showing boys as being dominant (see Lockheed 1985 for a review of this research). No previous explanation seems to have been offered which can explain why girls were more likely to dominate or engage equally in the laboratory activity. However, our qualitative results might provide possible explanations which are described as follows.

Large variations were observed in verbal-communication patterns among mixed-gender groups. In one, girls initiated more questions than boys, and boys provided more solutions to problems raised by their laboratory partners - even though two of the boys were considered to be below average in terms of academic achievement. These observations support the idea that girls are more likely to search or ask for help and that boys are more likely to provide help or solutions to problems - confirming Baird's (1976) description of boys. That description does not hold true, however, for the other two mixed-gender groups, where girls were either equally or more involved in discussions than boys.

There are several possible explanations for these observations. First, it may be that these girls are typical of a younger generation of girls who are being encouraged to be more aggressive and independent. Second, certain boys were occasionally excused or otherwise absent from laboratory classes; the remaining boys may have been much more passive, therefore skewing frequencies on the measurement instruments used in this study. Third, students at this age are less likely to talk to students of the opposite sex. This is supported by Lockheed's (1985) study when he noted the self-imposed gender segregation which is widespread among elementary and junior high school students.

Gender and individual characteristic effects

Upon closer analysis of quantitative (tables 1, 2 and 3) and qualitative results (excerpts A and B), differences between boy-boy and girl-girl interaction become clearer. In general, boys did more manipulating instrument/doing experiments, and girls did more recording results/data and reading material (table 1). This supports Jones and Wheatley's (1989) findings that gender difference existed in the physical engagement behaviour of same-gender groups students. According to the results of the same-gender groups students' verbal communication (tables 2, 3), girls did more problem initiation than boys, and boys did more verification than girls. This confirms excerpts A and B that male students in this study were more likely to ask or give orders to others to do things, while the girls spent more time asking questions, especially concerning experimental set-up and procedures. In same-sex groups, boys tend to ask their teacher questions when problems arise rather than ask their laboratory partners. On the other hand, girls working in same-sex groups were more likely to ask their laboratory partners questions when they have problems. Again, these results imply that gender difference exists in the same-gender groups' verbal communication. In addition, excerpts A and B also indicate that there are one or two students within the same-gender groups more dominant than others, regardless of whether it is an all-male or all-female group, which further suggested that individual difference also exists within same-gender groups.

The effect of gender difference is less clear in the mixed-gender groups. Tables 1, 2 and 3 show that females in the mixed-gender groups did slightly more manipulating instrument/doing experiments, recording data-results, problem initiation, problem solving, reaching consensus and result reporting than boys, but none of these categories or items reach the statistical significant difference level. Excerpts C and D might help explain why boys and girls did not differ much on most of the interaction measures. It is because in one mixed-gender group, the two boys whose academic score was below average (one in particular, B2) were clearly more controlling (verbal communication plus physical engagement) than the two girls, but the opposite was true in the two other mixed-gender groups. It is difficult to ascertain whether this is the result of differences in individual characteristics, or some other factor that has a mitigating effect on gender.

Wilkinson and Subkoviak (1985) argued that request and response sequences and dissension episodes which occur in small groups are influenced by the social characteristics of group members, including gender. Any speech event (i.e. request or dissension) initiated by a group member influences other group members' speech events. Therefore, every group creates its own sociolinguistic context based on the observations of its members' speech. In the present study, it appears that a combination of gender differences and differences in the individual students' characteristics (including social status) were the primary factors in the creation of the laboratory groups' social context. As confirmed by Jones and Wheatley (1989) and She and Barrow (1997), individual characteristics appear to be more crucial in same-sex groups.

Scientific concepts construction

Excerpts A, B, C and D indicated that students rarely discuss science concepts with their partners during their laboratory work. Instead they frequently give priority in the discussion of experimental set-ups, procedures, how to perform the experiment and achieving the correct results. A possible explanation might be that the teacher provided students with experimental procedures without giving them details of experiment set-ups, therefore, students spent a lot of time discussing this in order to make sure they did it right. In addition, the teacher requested students to hand in the report after finishing their experiment, so the limited time might be the other reason why students focus on discussing the experiment results/changes, how to make colour changes, and what they should report.

Conclusion

This article shows that both gender differences and individual characteristics were the factors contributing to the same-gender and mixed-gender groups students' interaction in the biology laboratory. Several suggestions for teachers and schools, based upon the study findings, are put forward. First, increase awareness on the part of teachers when placing individual students into same- or mixed-sex groups based on their understanding and knowledge of individual student characteristics, e.g. avoid placing aggressive boys with passive girls or vice versa, regroup students as necessary, or regroup students every five or six weeks to allow students to work with different partners. Second, increase the teachers' awareness of gender differences, the willingness to provide equal opportunities for participation to both boys and girls, and an understanding that both boys and girls have the potential to perform equally well in the science classroom or laboratory.

Finally, this study also highlights the need to restructure the laboratory experiment. According to this study, it shows that students were involved more in the processing of procedural knowledge instead of declarative knowledge during the biology laboratory work. Both procedural and declarative knowledge are important in students' learning of science. In order to provide students with the opportunity to obtain a meaningful and relevant understanding of science through active involvement in both procedural and declarative knowledge in the biology laboratory, the teacher should organize the experiment to be more oriented towards a guided inquiry and should prepare several specific questions requiring students to discuss science concepts more in the laboratory. It is hoped this study will promote a learning environment of gender equality for socially constructed biology.

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