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ABSTRACT

The purpose of this study was to examine how students acquire their knowledge through peer collaboration in a new educational environment called "Computer Supported Intentional Learning Environment (CSILE)." Twenty-seven 5th- and 6th-grade students were instructed to create their collective database for a study topic, "electricity." Their reported thoughts were shared with others in the database, and the others could easily comment on the thoughts. Thus, mediated by the database system, students were allowed to asynchronously collaborate with their friends. Based on the quality of their finally constructed knowledge in the database, students were divided into three types of learners: (1) Good Theory Builders, (2) Average Theory Builders, and (3) Poor Theory Builders. The processes of students' learning were compared among the types of learners based on the records of their computer manipulation. The results showed: (1) that successful learners planned their learning in the initial period and constantly produced their thoughts in the database; (2) that successful learners spent much metacognition effort on their evidence but not on their theories; and (3) that successful learners effectively used their personal resources in the classroom to construct their theories in the second half of learning. (Author)

The Relationship between Type of Knowledge and Process of Peer Collaboration in a Computer-Mediated Classroom*

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ABSTRACT

The purpose of this study was to examine how students acquire their knowledge through peer collaboration in a new educational environment called "Computer-Supported Intentional Learning Environments (CSILE)." Twenty-seven 5th- and 6th-grade students were instructed to create their collective database for a study topic "electricity." Their reported thoughts were shared with others in the database, and the others could easily comment on the thoughts. Thus, mediated by the database system, students were allowed to asynchronously collaborate with their friends. Based on the quality of their finally constructed knowledge in the database, students were divided into three types of learners: (1) Good Theory Builders (GTBs), (2) Average Theory Builders (ATBs), and (3) Poor Theory Builders. The processes of students' learning were compared among the types of learners based on the records of their computer manipulation. The results showed: (1) that successful learners planned their learning in the initial period and constantly produced their thoughts in the database; (2) that successful learners spent much metacognitive effort on their evidence but not on their theories; and (3) that successful learners effectively used their personal resources in the classroom to construct their theories in the second half of learning.

PROBLEM

In several schools of child development, collective activity with peers is considered to play an important role in knowledge acquisition (e.g., Perret-Clermont, 1980; Rogoff, 1990). In particular, Vygotskian approach to child development presents us with a clear mechanism of child development through collective activity (Brown & Palincsar, 1989; Forman & Cazden, 1985; Vygotsky, 1978). The Vygotskians emphasize that human intelligence originates in our culture or society, and that human development happens through two different phases: (1) interpersonal, and (2) intrapersonal. This means our high level of thinking first appears through interaction with social circumstances including others, and it is internalized to function intrapersonally.

From this perspective, many researchers have tried to figure out how children interact with others in their collective activity to acquire new knowledge (Azmitia, 1988; Forman & Cazden, 1985; Tudge, in press). For instance, Forman and Cazden's (1985) observation of students' discourse in solving collaboratively a Piagetian task shows that children's collaboration involves two different types of social processes. The first one is "parallel working or closely coordinated cooperative patterns." In this initial stage of the collaborative task solving, mutual guidance, encouragement and support are often observed. The following stage is "individual conclusion and interpersonal argumentation." In this second stage of the collaborative task solving, children try to detect their own conclusions based on experimental evidences. When conflicts between students happen, they facilitate their argumentation for resolving their conflicts. Thus, Forman and Cazden (1985) conclude that children can gain new strategies through peer collaboration by assisting each other or managing complementary problem solving roles. In this way, interpersonal discourse is found to facilitate individual knowledge acquisition.

Furthermore, based on the above theoretical studies of children's knowledge acquisition in operational tasks, recent studies extend their objects from theoretical ones to practical or pedagogical implications of peer collaboration in the classroom. Brown et al. (Brown & Campione, 1990; Brown & Palincsar, 1989; Palincsar & Brown, 1984) present how the benefits of collective activity, especially peer collaboration, are applicable to education. They imply the following things: First, by having students take different roles of problem solving and help one another, they can share their mental power and are capable of acquiring new knowledge that they cannot gain alone. Second, by having students with expertise in different parts of a curriculum take complementary roles in collaboration, the students naturally generate their "zones of proximal development", which facilitate each individual's knowledge acquisition through internalization. Third, in students' collective activity, a teacher facilitates scaffolding off students such that they take easily their roles of complementary problem solving. Based on these ideas, Brown et al. propose a teaching style in the classroom called "reciprocal teaching" (Brown & Palincsar, 1989), and demonstrate how students in this teaching style actually gain new knowledge better than those in a conventional schooling.

A current topic is how we should establish a circumstance where students' succeed in their knowledge acquisition through their collective activities (Collins, Brown & Newman, 1989). From the preceding studies of students' collective activities in the classroom, it is found that students can benefit from their collective activities, but that it does not always happen (Azmitia & Perlmutter, 1990). An approach to the problem of how students succeeds in gaining knowledge through peer collaboration is to assess students' post performances by considering several hypothesized variables such as students' internal ability and structures of groups (Slavin, 1983). This is useful in a sense that we can regulate fixed variable known before learning happens in order to make their learning successful.

However, as Vygotskian approach suggests, we cannot see how students acquire their knowledge in learning without investigating the genetic process of the knowledge acquisition. Although students are exposed to the educational environment considered to be the best for them, the success of their learning depends on how they interact with it. Thus, in order to discuss how students make use of their new contexts of learning, we should investigate micro-genetic processes of students' learning in the new educational environments. In addition, although, in the classroom, students are involved in various types of knowledge (e.g., concepts, theories, and information that supports their theories in science education), how the type of knowledge is gained through peer collaboration has not been discussed. Therefore, the aims of this paper are to discuss processes of students' learning through peer collaboration in a new educational environment, and to examine the relationship between the process of learning and the type of knowledge acquired through peer collaboration in the environment.

The New Educational Environment Discussed in This Paper

As described above, the author focuses on a new circumstance in the classroom where students easily collaborate with others in their intentional learning (Brown & Campione, 1990; Collins, Brown & Newman, 1989; Scardamalia

& Bereiter, 1991). The main principle in creating such an educational environment is "cognitive apprenticeship" (Collins, Brown & Newman, 1989). All we have to do is to support students' learning so that they can naturally take the best course in succeeding in acquiring knowledge. Among several approaches to establish the educational environments, the educational environment that the author focuses in this paper is "Computer-Supported Intentional Learning Environments (CSILE)" (Scardamalia, Bereiter, McLean, Swallow & Woodruff, 1989).

CSILE is a hypertextual database system for students' intentional learning (Bereiter & Scardamalia, 1989), and supports students' learning by providing means to construct their collective database of their thoughts. Students can report their thoughts in the form of charts and texts, and these reported thoughts are available to everyone. They can easily access others' thoughts and add their thoughts to the others' as comments. Furthermore, CSILE encourages students to organize their thoughts by linking charts and by labeling their texts with several states of their thoughts such as "problem", "questions", "what I know", "new learning", and so on. Thus, students can easily control their externalized thoughts by manipulating their databases in CSILE, and be engaged in higher-order thinking, organizing their thoughts and their friends' thoughts. In CSILE classrooms, students are instructed to create their own database for their studies. In the first class of each curriculum, teachers propose a very general goal of the curriculum (e.g., "How electricity works"), and students generate their own learning goals and pursue them by collaborating with others.

Because of the circumstance mediated by the database system, students in CSILE classrooms are involved in an unique type of collective activity that cannot be seen in natural classrooms. First, because CSILE is a whole database shared by students in the classroom, their activities in the database system have various meanings in peer collaboration. They generate their thoughts to present their ideas with unspecified peers or all in their classroom, and they intentionally access peers' thoughts to communicate with the peers. In addition, students are communicated from others. Thus, the database system makes students' intentions to communicate with their peers apparent. This context is critically different from the context of natural collaboration in which participants can get information from others through oral discourse regardless of their intentions. This feature of CSILE communication is a merit of our analysis of peer collaboration in the database system. Although the analyses of their communication with peers are limited within the database circumstance, we can figure out when and how students communicate with whom, and infer why they do so by tracing each individual's record of computer manipulation. Second, since CSILE database is a whole storage of students' thoughts at different times of learning, their collaboration happens in their own ways. That is, at anytime they want to communicate with someone, students can access others' thoughts at different times. Topics or thoughts which students access are not necessarily topics for others. From this perspective, students' communication is asynchronous, and they can share their thoughts with others beyond temporal limitation in natural communication.

In sum, with taking the above features of CSILE collaboration into consideration, we examined the process of students' knowledge acquisition through peer collaboration by analyzing the following activities.

1. Students' Note Generation: As the author explained above, students are allowed to externalize their thoughts in the forms of text or charts. These are called notes in this study.

2. Students' Note Revision: As they report their thoughts in CSILE, they revise their previous thoughts. This is a metacognitive aspect of their learning.

3. Students' Monitoring: In addition to their Note Revision, students also monitor their learning to check the process of their learning. This is another aspect of their metacognition.

4. Other Referring: This is an aspect of students' collective activities. How they access others' notes with their purposes is discussed.

5. Comment Receiving: This is another aspect of students' collective activities. Regardless of their intentions, some comments come into their thoughts at various times, and these are considered to affect students' further thoughts and their note revision.

In order to examine the process of students' learning in the new educational environment, all measures were analyzed in five different periods of a whole learning. Furthermore, in order to discuss the relationship between the process and the type of knowledge acquired by students, students in this study were divided into three different groups, which had finally acquired different types of knowledge. Therefore, we examined the above measures by 3 (Groups of Students: Between-Subjects) X 5 (Periods of Learning: Within-Subjects) experimental design.

METHOD

Subjects: Twenty-seven 5th- and 6th-graders in a Toronto public school participated in this study as part of their regular curriculum.

Procedure: Before starting the computer communication, the students did some basic experiments about the topic "electricity" as introduction of the curriculum. After these experiments, they were instructed by their teacher to create their knowledge databases for their topic by using the computer database system. There were eight micro computers in the classroom. The students were permitted to use them at assigned times. The teacher wrote the following assignment that was available through the computer network:

> Students of Room 25:
>
> For the CSILE part of your electricity report, you are required to try to solve the problem, "How Does Electricity Work?"
>
> Your first note is to be a note which tells what you know about electricity from the experiments which you did in the kit. Store it under the topic "Electricity" and the thinking type "What I Know."
>
> Your second note must be a listing of things you think you would need to understand more fully if you were to be able to explain electricity. Store it under the topic "Electricity" and the thinking type "High Level Questions."
>
> The rest of your notes and charts should explain your ideas about how electricity works, especially what happens to the molecules in all the materials you used. Your own ideas are very important in this part of your work.
>
> You are able to use comments to help other students develop their ideas. This is also a very important part of the assignment. All the notes and charts are to be published.

The curriculum continued for five weeks in the winter of the academic year. There was a 1 week blank between the second and the third weeks because of mid-winter break in the Ontario schools, Canada. All the manipulations of the students and the created notes were automatically recorded as computer tracking data in the database system.

Data: All the students' activities in the computer database were recorded as computer tracking data (see an example in Table 1), which included: (1) time at which each student used the computer, (2) the contents of the texts and the charts created by the students, and (3) the students' operations of the computer system such as accessing database and searching information. Table 1 shows a simple example: A student started his computer communication and wrote a new note about the study topic. Other activities such as note editing, note searching, and commenting were recorded in the same format as note writing. These activities were represented as NE, PS, and CM respectively.

Insert Table 1 about here

Measures: On the basis of the contents of students' databases, the following variables were coded for analyses. In this database environment, students not only report their new thoughts but also revise previous ones at various points of their learning processes. By tracking the recorded contents of their notes, we can assess how students report new ideas and revise previous ones.

(1) Note-score: To categorize students into groups by the degree of success in their learning, students' finally constructed databases were evaluated by the criterion of "how important their notes are for the goal of how electricity works." Two raters independently chose each student's notes that describe his/her theories. The agreement was over 95%, and they were instructed to discuss their disagreements to decide whether the notes were chosen. Next, they evaluated each chosen note by a five-point scale[1]. The correlation of the ratings between the raters was high (r = .91, $p < .05$), and the average score between the raters' was used as the note-score (see Appendix A for examples of evaluated notes).

(2) Students' Activities: As described above, students' activities were evaluated from the following aspects of their learning. Along with the above experimental design, each measure was calculated in each week.

Frequencies: For the quantitative analysis of students' learning processes, frequencies of Note Generation, Note Revision, Monitoring, Other Referring, and Comment Receiving were calculated in each week.

[1] As for the evaluation of charts, the raters were instructed to assess the charts based on textual explanation in them.

Contents: For the qualitative analysis of students' learning, the contents of students' activities were categorized.

In Note Generation, the contents of notes were categorized as one of three types:

(a) Theory: Students explained their ideas about "how electricity works."

(b) Evidence: They presented some evidence that supports their theories.

(c) Planning: They externalize their learning goals and questions to control their own learning processes.

In Note Revision, percentages of critical revisions in Theory and Evidence notes were calculated.

In Other Referring, ways to access others' thoughts were categorized as one of two types:

(a) Private Search: Students accessed specific friends' notes by identifying the authors' names.

(b) Public Search: They accessed simultaneously all the members' notes in the classroom.

Two raters were independently involved in each categorization. The agreements were over 95%, and the disagreements were discussed by them.

RESULTS

In this section, we first describe the classification of students' knowledge acquisition after learning in the new educational environment, and then examine the relationship between the type of knowledge acquired in learning and the process of peer collaborative learning.

The Differences in Knowledge Acquisition After Peer Collaborative Learning in the New Educational Environment[2]

On the basis of each student's note scores, we categorized students into the following groups.

Poor-Theory-Builders (PTBs): Students in this category mainly reported their experiences and information related to the curriculum, but they did not have any

[2] Some Readers may wonder the differences in types of acquired knowledge come from individual differences in students' existing knowledge before learning and their ability to learn. The author assumes that they were at the same starting point of constructing their theories of the study topic although they had various experiences related to the topic. As for the differences in students' ability to learn, post hoc analysis of "problem solving" score in the Canadian Tests of Basic Skills showed no significant difference among the three groups of students.

explanations of how electricity works. Fourteen students were included in this category.

Average-Theory-Builders (ATBs): Students in this category had several explanations in their notes, but the highest note-scores were equal to or less than the midpoint of the evaluative scale, 3.0. There were seven students in this category.

Good-Theory-Builders (GTBs): Students in this category had more elaborate explanations in their notes. The highest note-scores were more than 3.0. Six students were in this category.

The Analyses of the Processes of Peer Collaborative Learning in the New Educational Environment

The Processes of Note Generation: In order to compare the processes of Note Generation among PTBs, ATBs, and GTBs, frequencies of Note Generation were first analyzed, and then percentages of each category (i.e., Theory, Evidence, and Planning) were examined.

The Analysis of Frequencies of Note Generation: First, to examine the differences in the frequencies of Note Generation among groups in each week, one-way ANOVAs with the group as a factor were conducted (Fig. 1). Significant results were found in weeks 1 and 4 ($F(2, 24) = 4.50$ and 5.68, respectively, ps < .05), and a marginal difference was found in week 5 ($F(2, 24) = 2.57$, $p < .10$). The post comparison revealed: (1) that, in weeks 1 and 4, the means of frequencies in GTBs were higher than those in both ATBs and PTBs; and (2) that, in week 5, the mean of frequency in GTBs was higher than that in ATBs.

Second, to examine the process of Note Generation across five weeks in each group of students, t tests were conducted on the means of frequencies in all possible comparisons. In GTBs, no significant results were found. In ATBs, significant results were found: (1) between weeks 1 and 2 ($t = -2.66$), and (2) between weeks 1 and 3 ($t = -2.83$). In PTBs, significant results were found: (1) between weeks 1 and 2 ($t = -2.41$), (2) between weeks 1 and 3 ($t = -2.66$), (3) between weeks 2 and 4 ($t = 2.83$), (4) between weeks 3 and 4 ($t = 4.32$), and (5) between weeks 4 and 5 ($t = -2.51$).

Insert Figure 1 about here

The Analyses of Percentages of Categories of Note Generation: In order to examine on what types of activities in Note Generation different groups of students spent their efforts, percentages of each category in Note Generation were analyzed. First, to compare the percentages among three groups in each week, one-way ANOVAs were conducted with group as a factor (Figure 2, 3, and 4). In the analysis in Evidence, a significant result was found in week 3 ($F(2, 24) = 4.97$). The post comparison revealed that means of percentages in GTBs and PTBs were higher than that in ATBs. In Theory, a marginally significant result was found in week 4 ($F(2, 24) = 2.70$). The post comparison revealed that the mean of percentage in GTBs was higher than those in both ATBs and PTBs. In Planning, no significant results were found.

Insert Figures 2, 3, and 4 about here

Second, to examine the changes in percentages of each category across five weeks in each group, t tests on means of percentages in all possible comparisons were conducted.

The Changes in Percentages of Theory: In GTBs, a marginally significant result was found between weeks 1 and 2 ($t = 2.06$). In ATBs, a significant result was found between weeks 2 and 5 ($t = 2.50$), and a marginally significant result was found between weeks 3 and 5 ($t = 1.98$). In PTBs, a significant result was found between weeks 1 and 3 ($t = 2.52$), and a marginally significant result was found between weeks 1 and 5 ($t = 1.95$).

The Changes in Percentages of Evidence: In GTBs, significant results were found: (1) between weeks 1 and 2 ($t = -4.34$), (2) between weeks 1 and 4 ($t = -2.61$), and (3) between weeks 1 and 5 ($t = -3.67$). A marginally significant result was found between weeks 1 and 3 ($t = -2.28$). In ATBs, significant results were found: (1) between weeks 1 and 3 ($t = -2.75$), and (2) between weeks 1 and 4 ($t = -3.24$). A marginally significant result was found between weeks 1 and 2 ($t = -2.12$). In PTBs, significant results were found: (1) between weeks 1 and 3 ($t = -5.27$), (2) between weeks 1 and 5 ($t = -2.40$), and (3) between weeks 3 and 4 ($t = 4.81$). Marginally significant results were found: (1) between weeks 1 and 2 ($t = -1.90$), and (2) between weeks 2 and 3 ($t = -1.80$).

The Changes in Percentages of Planning: In GTBs, marginally significant results were found: (1) between weeks 1 and 3 (t = 2.20), (2) between weeks 1 and 4(t = 2.20), and (3) between weeks 1 and 5(t = 2.20). In both ATBs and PTBs, no significant results were found.

The Processes of Note Revision: In order to compare the processes of Note Revision among PTBs, ATBs and GTBs, frequencies of Note Revision were first analyzed, and then percentages of critical revision in previous notes (i.e., Theory, Evidence) were examined.

The Analysis of Frequencies of Note Revision: First, to examine the differences in the frequencies of Note Revision among groups in each week, one-way ANOVAs with the group as a factor were conducted (Fig. 5). Significant results were found in weeks 2, 4, and 5 ($Fs(2, 24)$ = 4.11, 3.98, and 9.81, respectively), and a marginally significant result was found in week 1 ($F(2, 24)$ = 3.20). The post comparisons revealed that means of frequencies in GTBs were higher than those in both ATBs and PTBs in weeks 1, 2, 4, and 5.

Second, to examine the process of Note Revision across five weeks in each group of students, t tests were conducted on means of frequencies in all possible comparisons. In GTBs, significant results were found: (1) between weeks 1 and 2 (t = -5.16, and (2) between weeks 1 and 4 (t = -2.79). In ATBs, significant results were found: (1) between weeks 1 and 2 (t = -3.53), and (2) between weeks 1 and 3 (t = -3.42). A marginally significant result was found between weeks 4 and 5 (t = 2.34). In PTBs, significant results were found: (1) between weeks 1 and 2 (t = -5.19), (2) between weeks 1 and 3 (t = -4.88), (3) between weeks 1 and 5 (t = -2.36), and (4) between weeks 3 and 5 (t = 2.32). Marginally significant results were found: (1) between weeks 1 and 4 (t = -2.13), and (2) between weeks 2 and 5 (t = 1.97).

Insert Figure 5 about here

The Analysis of Percentages of Critical Revision in Previous Notes: In order to examine how students in different groups critically revised their thoughts, percentages of critical revision in previous notes were analyzed. First, to compare the percentages among three groups in each week, one-way ANOVAs were conducted with the group as a factor (Figure 6 and 7). In the analyses in both Theory and Evidence, no significant results were found.

Insert Figures 6 and 7 about here

Second, to examine the changes in percentages of critical revision in Theory and Evidence across five weeks in each group, t tests on means of percentages in all possible comparisons were conducted.

The Changes in Percentages of Critical Revision of Previous Theory: In all GTBs, ATBs and PTBs, no significant results were found.

The Changes in Percentages of Critical Revision of Previous Evidence: In GTBs, marginally significant results were found: (1) between weeks 1 and 2 (t = -2.14), and (2) between weeks 1 and 3 (t = -2.14). In ATBs, no significant results were found. In PTBs, a significant result was found between weeks 1 and 3 (t = -3.57). Marginally significant results were found: (1) between weeks 1 and 2 (t = -2.14), (2) between weeks 2 and 3 (t = -1.95), and (3) between weeks 3 and 5 (t = 2.13).

The Processes of Monitoring: In order to compare the processes of Monitoring among PTBs, ATBs, and GTBs, the frequencies were analyzed.

The Analysis of Frequencies of Monitoring: First, to examine the differences in the frequencies of Note Revision among groups in each week, one-way ANOVAs with the group as a factor were conducted (Fig. 8). A significant result was found in week 1 ($F(2, 24) = 4.25$), and a marginally significant result was found in week 2 ($F(2, 24) = 3.24$). The post comparisons revealed that means of frequencies in GTBs were higher than those in both ATBs and PTBs in weeks 1 and 2.

Second, to examine the process of Monitoring across five weeks in each group of students, t tests were conducted on means of frequencies in all possible comparisons. In GTBs, significant results were found: (1) between weeks 1 and 5 (t = -4.18), and (2) between weeks 3 and 5 (t = -3.78). Marginally significant results were found: (1) between weeks 1 and 2 (t = -2.31), and (2) between weeks 3 and 4 (t = -2.08). In ATBs, significant results were found: (1) between weeks 1 and 2 (t = -3.12), and (2) between weeks 1 and 3 (t = -2.77). A marginally significant result was found between weeks 1 and 4 (t = -2.05). In PTBs, significant result was found between weeks 1 and 2 (t = -2.84).

Insert Figure 8 about here

The Processes of Other Referring: In order to discuss how students in different groups accessed their peers' thoughts, frequencies of Other Referring were analyzed, and then how to access others' thoughts were also examined.

The Analysis of Frequencies of Other Referring: First, to examine the differences in the frequencies of Other Referring among groups in each week, one-way ANOVAs with the group as a factor were conducted (Fig. 9). No significant results were found.

Second, to examine the process of Other Referring across five weeks in each group of students, t tests were conducted on means of frequencies in all possible comparisons. In GTBs, marginally significant results were found: (1) between weeks 1 and 5 (t = -2.39), and (2) between weeks 2 and 5 (t = -2.45). In ATBs, no significant results were found. In PTBs, significant results were found: (1) between weeks 2 and 3 (t = -2.50), and (2) between weeks 2 and 4 (t = -2.41). Marginally significant results were found: (1) between weeks 1 and 3 (t = -1.98), and (2) between weeks 1 and 4 (t = -2.05). In ATBs, no significant results were found. In PTBs, significant results were found: (1) between weeks 2 and 3 (t = -2.50), and (2) between weeks 2 and 4 (t = -2.41). Marginally significant results were found: between weeks 1 and 3 (t = -1.98), and (2) between weeks 1 and 4 (t = -2.05).

Insert Figure 9 about here

The Changes in Percentages of Each Type of Search: In order to examine how students in different groups accessed their friends' thoughts, percentages of each type of database search (i.e., Private Search or Public Search) were analyzed. First, to compare the percentages among three groups in each week, one-way ANOVAs were conducted with the group as a factor (Figures 10 and 11). In both Private and Public Searches, no significant results were found.

Insert Figures 10 and 11 about here

Second, to examine the changes in percentages of each type of search across five weeks in each group, _t_ tests on means of percentages in all possible comparisons were conducted.

The Changes in Percentages of Private Search: In GTBs, a significant result was found between weeks 1 and 5 ($t = -3.81$), and a marginally significant result was found between weeks 1 and 4 ($t = -2.24$). In ATBs, no significant results were found. In PTBs, a marginally significant result was found between weeks 2 and 3 ($t = -1.79$).

The Changes in Percentages of Public Search: In GTBs and ATBs, no significant results were found. In PTBs, marginally significant results were found: (1) between weeks 2 and 3 ($t = -1.79$), and (2) between weeks 2 and 5 ($t = -1.88$).

The Processes of Comment Receiving: In order to discuss how students in different groups received comments on their own thoughts from their friends, frequencies of Comment Receiving were analyzed.

The Analysis of Frequencies of Comment Receiving: First, to examine the differences in the frequencies of Comment Receiving among three groups in each week, one-way ANOVAs with the group as a factor were conducted (Fig. 12). No significant results were found.

Second, to examine the changes in Comment Receiving across five weeks in each group of students, _t_ tests were conducted on means of frequencies in all possible comparisons. In GTBs, significantly results were found: (1) between weeks 1 and 5 ($t = -2.71$), (2) between weeks 2 and 5 ($t = -2.71$), and (3) between weeks 3 and 5 ($t = -2.71$). Marginally significant results were found: (1) between weeks 1 and 4 ($t = -2.44$), (2) between weeks 2 and 4 ($t = -2.44$), and (3) between weeks 3 and 4 ($t = -2.44$). In ATBs, no significant results were found. In PTBs, marginally significant results were found: (1) between weeks 1 and 3 ($t = -1.88$), (2) between weeks 1 and 4 ($t = -1.99$), (3) between weeks 1 and 5 ($t = -1.93$), (4) between weeks 2 and 3 ($t = -1.88$), (5) between weeks 2 and 4 ($t = -1.99$), and (6) between weeks 2 and 5 ($t = -1.93$).

Insert Figure 12 about here

DISCUSSION

In this section, first, we discuss students' Note Generation in CSILE and examine how different groups of students constructed their thoughts during learning. Second, we discuss the relationship between their metacognitive aspects of learning (i.e., Note Revision, and Monitoring) and the type of their acquired knowledge. Finally, we argue the relationship between students' collective phase of their learning and the type of their acquired knowledge, examining the relationship between the individual and the collective phases of their learning.

The Processes of Note Generation

From the analysis of the differences in frequencies of Note Generation in each week and the changes in frequencies across weeks in each group (Fig. 1), the following points are clear. First, GTBs outperformed the other groups in several weeks, especially in the initial period of learning and the late period of learning. Second, GTBs were constantly generating their thoughts whereas the changes in frequencies in other groups were fluctuated. These results suggest that successful students outperformed unsuccessful students in the quantity of activities. Especially, their better performance seen in the initial period reveals that the successful students are fast starters. In this way, students' activity to externalize their thoughts in the initial period is likely related to the success of their learning in this educational environment.

Then, on what types of thoughts did students spend their efforts? The qualitative differences in Note Generation among three groups of students were examined by the analysis of percentages of each category in Note Generation (Fig. 2, 3, and 4). In this study, students' Note Generation was divided in its content into: (1) Theory, (2) Evidence, and (3) Planning. The results of the analyses of the differences in percentages of categories in each week showed: (1) that, in Theory, GTBs outperformed other two groups of students in the late period of learning; and (2) that, in Evidence, GTBs and PTBs outperformed ATBs in the middle of learning. These results suggest that, even in quality of their activities, successful students spend more effort on their Theory than unsuccessful students, especially in the late period of learning.

The further analyses of the changes in percentages of each category of Note Generation leads us to discuss in more detail the processes of learning. The results are summarized as follows. In the changes in percentages of Theory, ATBs and PTBs were gradually reducing their efforts as their learning went by, whereas GTBs were keeping their efforts although a radical decrease was seen in week 2 (Fig. 2). In the changes in percentages of Evidence, GTBs radically increased their efforts in the initial period and kept their pace. ATBs gradually increased their efforts. The changes in percentages in PTBs were very fluctuated. In the changes in percentages of Planning, GTBs decreased their efforts as their learning went by, whereas ATBs and PTBs continued to generate the type of notes. These results suggest the differences in the courses of learning which different groups of students took. GTBs clearly set their learning goals in the initial period of learning, and they constantly generated both theories and evidence. In contrast, ATBs generated their theories in the initial period, and then moved to generating evidence. PTBs are considered not to have clearly decided their learning goals or to have continued to generate their goals of learning.

In sum, in the analysis of the processes of Note Generation, we found that, as we expected, the processes of learning were different among the different groups of students that acquired different types of knowledge. In next section, we discuss how the processes of students' metacognitive activities such as Note Revision and Monitoring affected their knowledge acquisition.

<u>The Processes of Note Revision and Monitoring</u>

For discussing the relationship between the processes of students' metacognitive activities in learning and the type of their acquired knowledge, we analyzed the frequencies of Note Revision and Monitoring, and furthermore the differences in percentages of critical revision in Theory and Evidence notes.

The results of the analyses of the frequencies of Note Revision showed the following points (Fig. 5). First, GTBs more often revised their previous notes than those in other groups except in week 3. Second, GTBs radically increased the frequency in the initial period of their learning and kept their pace, whereas ATBs and PTBs also increased their Note Revision at the same time, but did not keep pace. In addition, the results of the analyses of Monitoring showed: first, in the initial period of learning, GTBs monitored their learning process more often than ATBs and PTBs did; Second, GTBs gradually increased the frequencies of Monitoring in the late period of learning, whereas ATBs and PTBs did not. These results suggest that successful students spend more effort on their metacognitive activities than unsuccessful students do, and this is consistent with the results of the research on metacognition.

Further analyses of the changes in percentages of critical revision in Theory and Evidence showed the following point (Fig. 7 and 8). Although no significant differences were found among these groups of students in any periods of learning, GTBs and PTBs increased their critical revisions of Evidence in the initial period of learning, and PTBs then decreased their pace. Thus, The results suggest that students' metacognitive activities mainly focus on their Evidence in learning as their learning goes on, but not on their Theory. If so, how do we explain the significant difference in the frequency of Theory between GTBs and the other groups in the late period of learning (Fig. 2)? We discuss this problem in the next section.

<u>The Processes of Other Referring and Comment Receiving</u>

In the analysis of students' metacognitive activities, we found that students focused on critical revision of their Evidence notes rather than Theory notes and the differences among groups were remarkable in the first half of their learning. This suggests that students' metacognitive activities explain the differences in the processes of learning based on Evidence in the first half of learning, but this cannot explain the difference in generating Theory notes in the second half. That is to say, why could GTBs keep generating their theories even in the second half of learning whereas ATBs and PTBs decreased efforts on generating Theory notes. In this section, first, we discuss the changes in students' collective activities such as Other Referring and Comment Receiving, and then argue how their collective activities affect knowledge acquisition.

The results of analyses of frequencies of Other Referring and Comment Receiving showed that GTBs radically increased the frequencies of Other Referring in the second half of learning whereas the other groups did not (Fig. 9). This result suggests that the successful students' collective activity to access others' thoughts kept the high pace of generating Theory notes. Thus, in successful students, their knowledge acquisition is found to be based on interpersonal activities rather than individual activities.

Although it was not so radical, PTBs also increased their Other Referring across their learning. The differences in meanings of Other Referring between

GTBs and PTBs were examined by the analysis of the ways to search the database system (Fig. 10 and 11). We divided all Other Referring activities into Private Search and Public Search. The results of the analyses of changes in percentages of Private and Public Searches revealed that the percentage of Private Search critically increased in GTBs, whereas both percentages of Private and Public Searches gradually increased in PTBs. The results suggest the following differences in the meanings of Other Referring between GTBs and PTBs. GTBs attempted to use their personal resources in the classroom in order to pursue their learning goals, whereas PTBs use their Search activities to collect much information from unspecified others. Thus, based on the results of the analysis of Other Referring, we can say that successful students can effectively manipulate their interpersonal resources, and this further facilitates their knowledge acquisition beyond their individual efforts.

CONCLUSION

In this study, we discussed the processes of students' learning in a new educational environment called "Computer-Supported Intentional Learning Environments (CSILE)." Although our analysis of students' learning is limited within their activities in the computer-mediated environment, we could understand how students' knowledge was constructed through collaboration in the educational environment. The main findings are summarized as follows.

First, as we expected, the processes of learning were critically different among students who acquired different types of knowledge. Successful students clearly set their learning goals in the initial period of their learning, and they spend the remaining time on both generating their theories and evidence. In contrast, unsuccessful students were confused by their continuous planning.

Second, we also found critical differences in their metacognitive activities between successful and unsuccessful students in the environment. Successful students revised their previous thoughts more often than unsuccessful students. Thus, students' metacognitive activities are related to the differences in students' knowledge acquisition. However, the results of the analysis of students' metacognitive activities could not fully explain the process of successful students' learning. Students were found to focus metacognitively on their Evidence that supported their previous theories, but not on the theories themselves. Thus, students' metacognitive activities did not explain how successful students could continue to generate new theories in the late period of learning.

Third, the above problem was examined by analyzing students' collective activities such as Other Referring and Comment Receiving. Although we did not see critical differences in Comment Receiving, we found some important results to explain the process of successful learners' knowledge acquisition in Other Referring. Successful students attempted to use their personal resources by privately accessing others' thoughts whereas unsuccessful students did not.

In sum, we found that both metacognitive and collective activities in peer collaboration were important for students to succeed in their learning. In particular, collective activities in the late period of learning facilitates students' knowledge acquisition beyond their individual work in the initial period of learning. Thus, successful students are likely to recognize their interpersonal circumstances for their purposes to exchange their thoughts.

Finally, this study was conducted only based on students' computer communication. This phenomenon is a-tip-of-iceberg of their peer collaboration in the classroom. They can communicate with their friends outside of the educational environment, and they can also co-construct their knowledge by interacting with friends in front of computers. These suggest that we should discuss what is going on in the classroom, and integrate their activities in the database system and in the classroom. We are sure that the new studies of both students' learning processes on computers and in their classrooms will provide us with more powerful mechanism of peer collaboration in Computer-Supported Intentional Learning Environments.

REFERENCES

Azmitia, M. (1988). Peer Interaction and Problem Solving: When Are Two Heads Better Than One? Child Development, 59, 87-96.

Azmitia, M. & Perlmutter, M. (1990). Social Influences on Children's Cognition: State of the Art and Future Directions. In H. W. Reese (Eds.), Advances in Child Development and Behavior (pp. 89-144).

Bereiter, C. & Scardamalia, M. (1989). Intentional Learning as a Goal of Instruction. In L. B. Resnick (Ed.), Knowing, learning, and instruction: Essays in Honor of Robert Glaser (pp. 361-392). Hillsdale NJ: Lawrence Erlbaum Associates.

Brown, A. L. & Campione, J. C. (1990). Communities of Learning and Thinking: or a Context by any Other Name. Human Development, 21, 108-125.

Brown, A. L. & Palincsar, A. S. (1989). Guided, Cooperative Learning and Individual Knowledge Acquisition. In L. B. Resnick (Ed.), Knowing, learning, and instruction: Essays in Honor of Robert Glaser (pp. 393-451). Hillsdale NJ: Lawrence Erlbaum Associates.

Collins, A., Brown, J. S. & Newman, S. E. (1989). Cognitive Apprenticeship: Teaching the Crafts of Reading, Writing, and Mathematics. In L. B. Resnick (Ed.), Knowing, learning, and instruction: Essays in honor of Robert Glaser (pp. 453-494). Hillsdale NJ: Lawrence Erlbaum Associates, Inc.

Forman, E. A. & Cazden, C. B. (1985). Exploring Vygotskian perspectives in education: the cognitive value of peer interaction. In J. V. Wertsch (Ed.), Culture, communication, and cognition: Vygotskian perspective (Pp. 323-347). Cambridge: Cambridge University Press.

Palincsar, A. S. & Brown, A. L. (1984). Reciprocal teaching of comprehension-fostering and monitoring activities. Cognition and Instruction, 1 (2), 117-175.

Perret-Clermont, A. N. (1980). Social Interaction and Cognitive Development in Children. London: Academic Press.

Rogoff, B. (1990). APPRENTICESHIP IN THINKING: Cognitive Development in Social Context. New York: Oxford University Press.

Scardamalia, M. & Bereiter, C. (1991) Higher levels of agency for children in knowledge-building: A challenge for the design of new knowledge media. The Journal of the Learning Sciences, 1 (1), 37-68.

Scardamalia, M., Bereiter, C., McLean, R. S., Swallow, J. & Woodruff, E. (1989) Computer supported intentional learning environments. Journal of Educational Computing Research, 5, 51-68.

Slavin, R. E. (1983). COOPERATIVE LEARNING. NY: Longman.

Tudge, J. R. H. (in press). Processes and Consequences of Peer Collaboration: Vygotskian Analysis. Child Development.

Vygotsky, L. S. (1978). Mind in society. Cambridge, MA: Harvard University Press.

Table 1. An Example of the Computer Tracking File

CS 91-02-27-12:27:30 301

NB 91-02-27-12:27:31

NW 91-02-27-12:53:02 2163

A-> 91-02-27-12:53:02 2163

I THINK ELECTRICITY WORKS LIKE THIS:

First you need some source of energy, which is contained in batteries and can be made by turning something very rapidly

like with a hand generator.To get the energy from the source to the light bulb you need an electricity conductor.The energy then flows through the electricity conductor at an amazing speed.

When the electricity goes through the tiny wires in the light bulb you can see the electricity and that is how I think the bulb is lit.

When the electricity comes out of the light bulb it goes in to a wire and then back to the source where it repeats the circle until the bulb is either turned of burned out. <-A

TO 91-02-27-12:53:02 2163 Electricity

Appendix A. Examples of Evaluated Students' Theories

An Example of Theory Evaluated as Score 1

I THINK ELECTRICITY WORKS LIKE THIS:

My theory is if you don't have a power source you won't have any electricity. The power source could be a battery , hand generator , and there are also many other sources. There is also natural energy like windmills , solar electricity, or turbines , but these things cannot be turned on and off. Then the electricity travels through a wire or other things and goes to houses , factories , schools , and other places. Say it went to a light bulb it would go in through the light bulb and then go back to the power source.Then it would keep on doing that until the light bulb was turned off.

An Example of Theory Evaluated as Score 2

I THINK ELECTRICITY WORKS LIKE THIS:

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Our class recieved a kit on electricity. We were divided into groups and conducted experiments to see how electricity works.

In our experiments we learned how to set up circuits, and how they work. Almost all of our electricity comes from power plants.

The electricity in a power plant could be formed by very large electromagnets. Wires or thick metal cables would be attached to the electromagnet, hooked up to these wires would be many of the switches and other materials used to create an electric current for a city.

I think that the circuit used to create the electricity would have to be parallel because you can keep adding on to the circuit. This circuit will stay on even if a light is turned off in a house.

Once a full circuit is built the electricity would start to run from its source through all of the wires and other materials into the object and then back to the power source. This will work until the source runs out or the object is broken.

(to be continued)

Appendix A (continued). Examples Evaluated of Students' Theories

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An Example of Theory Evaluated as Score 3

MY THEORY OF HOW CIRCUITS AND LIGHT BULBS WORK

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While working on our electricity experiments, we observed many different results from the light bulb and how circuits work in many situations. I have decided to write this note in order to explain how light bulbs and circuits work when they are used together.

In our experiments we used many different types of conductors that were small. While conducting the experiments we tried to think how these experiments would work if the conductors were much bigger and were used in an enormous current used to create electricity for a city.

All of the power that is used so we can have light comes from a source, that source may be an electromagnet that is ten times bigger. If the electromagnet is in a power plant the electricity would have to travel from the electromagnet, out of the power plant through wires, and out into an electric current. This current is made up of a circuit so it can travel all over the city. If you plugged one into a socket you would be adding another material to the circuit that would create a larger circuit. If you turned the light off or unplugged the lamp, you would be taking a material out of the current and making it smaller. I think the way a light bulb works when it is in a circuit is the beginning of the circuit would be at a power plant, the electricity would flow through the wires under the ground and through the cable poles on the street, into somebody's house, into the wires, and to the socket, into the plugs wires and through the light bulb and back into the current. The reason why I think that the circuit is parallel because if the circuit was series the other lights would go out if any of the other lights were turned out. This would not happen if it was parallel, for the electricity would have another way to flow.

(to be continued)

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Append:x A (continued). Examples of Evaluated Students' Theories

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An Example of Theory Evaluated as Score 4

*** ELECTRICITY***

Try this:

Blow up two balloons. Rub them on a woollen sweater(it might work if you rub it on your hair too) and put it on the wall. It will stick to the wall.
Why does it stick to the wall?
I think the explanation for this is, when you rubbed the balloon on your woollen sweater(or on your hair), some of the electrons from the sweater(or your hair) went into the balloon. So then the balloon had more electrons and it gave of the extra electrons to the wall. But after a short time the balloon will fall from the wall. I think that is because the extra electrons in the balloon had leaked away.
****
Try this:
Blow up two balloons.Tie them together. Then rub the balloons on a woollen sweater or on your hair. Put the balloons down on a table with the sides that you rubed on your sweater or your hair next to each other. As soon as you let go, the balloons will move apart. This is because both of the balloons have got some electrons from the sweater or your hair and they are negatively charged.

An Example of Theory Evaluated as Score 5

Wires and Light Bulbs
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Electricity flows through wires, after a while the wires get hot, this is why they are insulated. Some wires make it easy for electricity to flow through and others make it hard. The ones which make it harder get hotter faster.Electricity flows through wires, everyone knows that but it is not that simple. What really happens is that electrons(which are negative) are jumping from one atom to another, all this is happening so quickly that it is seen as a flash. This is an electric current. Some times the electrons bump into the atoms, this make them vibrate, that is why the wire gets so hot.

The Light Bulb also know as the incandesant lamp was invented by Thomas Edison in 1879. While inventing the light bulb Edison tried to make the design without the bulb.For some reason it did not work. He thought this was because the oxygen in the air made the light burn out. He then decided to place a glass bulb over the wires and it worked!<-A

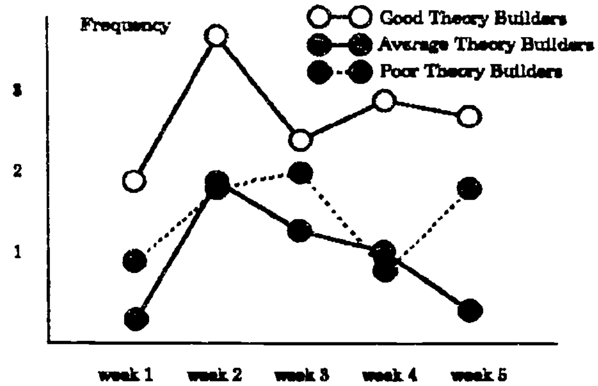

Figure 1. The Changes in Frequencies of Note Generation Across Five Weeks

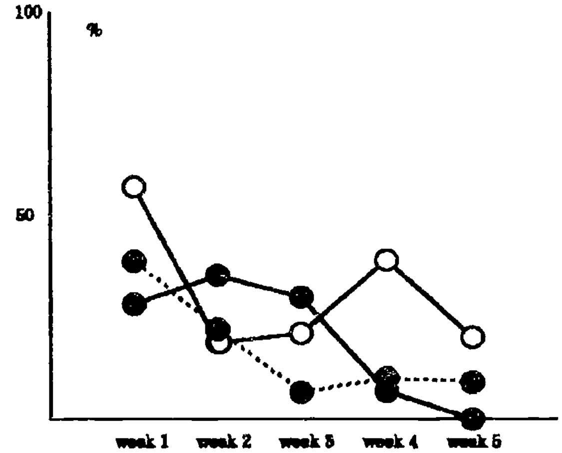

Figure 2. The Changes in Percentages of Theory in Note Generation Across Weeks

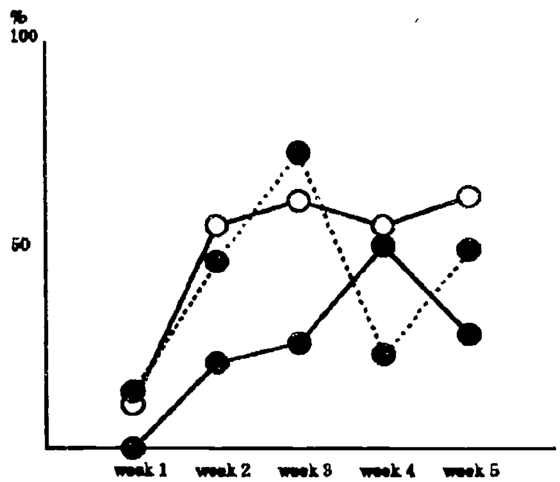

Figure 3. The Changes in Percentages of Evidence in Note Generation Across Weeks

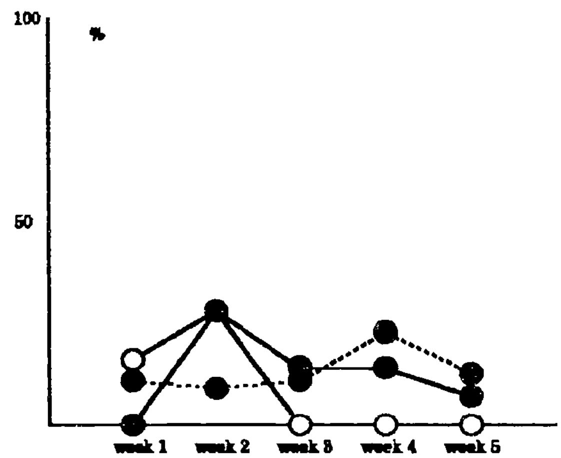

Figure 4. The Changes in Percentages of Planning in Note Generation Across Weeks

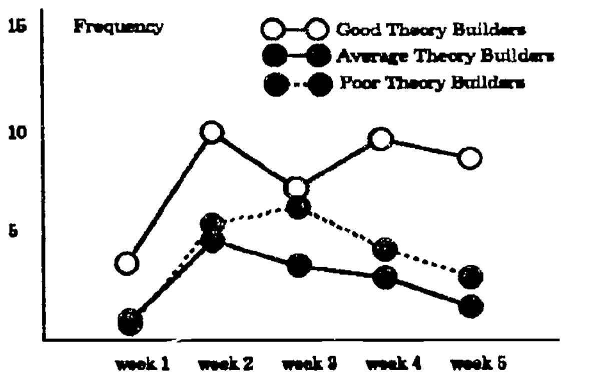

Figure 5. The Changes in Frequencies of Note Revision Across Weeks

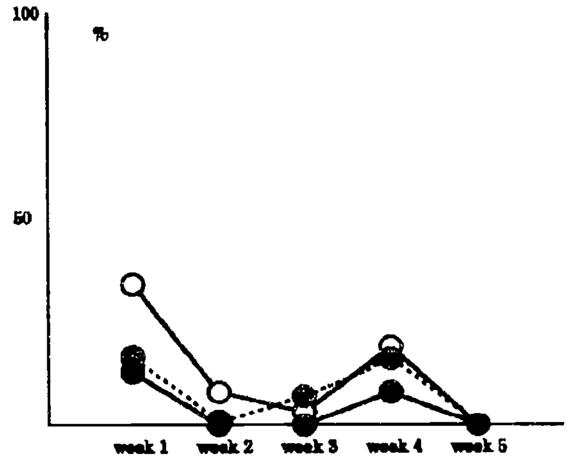

Figure 6. The Changes in Percentages of Critical Revisions in Previous Theory Across Weeks

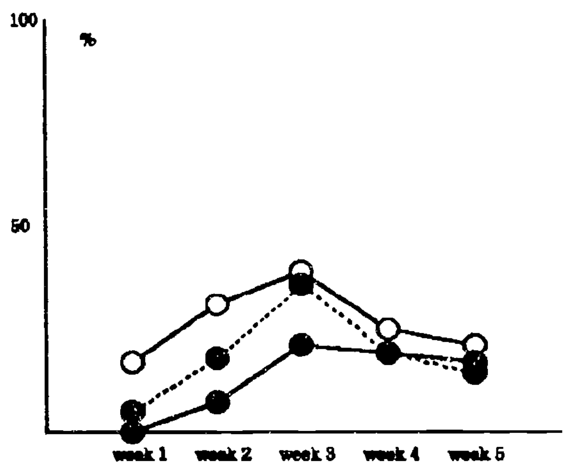

Figure 7. The Changes in Percentages of Critical Revision in Previous Evidence Across Weeks

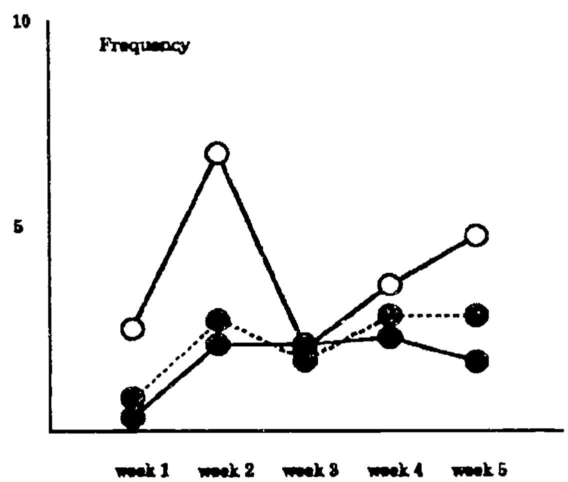

Figure 8. The Changes in Frequencies of Monitoring Across Weeks

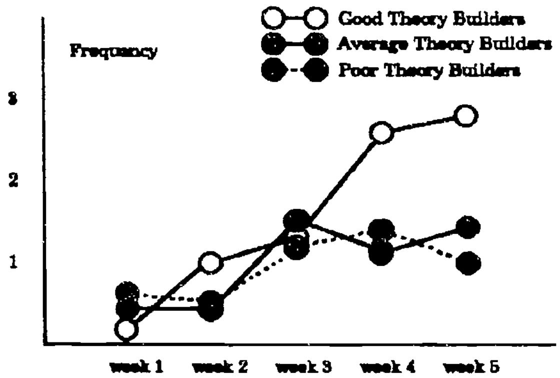

Figure 9. The Changes in Frequencies of Other Referring Across Weeks

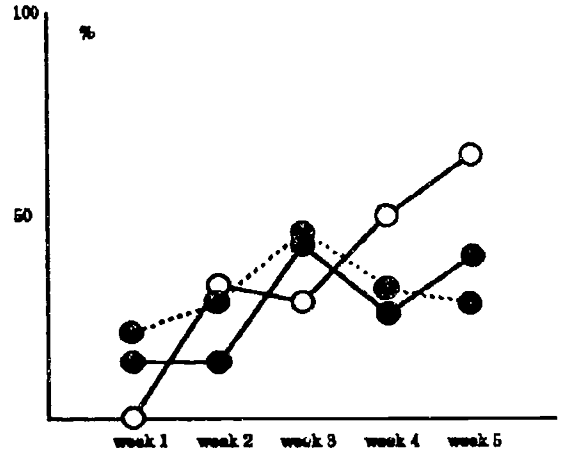

Figure 10. The Changes in Percentages of Private Search in Other Referring Activities Across Weeks

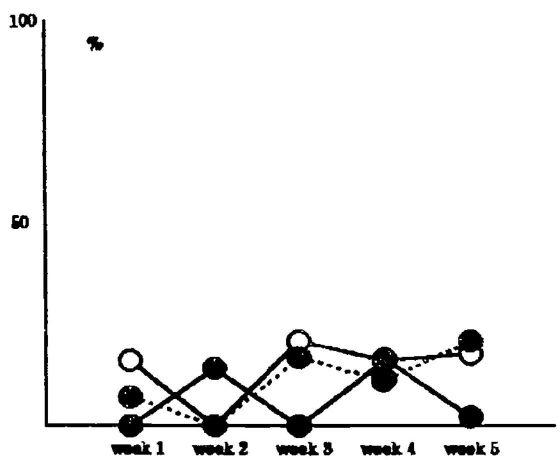

Figure 11. The Changes in Percentages of Public Search in Other Referring Activities Across Weeks

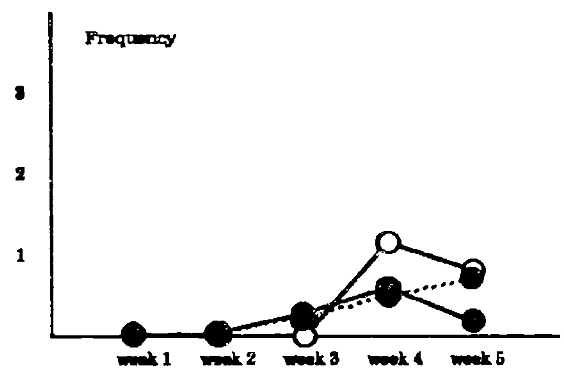

Figure 12. The Changes in Frequencies of Comment Receiving Across Weeks