An analysis of peer interaction patterns as discoursed by on-line small group problem-solving activity

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Received 1 March 2006; received in revised form 15 May 2006; accepted 9 July 2006

Abstract

Currently, numerous on-line discussion forums have been developed for educational purposes; therefore, a better understanding about peer student discussion or discourse interactions is quite important. Through gathering peer learning interactions on 57 college computer science students, who were randomly assigned into 14 small groups for solving programming problems, this study analyzed the content of their discourse interactions. First, it was revealed that the most frequent interactions were related to some questions or suggestions regarding how to effectively coordinate peer members. However, different features of peer interactions were found across different small groups. By time sequence analysis of peer interactions, it was found that issues and positions were proposed mostly in the initial and middle stages of the study, while the conflicts frequently occurred in the beginning stage. Finally, this study suggested five peer interaction patterns in terms of peer knowledge exchange, including centralized knowledge exchange, distributive knowledge exchange, group development impediment, ability impediment and partial knowledge exchange. A further analysis of students’ knowledge exchange patterns revealed that peer students’ background abilities played an important role on the ways of knowledge exchange involved in the on-line peer learning activity. Certain configurations of students’ background abilities tended to lead to a particular communication pattern. The implications derived from the findings for educational practice were also discussed. For example, the small groups with peer members of high achievement (or heterogeneous abilities) may not guarantee the success of group work. Many of them need teachers or moderators to scaffold the process of peer interactions and learning.

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Keywords: Discourse analysis; Communication pattern; Computer-mediated communication; Web-based peer learning; Problem-solving

1. Introduction

In recent years, web-assisted instruction has been advocated by contemporary educators. Web-based courses are numerous and allow students to perform various learning activities in a virtual classroom (Hiltz,
including reading, messaging, conferencing, accessing documents, and participating in interactive activities (Rafaeli, Barak, Dan-Gur, & Toch, 2004). Web-based curriculum environment allows students to develop their learning portfolio and interact with peers through a web learning system (Chou & Tsai, 2002). Such web learning systems can record learning activities in web logs. Meanwhile, powerful and convenient web-based communication facilities allow most web learning systems to provide discussion forums for teachers and students to exchange ideas. Students may freely join the discussion to seek or provide peer support (Guan, Tsai, & Hwang, 2006; Hammond, 2000).

In the context of education, it has been emphasized that peer discussion or peer interaction facilitates learning. For instance, peer tutoring or peer review has gained a lot of attentions among educators for the improvement of student learning (Falchikov, 2001; Liu & Tsai, 2005; Topping, 1998; Tsai, Liu, Lin, & Yuan, 2001; Tsai, Lin, & Yuan, 2002). Berge and Collins (1995) further pointed out that: “Talk and discussion provide an opportunity to articulate and explain one’s own thing and perhaps to modify one’s own ideas, beliefs or self-presentation in response to feedback from others. Incorporation of new data, the testing of arguments, and using one’s judgment and reasoning helps move a person toward new perspectives and higher levels of thinking” (p. 183). In other words, instead of passively receiving knowledge simply from teachers, students can develop problem solving and knowledge construction activities in the processes of peer discussion and interaction (Blumenfeld, Marx, Soloway, & Krajcik, 1996; Littleton & Häkkinen, 1999). This perspective is also consistent with recent ideas of the practice of constructivism in education (Chou & Tsai, 2002; Tsai, 2001). Nevertheless, students seldom have enough time to discuss with their peers and possibly solve problems together in a conventional classroom setting. Accordingly, computer-mediated communication (CMC) plays an essential role of on-line discussion or problem solving for educational purposes. CMC systems, such as electronic mail, computer conferencing, and bulletin board systems (BBS), have been widely used to support online peer discussion or problem solving (Hakkarainen & Palonen, 2003; Hammond, 2000; Lehtinen, Hakkarainen, Lipponen, Rahikainen, & Muukkonen, 1999). In current stage, as more and more on-line discussion forums are developed for learning, a better understanding about peer student discussion or discourse interactions is quite necessary. Consequently, this study attempted to explore the peer discourse interactions involved in on-line problem solving activity.

Social constructivists believe that collaborative work can help problem-solving or learning performance (Ben-Ari & Kedem-Froedroch, 2000; Pear & Crone-Tood, 2002). However, Wilson, Hoskin, and Nosek (1993) found that, in a computer programming task, high achievers were significantly associated with better performance when working in individuals, but surprisingly this association was not revealed for teams in a face-to-face collaborative problem solving activity. As on-line discussion forums have become widespread, it is important to investigate how student abilities affect interaction in groups and how the interaction among students affects the learning performance of individual students and groups.

Moreover, Chen, Wang, and Ou (2003) proposed a method utilizing communication patterns (Milson, 1976) and connectivity among group members (Wasserman & Pattison, 1996) to capture the topology of group communication networks and further utilized the topological feature to predict learning performance. Group communication patterns were found to be a good indicator that predicted group performance. Although the interaction patterns may affect individual and group learning performance, how the ability distributions among peer members in a group influence peer interactions remains unclear. Therefore, this study attempted to explore the link between ability distributions and peer interactions in on-line discussion forums. Consequently, teachers can configure groups that attain favorable interaction patterns.

The factors affecting the process of online peer interactions in learning are complex. In order to find out how to best design a discussion forum, researchers have been investigating the nature of online discussion by means of both quantitative and qualitative analyses of the discussion activity. However, the discussion activity is unstructured, considering for why the analysis of discussion activity is difficult to obtain precisely qualitative and quantitative results. Therefore, researchers (Kunz & Rittel, 1970) have devised issue-based information system (IBIS) model to structure discussion activities of collaborative design.

IBIS model was originally devised to support coordination and planning of political decision processes. Since it relies on a model of problem solving by an collaboratively argumentative process, IBIS articulates the discourse structure in order to solve a complex problem and arrive at a plan for decision. Conklin and Begeman (1988) further developed a graphic interface to represent the IBIS model in hypertext style. The
IBIS model is effective and widely used in collaborative design and analysis for student on-line group work (Eggersmann et al., 2003; Karacapilidis & Papadias, 2001). In addition, IBIS model is also applied to computer-mediated communication (CMC) learning environments to foster higher-order skills as it involves argumentation processes. For instance, Karacapilidis (2000) has adopted IBIS model as an argumentation tools in a web-based learning environment when students participated in a group project by solving course exercises together.

In the IBIS model, as illustrated in Fig. 1, students start with an issue. Many positions (solutions) are then proposed to resolve the issue. Next, various arguments are proposed to support or object to a certain position. Students may also suggest detailed operations or guidelines to perform an action. Therefore, student discussion interactions may include: proposing issues, offering positions, making arguments, responses and then showing supports or objections. This study would use the framework of IBIS model to analyze the peer interactions involved in on-line group problem-solving learning activities among college computer science students.

By gathering the data from 57 college students in Taiwan, who involved in a Java programming course as 14 small groups, this study was conducted to explore their discussion and problem-solving processes by utilizing IBIS model. The content of the student discourse interactions would be analyzed. This study would try to answer the following research questions based on the peer interaction analysis:

• What kinds of peer interactions can be observed and how students develop group works during on-line problem solving activities?
• By using IBIS model, what peer interaction patterns can be observed during on-line problem solving activities?
• How students of varying ability affect the ways of peer interactions in on-line problem solving activities?

2. Method

2.1. Participants and the course involved

This study was mainly conducted to explore the peer discourse interactions involved in on-line problem solving activity by providing students with a web-based learning system, which supported a variety of peer interaction functions to help student learning. The web learning system was designed to assist 57 computer science students in learning an undergraduate course entitled Java Programming Language at National Central University (Jhongli, Taiwan). Among these students, 49 were freshmen. The course was basically designed for the freshmen. Seven juniors and one sophomore were also enrolled in the course. Therefore, the student age was around 19–22.

Following instruction in a conventional classroom, students were also required to participate in the learning activities guided by a web learning system. The web system essentially provided learning environments for small groups to solve certain programming problems assigned by the course. The web system also provided a dictionary of keywords related to java program, with the explanations including definitions, illustrations, and examples of the keywords. Students could browse and consult the dictionary for explanations of these keywords. In addition, the web learning system also provided functions for students to submit homework. Certainly, the web system offered on-line forums for student small group discussion and problem solving.
2.2. On-line group problem-solving

The students involved were randomly assigned into 14 groups to collaborate on solving a programming problem. Each group contained approximately four students, and the collaborative problem-solving activity lasted for two hours. Students in a group must solve a Java sorting problem where students must deal with graphical user interface, arrays of data, strings, and sorting algorithm. A group submitted only an answer to the assigned problem to establish a common group goal. To acquire more complete peer interaction records, the students were not allowed to physically interact with each other when they participated in the on-line group problem-solving activity except using the on-line discussion forum. The students, in each group, could discuss the manner and relevant details of problem solving in a special discussion forum and online chat room, and the on-line dialogue was logged in the database for detailed analysis.

2.3. Programming scores

As the group task involved in this study was related to computer programming, it was hypothesized that each participant’s programming ability would possibly affect the ways as well as the content of peer discourse interactions on the web system. That is, in order to gain a better understanding about how each participant played a role in the peer interaction, each participant’s programming ability was considered for further exploration. Two test scores were used to represent each participant’s programming ability. The two tests were consisted of nine programming problems. Solving these problems required the skills of applying Java program instructions and algorithm knowledge such as variable, graphical user interface, looping, branching, Java applet, and array. Therefore, the two test scores could indicate each student programming ability. This study further categorized each student into low (L), middle (M), and high (H) achievers in programming ability by the test score mean and standard deviation. The students with the scores higher than 1/2 standard deviation from average were viewed as high achievers, while those with scores lower than 1/2 standard deviation were perceived as relatively low achievers. The rest of them were regarded as middle achievers.

2.4. Data analysis

All of the analyses of discourse interactions and interaction patterns were performed by two independent researchers (coders). The inter-coder reliability (agreement) for each analysis was at least 85%, indicating that the analysis was adequately reliable. The analysis or categorization that did not reach researchers’ agreement was resolved upon discussion.

3. Results

3.1. Descriptive data for issues and positions proposed in on-line group problem solving

Although this study included 57 students, only 46 students actually participated in the group problem-solving activity. That is, there were 11 students who did not join any discussion along the implementation of the web learning system; they did not log in for participating the discussion. Therefore, all of the later analyses were based upon the data of 46 students.

Among the 46 students of active participation, analysis of peer discourse revealed that 28 students (61%) asked or answered questions from peers; 21 (46%) students asked for peer support by proposing issues; 21 (46%) students provided peer support by proposing positions in response to the issues raised by others; and 14 students (30%) actively provided and asked for peer support during the group problem-solving activity. Students raised 81 issues during the two hour activity period. Of these issues, 59 (73%) were responded while 22 (27%) were not. Students proposed a total of 91 positions in response to the 59 issues. Each issue stimulated an average of 1.54 (91/59) positions (solutions) in response. Therefore, a certain proportion of students’ learning problems met with peer support. Table 1 presents students’ descriptive behaviors in the group problem-solving activity.
Table 2 further shows the issues and positions proposed in group problem-solving activity by each group, a total of 14 groups. Based on the results in Table 2, the students in Groups A, B, G and H were more active in posing issues and providing solutions. However, Groups D and J were almost inoperative along the on-line discussion activity. Table 2 also indicated that this study originally assigned about four students to each group, but number of the students actually involved in each group was varying. For instance, Group F finally included only two students, and many other groups (e.g., Groups D, G, L, M) had three peer members. That is, the students who did not join the on-line discussion were excluded from the data analyses.

3.2. Discourse interaction analysis

In addition to the descriptive data above, student discourse records were analyzed in more details to explore the peer interaction in the group problem-solving activity. By mainly utilizing the framework of IBIS discussion model, discourse analysis indicated that students conducted nine main types of interaction during the on-line activity, including issues, positions, arguments, group developments, responses, acceptance of responses, objections to responses, conflict, and support request, which are described below:

- **Issues** represent what needs to be done and problems to be solved, and relate to the concepts and skills being learned by students. For instance, students may seek peer support to solve a learning problem by raising questions such as “What should I import in our program?”, “What does ‘increasing strings’ mean?”, and “How can I record the input words as a string after pressing a button?”.

- **Positions** represent methodologies for resolving an issue, and are answers from peers in response to issues that have been raised. Students may help others by responding to issues. For instance, students answered questions raised by others by proposing positions such as “Just import javax.swing.*”, “Use String str=e.getSourceCommand();” and “State c.getContentPane allows you to create a location in your window where information can be stored”.

- **Arguments** represent opinions that support or object to a position. For instance, students comment on the positions of others by statements such as “Oh, right. Then I should use another variable” or “No, that’s more troublesome”.

- **Group development** represents questions raised to coordinate members to work together. For instance, when students coordinate the process of problem solving, questions such as “Does anyone know how to write the program?”, “Who is my partner?”, ”Does anyone have any opinions on this problem?”, and “Who knows how to develop the algorithm?” are frequently raised in the discourse.
- **Response** represents a suggested answer to a group development question. For instance, students frequently respond to the development questions of others with comments such as “Actually, we can try page 289.” and “I’ve developed a draft graphical user interface. I think that’s enough”.

- **Acceptance of response** represents the acceptance or agreement of a response. For instance, students frequently agreed to the responses of others with comments such as “Okay! I will wait for you.” and “I agree to try page 289”.

- **Objection to response** represents student objection or disagreement to responses. For instance, students frequently disagree with the responses of others with comments such as “I do not have JDK. How can I write that program?”,”No, I can not finish the first part of the program.” and “No, why don’t you transfer it into text file?”.

- **Support request** represents a request for resources and help from other group members. For instance, students frequently request resources with comments such as “I don’t have the example. Can you give it to me?” and “Has anyone finished the program? I have only partially finished”.

- **Conflicts** occur among group members. For instance, dialogues such as “Go away, don’t interrupt the discussion.” and “idiot!!” are expressed in the discourse. This type of interaction often occurs when a group member is unable to obtain support from other group members.

Table 3 lists the frequency of each type of peer discourse interaction. Table 3 revealed that students frequently raised group development questions (frequency = 149). Objections to responses were more common than acceptance. In addition to offering positions (frequency = 91), students often ask for resource support from others (frequency = 100). Table 4 presents the discourse interaction in each group. According to Table 4, Groups A, B, G and K involved more discourse interactions. Group E also had frequently discourse interactions, but most of them were related to “group development”, “objection to response”, and “conflict”, while the issues raised in the group were only three; therefore, one could predict that learning rarely occurred in the group. Group M initiated seven issues; however, only got one response from peers. Peer feedback was quite inadequate to facilitate learning. Groups D and J have almost no peer discourse interactions along the implementation of the on-line learning activity.

<table>
<thead>
<tr>
<th>Interaction type</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Issue</td>
<td>81</td>
</tr>
<tr>
<td>Position</td>
<td>91</td>
</tr>
<tr>
<td>Argument</td>
<td>30</td>
</tr>
<tr>
<td>Group development</td>
<td>149</td>
</tr>
<tr>
<td>Response</td>
<td>104</td>
</tr>
<tr>
<td>Acceptance of response</td>
<td>59</td>
</tr>
<tr>
<td>Objection to responses</td>
<td>80</td>
</tr>
<tr>
<td>Conflict</td>
<td>35</td>
</tr>
<tr>
<td>Support request</td>
<td>100</td>
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</table>

Table 4

<table>
<thead>
<tr>
<th>Group</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
<th>L</th>
<th>M</th>
<th>N</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Issue</td>
<td>13</td>
<td>8</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>14</td>
<td>11</td>
<td>3</td>
<td>0</td>
<td>7</td>
<td>6</td>
<td>7</td>
<td>5</td>
<td>81</td>
</tr>
<tr>
<td>Position</td>
<td>12</td>
<td>18</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>13</td>
<td>17</td>
<td>3</td>
<td>0</td>
<td>9</td>
<td>12</td>
<td>1</td>
<td>2</td>
<td>91</td>
</tr>
<tr>
<td>Argument</td>
<td>2</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>6</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>5</td>
<td>30</td>
</tr>
<tr>
<td>Group development</td>
<td>17</td>
<td>29</td>
<td>5</td>
<td>0</td>
<td>22</td>
<td>2</td>
<td>14</td>
<td>8</td>
<td>4</td>
<td>0</td>
<td>27</td>
<td>0</td>
<td>6</td>
<td>15</td>
<td>149</td>
</tr>
<tr>
<td>Response</td>
<td>10</td>
<td>29</td>
<td>2</td>
<td>1</td>
<td>27</td>
<td>1</td>
<td>6</td>
<td>8</td>
<td>1</td>
<td>0</td>
<td>14</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>104</td>
</tr>
<tr>
<td>Acceptance of response</td>
<td>8</td>
<td>16</td>
<td>2</td>
<td>0</td>
<td>6</td>
<td>2</td>
<td>8</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>9</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>59</td>
</tr>
<tr>
<td>Objection to responses</td>
<td>7</td>
<td>8</td>
<td>1</td>
<td>1</td>
<td>20</td>
<td>1</td>
<td>8</td>
<td>6</td>
<td>4</td>
<td>0</td>
<td>12</td>
<td>7</td>
<td>3</td>
<td>2</td>
<td>80</td>
</tr>
<tr>
<td>Conflict</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>6</td>
<td>8</td>
<td>0</td>
<td>35</td>
</tr>
<tr>
<td>Support request</td>
<td>16</td>
<td>20</td>
<td>2</td>
<td>1</td>
<td>14</td>
<td>1</td>
<td>14</td>
<td>5</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>13</td>
<td>100</td>
</tr>
</tbody>
</table>
Furthermore, Fig. 2 displays the time sequence of issues, positions, and arguments for all groups. Time sequence analysis of the discourses indicated that positions often outnumbered issues, and issues were proposed and positioned increasingly during the initial and middle stages of the activity. However, following
the middle stage, issues and positions decreased dramatically. Therefore, knowledge exchange might be concentrated during the early stage of the group problem-solving activity.

Moreover, Figs. 3 and 4 display the time sequence of group developments, responses, conflicts, and support requests for all groups. Time sequence analysis of discourse also revealed two peaks of group development frequency. Initially, students frequently communicated to develop tentative solutions. Meanwhile, during the late-middle stage of group problem-solving activity, students began to communicate to refine these solutions, and then the group development frequency increased. Support requests peaked around the late-middle stage of the activity because students require more resource support and solution revision from others after they have developed the initial solution. Time sequence analysis of the discourse also showed that conflicts frequently occurred at the beginning stage of the activity, probably before the students began to propose issues and group developments. Frequencies of response acceptance and objection were likely analogous to the frequency of responses.

3.3. Communication network analysis and peer interaction patterns

Student dialogue during the group problem-solving activity was analyzed to reveal the nature of student interaction. Meanwhile, group knowledge exchange was revealed via a communication network (Milson, 1973). The network has contained directed lines linking two students, indicating that one proposed an issue and the other offered a position or solution. The number in the line indicates the number of issues answered by positions. It should be noted that only the issue with responding position was shown in the communication network analysis (so, there is a gap between the data listed in Table 4 regarding the number of issues and positions, and those presented here). Therefore, if a student did not involve any link in the communication analysis, indicating he or she did not have meaningful issue-position interaction, but he or she might also have other contributions to the discussion (for example, the student might propose an issue but got no response or he/she might have some ideas about group development).

Fig. 5 displays the communication network for each group. For example, in Group A, a1 student and a3 student proposed 7 issues and 5 issues respectively and a2 provided responding solutions to the issues. Again, the students who did not log in the system to participate in the on-line group problem solving activity were excluded from the peer interaction analysis in Fig. 5. Clearly, students in Group B involved more complicated peer interactions. Student c1 in group C proposed an issue, and he responded a position to it by himself. Groups D and J did not involve issue-position interactions during the on-line problem solving activity.

In order to gain a better understanding about how peers in each group interacted in on-line problem solving activity on programming (conducted in this study), information about each participant’s programming ability is quite helpful. As described previously, this study represented the programming ability from two programming tests for each student and further categorized each student into low (L), middle (M), and high (H) achievers in programming ability by score mean and standard deviation. The students with the scores higher than 1/2 standard deviation from average were viewed as high achievers, while those with scores lower than 1/2 standard deviation were perceived as relatively low achievers. Student programming abilities, i.e. H, M or L, are represented in the braces of nodes in Fig. 5.

When integrating the communication network analysis with peer members’ background information (i.e., programming ability), we proposed five peer interaction patterns occurred in on-line peer problem solving activity as observed in this study. In other words, we analyzed student peer interaction patterns by particular consideration of student background ability involved in the peer learning activity. Peer interaction patterns are described below, in terms of the ways of their knowledge exchange:

- **Centralized knowledge exchange:** where a student became the center of knowledge exchange in a group. This student suggested many positions or solutions to issues raised by others and did not ask for others’ supports. The student was perceived as major information provider and he or she probably played an authority role during the discussion. Other students frequently requested this student’s support. In such group, the student occupying the position of knowledge exchange center usually has well-established abilities to solve related problems. For instance, group L in Fig. 5 demonstrated that the high achiever frequently proposed positions in response to middle achiever’s requests. Group A can also be viewed as this type of knowledge exchange. Although student a2 did not attain very high achievement in the programming tests, he actually
had very good programming ability recognized by the other peer members in group A. Consequently, student a2 also became the knowledge center of group A and student a1 and a3 frequently asked for solutions from him.

- **Distributive knowledge exchange**: where knowledge exchange did not converge only on a single student. In such a group, all of the students exchanged knowledge with each other, and they usually had middle or above average background (programming) abilities. Some individuals were unable to solve the problem.
assigned, and then the students had frequent interactive discussions and distributive knowledge exchanges during the group problem-solving activity. Groups B and G are examples of such knowledge exchange group. This type of knowledge exchange is the optimal one for group work.

- **Group development impediment:** Groups C and D are examples of this pattern of knowledge exchange group, which involved little group development, provision of responses, and acceptance of responses among group members. In such a group, most students had above average background abilities. However, students did not converge on a common approach to solving the assigned problem. Consequently, knowledge exchange to be developed was very limited in such groups. In this interaction pattern, the lack of knowledge exchange might not come from the inadequacy of student background ability; rather, it might stem from the failure of developing effective group problem-solving approach.

- **Ability impediment:** Groups E, F, J, and M are examples of this pattern of knowledge exchange group. In such group, students generally had limited background abilities. Conflicts among members might often arise in such groups, generally occurring when a student was unable to obtain support from others. For example, according to Table 4, Group E had frequent discourse interactions, but most of them were categorized as “group development” questions and responses, “support request” and “conflict”. The issues and positions proposed were rare. As a result, Group E in Fig. 5 contained only two times of meaningful issue-position interactions. The situation in Group M was similar to Group E. The peer members in Groups F and J involved few interactions (based on the data of Table 4); thus, almost no issue-position communication occurred in these groups. In sum, knowledge exchange is also very limited in the groups of this interaction pattern, and the lack of peer knowledge exchange mainly stems from the deficiency of their background knowledge and abilities.

- **Partial knowledge exchange:** Groups H, I, K and N can be perceived as examples of this pattern of knowledge exchange. In such groups, student background abilities are diverse. Problem solving process and knowledge exchange occurred only between selected students, while some lower achievers (e.g., h3 and k2) did not actively join the activity. In the groups of centralized knowledge exchange (the first pattern), one more capable achiever suggested many positions to the issues raised by others and likely play an authoritative role. However, in this pattern, students with middle or above abilities in these groups (e.g., h2, k3, n1) did not occupy the position of knowledge center but they were active in the group work.

These patterns emerged on the basis of the topological features of communication network in groups. By comparing the differences and similarities of the 14 groups, we have developed some basic rules to categorize the interaction patterns, shown below:

- **Centralized knowledge exchange:** There exists a center student. If any student proposes an issue, only the center student responds to the issue.
- **Distributed knowledge exchange:** Each student contributes to both proposing issues and responding positions.
- **Group development impediment:** There exists no issue and position link between any two students while most students have high background ability.
- **Ability impediment:** There is very few (none or only one) issue and position links between any two students while no students have high background ability.
- **Partial knowledge exchange:** There are some students who do not contribute to proposing issues or responding positions. Issue and position links only occur between selected students, and the students’ abilities are diverse.

The discussion above is summarized in Table 5. Analysis of students’ knowledge exchange behaviors and their background abilities suggested that student abilities required to solve the assigned problems might have affected the ways of knowledge exchange among students for the on-line peer learning activity. Certain configurations of students tended to lead to a specific communication pattern. For instance, the group with one student of well-established ability may lead to centralized knowledge exchange. The groups with peer members of only middle and low achievers might have obvious difficulties in peer learning and then have unfavorable outcomes.
Finally, it is valuable to explore the interplay between interaction patterns and the quality of the completed programming assignments of the groups. Each group in this study submitted a group programming work after the on-line discussion. The work of each group was evaluated by an expert and it was found that the groups in the pattern of centralized knowledge exchange attained average score 85, distributive knowledge exchange 84, group development impediment 76, ability impediment 83.25, and finally partial knowledge exchange 83.75. It was interesting to find that the groups in “group development impediment” pattern gained the lowest score. They did not achieve high quality of group work, although most individuals in these groups were high achievers. This finding strengthens the fact that group development strategy is highly essential for enhancing effective knowledge exchange during group work.

4. Conclusions and implications

Many educators have highlighted the importance of using on-line discussion systems to help peer learning (Hammond, 2000; Hwang, Chen, & Hsu, 2006; Hyun, 2005). A further analysis about peer discourse interaction on these discussion systems is beneficial for improving the learning involved. Through gathering the small group peer learning interactions on college computer science students, this study, by using issue-based information system (IBIS) model, analyzed the content of their discourse interactions, and then proposed five peer interaction patterns, including centralized knowledge exchange, distributive knowledge exchange, group development impediment, ability impediment and partial knowledge exchange. It was found that IBIS was useful for quantitatively and qualitatively analyzing student on-line discussion or collaborative problem-solving activity.

In the two-hour period of on-line interactions, the students proposed 91 issues, while 59 of them were answered. On average, there were 1.54 positions (solutions) for each issue answered. A future study might be conducted to investigate why some issues were not responded by peers. Educators may also find more strategies to increase the issues answered and to enhance the number as well as the quality of positions offered by peer learners. For example, Guan et al. (2006) have discussed the importance of on-line moderators in fostering students’ interactions and quality of discussion.

Moreover, this study revealed that the most frequent interactions were related to some questions or suggestions regarding how to effectively coordinate peer members (i.e., group development). This finding suggested that even college students in this study, might not have sufficient competences for web-based team work or collaboration.

| Table 5 |
| The interaction patterns in terms of knowledge exchange observed in on-line group problem solving |
| Interaction pattern | Features | Examples | Peer members* |
| Centralized knowledge exchange | A student with well-recognized ability becomes the center of knowledge exchange in a group | Groups A & L | A: (2, 2, 0) |
| | | | L: (1, 2, 0) |
| Distributive knowledge exchange | Most members have middle or above average problem solving abilities. All of the students exchange knowledge with each other | Groups B & G | B: (2, 2, 0) |
| | | | G: (2, 1, 0) |
| Group development impediment | Most members have above average problem solving abilities. However, students did not converge on a common process to solve the assigned problem | Groups C & D | C: (3, 0, 1) |
| | | | D: (2, 0, 1) |
| Ability impediment | Most students have lower problem solving abilities and were unable to obtain support from others | Group E, F, J & M | E: (0, 2, 2) |
| | | | F: (0, 1, 1) |
| | | | J: (0, 2, 1) |
| | | | M: (0, 2, 1) |
| Partial knowledge exchange | The range of problem solving abilities is diverse. Problem solving process and knowledge exchange occurred only between selected students, while some lower achievers did not actively join the activity | Groups H, I, K & N | H: (0, 1, 2) |
| | | | I: (1, 1, 1) |
| | | | K: (1, 1, 1) |
| | | | N: (1, 1, 2) |

* Peer members represent the number of members of high, middle, and low achievements. For example the notion N: (1, 1, 2) represent group N is comprised of one high, one middle and two low achievers.
collaborative learning. It is expected that this problem would be more critical for younger students (e.g., Hyun, 2005). Teachers should be highly aware of this, and allow more time for students to discover their ways of working together. If necessary, teachers should assist the process of group development.

By time sequence analysis of peer interactions, it was found that issues and positions were proposed mostly before the middle stage of the study, implying that knowledge exchange might predominantly occur in early stage in the on-line learning activity. Researchers should try to discover better ways to help students develop as well as share knowledge for the lasting effects of on-line learning community. In addition, this study revealed that peer conflicts were frequent in the beginning stage; hence, teachers should pay particular attention to these and try to help peers to resolve them.

The analysis by communication network with student background ability showed that the group with both high and middle achievers may have better peer interactions, and possibly learning outcomes, such as the distributive knowledge exchange pattern defined in this study. The combination of high and middle achievers may create favorable (perhaps sufficiently challenging) environments for peer interactions. Moreover, this study found that the lack of developing knowledge exchange may come from two types, one from the deficiency of background ability (ability impediment), and the other come from the inadequacy of group development skills (group development impediment). For the first type, educators can assign some higher achievers to join the group to enhance the quality of peer interactions. For the second type, many of the students may have high achievement but fail to learn from on-line discussion. In this situation, teachers may scaffold peer discussion and provide appropriate support to guide the group development of peer learning. That is, the small groups with peer members of high achievement or heterogeneous abilities may not guarantee the success of group work. Many of them need teachers or moderators to scaffold the process of peer interactions and learning. This is also consistent with the finding presented previously that the students in this study had most frequent peer interactions about group development and coordination, implying students might not be experienced in on-line peer discussion and learning.

The analysis of group work quality and interaction patterns revealed that the groups in the “group development impediment” pattern in this study attained the lowest scores, suggesting the development strategy was highly essential for enhancing effective knowledge exchange during group work. This again supported our conclusion that the small groups with peer members of high achievement might not assure the success of group work. The groups in the patterns of centralized knowledge exchange and distributive knowledge exchange achieved relatively higher quality of group work than the other groups; nevertheless, the difference among the patterns (except the pattern of group development impediment) was not very obvious. Further investigation is required to explore the group work quality and peer interaction patterns.

This study aimed to explore the interaction patterns and how abilities of different students affected these interaction patterns when students were willing to participate in on-line discourses. However, among the 57 students selected for this study, eleven students did not join the on-line problem solving activity. Among the eleven students, seven of them were juniors and had failed in the Java course in prior semesters since the Java course was a requirement course for freshmen. These seven juniors did not frequently attend the course, and it was expected that they were not very interested in this course. In addition, among the eleven students, there were three students who were clearly low achievers. By and large, these students did not demonstrate high motivation to participate in learning activities. However, more research may be conducted to explore more details about the “dormant” students and then to find some effective ways to enhance their intention and participation of engaging in such on-line learning activity in the future. In addition, the teacher did not intervene the problem solving activity and peer interactions in this study. Further research is required to find the mediating strategies that teachers can apply to promote peer interactions for peer groups with ability impediment and group development impediment.

Acknowledgements

Funding of this research work was supported by National Science Council, Taiwan, under Grant numbers NSC 93-2524-S-009-003 and NSC 94-2524-S-009-003. The authors also express their gratitude to two anonymous reviewers for their helpful comments about this paper.
References


