

Analysis of Problem-Solving-Based Online Asynchronous Discussion Pattern

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ABSTRACT

This research explores the process of asynchronous problem-solving-based discussion activities and aims to understand limitations likely to arise during learners' problem-solving discussions. The research has combined lag-sequential analysis and quantitative content analysis, and expects to use such analyzing methods to further understand the sequential pattern of students' problem-solving discussion behaviors and knowledge-construction levels. In order to avoid influence caused by teachers' subjective guiding methods and ensure objective observations, we observed learners' online problem-solving discussions without intervention or guidance from the teachers. From the sequential pattern derived, we have not only induced a pattern of students' discussion behavior but also discovered that, compared to discussion activity based on a single topic appointed by the teacher, the problem-solving online discussion activity is more helpful for students' knowledge construction. In addition, this research also revealed certain limitations toward the content and behavior of students' discussion without teachers' guidance. Based on the results, this paper proposes a strategy in which teachers can intervene and guide, which is expected to enhance the depth of students' discussion and knowledge construction when a teacher is applying a problem-based learning activity.

Keyword

Problem solving, Asynchronous discussion, Knowledge construction, Problem-based learning, Sequential analysis

Introduction

Over recent years, the application of a problem-solving strategy for learning has become progressively more popular, and problem-solving models have been discussed extensively (Mayer, 1992; D'Zurilla & Goldfried, 1971). Through problem-based learning, students can raise questions, collect information, discuss with each other, propose solutions, and share results, which further trains students for problem solving. Due to the development of learning technology, teachers' request for students' asynchronous online discussion has been extensively applied in actual learning scenarios, and many researchers have also explored the benefits of asynchronous discussion toward learning (Vonderwell, 2003; Bodzin & Park, 2000; Henri, 1992). In view of this, the combination of online discussion and problem-solving activities can establish a problem-solving-based online discussion learning activity. Within the activity, teachers can define the scope of the problem and allow students to raise various questions among themselves. After that, students can collect information from the Internet and discuss possible solutions on the Internet, as well as share their solutions. This encourages students to solve various problems and construct their knowledge. During the process, teachers will provide adequate guidance to improve the quality of students' discussion.

Many researchers have discovered that the design of online discussion activities imposes great influence on the quality of online discussion (Patricia & Dabbagh, 2005; Hewitt, 2003; Vonderwell, 2003; Swan et al., 2000; Vrasidas & McIsaac, 1999). In order to design more suitable problem-solving online discussion activities, adequate guidance from teachers and strategies for intervention are key; furthermore, the exploration of how teachers shall diagnose learners' discussion status and post suitable articles, which guide students to solve the problems correctly and utilize more effective problem-solving skills, will be an important topic that is worth researching and will help improve

achievement of problem-solving learning. To address this aspect, the observation of learners' discussion processes is helpful to understand the limitation of students' discussion, and a systematic guiding strategy can be inferred. At present, the research that executes behavior process analysis, particularly against the process of problem-solving discussion, is rather limited. If the learners' problem-solving online discussions, carried out without teachers' intervention, can be further observed, the difficulties and limitations experienced by students when they carry out problem-solving discussion by themselves can be analyzed. The influence caused by subjective guidance from different teachers can be prevented, which ensures the objectivity of observation. From these results, it will be easier to design more adequate guiding strategies.

Many researchers have analyzed the messages of asynchronous discussion (Hewitt, 2005; Gunawardena, Lowe, & Anderson, 1997; Newman, Webb, & Cochrane, 1995; Levin, Kim, & Riel, 1990; Hou, Chang, & Sung, 2007), and coding schemes had been developed for online discussion content analysis (Henri, 1992; Gunawardena, Lowe, & Anderson, 1997). In addition, some researchers also use social network analysis to understand the patterns of social interaction between learners (Zhu, 2006).

Content analysis mainly provides data of frequency and percentage to focus understanding of discussion content; social network analysis, on the other hand, focuses on understanding the style of social interactions between individual students. However, the mere utilization of these methods provides rather limited inference on understanding sequential relationships between each type of coded discussion content, and the overall sequential pattern of a learning community's online problem-solving discussion cannot be inferred by means of statistical examination (e.g., after discussion of a certain content, what type of discussion content immediately follows? Is the sequential continuity significant? In overall speaking, what type of sequential pattern is formed during the discussion?). Such a sequential pattern can be compared with theoretical models of problem solving; it also helps us to understand more clearly the practical process and limitations of students' problem-solving discussions. Possible reasons can be inferred from this (e.g., Why does the learner come to a conclusion hastily or stop the discussion?). The timing of a teacher's intervention and guidance strategy can also be inferred, which makes a behavioral pattern that is worth analysis. However, the application of lag-sequential analysis (Bakeman & Gottman, 1997) will be more capable of inferring sequential speculative patterns of students' overall online discussion, as compared to other research methods. Such a method can individually examine and observe whether the sequential relationship between each discussion behavior has been achieved significantly, and it has been progressively used on a number of research studies related to online discussion (Jeong, 2003; England, 1985; King & Roblyer, 1984; Hou, Chang, & Sung, 2007). In order to understand a learner's level of knowledge construction during problem-solving discussions, this research has adopted the coding scheme interaction analysis model (IAM) (Gunawardena, Lowe, & Anderson, 1997), which is often used to evaluate the level of knowledge construction during online discussions, so the level of knowledge construction and the limitations of students' online problem-solving discussions can be evaluated.

Therefore, the purposes of this research are as follows:

1. Conduct an online problem-solving learning activity and observe students' processes of online problem-solving discussions without teachers' intervention and guidance.
2. Combine lag-sequential analysis and content analysis, which analyzes sequential pattern and level of knowledge construction from students' problem-solving discussions.
3. Discuss limitations of students' self discussion, according to the results, and suggest strategies for teachers' intervention of guidance.

Coding scheme

This research explores students' problem-solving processes, including the behavioral sequential pattern and knowledge-construction level during students' problem-solving discussions. Therefore, the design of the coding schemes must be based on these two dimensions, so the results derived from the observations can be properly coded. The details of the coding schemes for these two dimensions will be discussed in the following sections.

Coding scheme for problem-solving discussion behaviors

Many researches have constructed coding schemes for what they want to explore in the content and process of online discussions, for example social interaction (Henri, 1992; Burnett, 2000), knowledge construction (Gunawardena,

Lowe, & Anderson, 1997), and critical thinking (Newman, Webb, & Cochrane, 1995). Since this research aims to explore the process of problem-solving discussion behaviors, a coding scheme for problem-solving discussion behaviors is needed to analyze online discussions. For this part, we have studied previous research related to the process of problem solving (Mayer, 1992; D’Zurilla & Goldfried, 1971). In organizing and summarizing past research, we have identified commonalities and organized these commonalities into five codes applicable to the analysis of problem-solving-based online discussions (as shown in Table 1). Furthermore, we have also provided a set of examples to give a more precise description of the meaning of each code and to illustrate a possible process of problem-solving-based online discussion.

Table 1. Coding scheme for problem solving discussion contents

Code	Phase	Description	Discussion example
P1	Propose, define, and clarify problem	Propose problem or clarify the definition of the problem	What is the process of forming an ice age?
P2	Provide solutions or information for possible answers	Provide information or propose solutions to the problem (provide information for partial or full solution)	The data I found is as follows: As for the cause of the ice age, the current explanation is the outward expansion of revolution orbit for Earth.
P3	Compare, discuss, and analyze	Analyze, compare, and comment on others’ opinions, solutions, or collected information	I think the statement from the classmate above is not thorough, and there is no explanation as to why the outward expansion of revolution orbit causes an ice age. I believe that there are more reasons, and a sudden temperature drop at that time might cause an ice age.
P4	Organize and form conclusions	Organize proposed solutions or comments and form conclusions for solutions	Summing up opinions and information from classmates above, I have concluded that outward expansion of an orbit’s revolution could cause an ice age because, under such state, Earth would be further away from the sun, the light and heat reaching the ground reduced, and the temperature lowered. Because the angle of inclination for Earth’s axis increased, the ice age was formed!
P5	Others	Messages not related to the subject of discussions	With this discussion of ice ages during winter, I feel chilly...

Coding scheme for the levels of knowledge construction

For another part of this research, regarding knowledge construction that takes place in the discussions, we used the interaction analysis model (IAM), which was proposed by Gunawardena, Lowe, and Anderson (1997). This coding scheme divides the discussion content into five phases (as shown in Table 2), which have been frequently used to analyze online discussions (Marra, Moore, & Klimczak, 2004; Jeong, 2003; Sing & Khine, 2006). This research uses

this coding system to explore the level of knowledge construction of each posted message. Using the coding system proven by a number of researchers will help to increase the validity of the content analysis (Rourke & Anderson, 2004).

Table 2. Gunawardena, Lowe, & Anderson's (1997) Interaction Analysis Model

Code	Phase	Operation
C1	Sharing or comparing information about discussion topics	Statement of observation or opinion; statement of agreement among participants
C2	Discovery and exploration of dissonance or inconsistency among participants	Identifying areas of disagreement, asking, or answering questions to clarify disagreement
C3	Negotiation of meaning or co-construction of knowledge	Negotiating the meaning of terms and negotiation of the relative weight to be used for various agreement
C4	Testing and modification of proposed synthesis or co-construction	Testing the proposed new knowledge against existing cognitive schema, personal experience, or other sources
C5	Agreement statement(s) or application of newly constructed meaning	Summarizing agreement and metacognitive statements that show new knowledge construction

Method

This research combined lag-sequential analysis and content analysis to analyze the sequential pattern and level of knowledge construction of students' problem-solving discussions. The recorded content of students' online problem-solving discussions without teachers' intervention and guidance were coded with the schemes in Tables 1 and 2. Content analysis was carried out on the coded data, and the behavioral pattern was then inferred via lag-sequential analysis. The application of such a method can progressively examine whether a sequence between each type of behavior reaches significant statistics, and the sequential relationship diagram derived after progressive examination will provide a greater foundation of inference towards explaining the students' behavior pattern because each behavioral sequence undergoes statistical analysis instead of being merely descriptive data presented as a ratio or quantity, which can be offered as a reference for consequent discussion and suggestions.

Participants

The participants in this research were 43 third-year students who major in information management at a college of technology. The course they were taking is management information system, which is a three-credit major course concerning basic theories of information management and case studies.

Tools

To observe students' online discussion behaviors, an online learning environment must be provided for teaching implementation and this tool must also have discussion forums to record the process of the discussions. Here, we used the web-based instructional design environment (WIDE) online learning platform (Chang, Sung, & Hou, 2006). This platform was designed based on instructional design theories and provides an environment that enables teachers and students to teach and learn via the Internet.

This research utilized the asynchronous discussion forum of WIDE as the tool for online discussions. Students are able to browse all posted topics as well as create new topics. By clicking on a topic link, students can enter the topic page to view the discussion messages and post responses.

Procedure

In this study, in order to truly reflect difficulties and limitations experienced by students during their self-directed problem-solving discussions, avoid influence caused by subjective guidance of certain teachers, and ensure objective observations so that inferences can be made on how teachers should intervene with guidance, this research executed a problem-solving-based learning activity from April to June 2005. In the activity, teachers drafted only the scope of topics for students' questions and allowed the students to raise questions and perform problem-solving discussions themselves. After an explanation of the scope of topics, the teacher no longer intervened in the students' discussions. The details of procedures are as follows:

1. During lessons in April, the teachers gave lectures on e-commerce.
2. After the lectures, the teachers requested that students raise various questions related to the topic of e-commerce and post these questions in the forum, which acted as the discussion topics (each topic had to have a title in question form instead of only a general statement that did not raise an issue). During the 45-day period of discussion activity from May to mid-June, students could enter the forum and browse a list of all problem topics (the list contained problem titles raised by all peers), enter the page of a specific problem by clicking the title hyperlink, and then post their responding messages, which included various answers, information, discussion, and conclusions.
3. The teachers would explain that participation of this discussion activity would be counted as part of the total semester scores and that during the activity, the teachers would not intervene or guide students' discussion behavior in either the physical classroom or the forum. In addition, all discussion content was recorded in the database.

Data Analysis

In addition to un-responded topics, 112 topics received responses (with a total of 517 messages). The messages were then coded based on the above-mentioned problem-solving coding scheme and IAM knowledge construction coding scheme by a rater from our research team. The rater received relevant coding training for this study and has a master's degree in education.

The problem topics posted by each student contained several responses related to each topic, and messages under each topic were arranged based on the posting time. The rater would perform the coding according to the content of each message. When one message contained more than two codes, the codes were arranged in order of time (for example, if the first paragraph of a message was P2 and the second paragraph was P3, this message was then coded as P2, P3). After messages from all problem topics were coded based on the above method, each topic was given a set of problem-solving discussion codes and a set of knowledge-construction codes. To test the reliability of the coding contents, we randomly selected 254 messages (approximately half of all messages) and transferred them to a second rater, who received the same coding training of this study and also has a master's degree in education, to analyze and ensure reliability of the coding. The inter-rater kappa reliability of the coding of problem-solving discussions was 0.624 ($p < .01$), and the kappa reliability for knowledge construction was 0.686 ($p < .01$). Both sets were statistically significant, and the coded data were then put through sequential analysis and knowledge construction content analysis.

Results and discussion

Sequential analysis for problem-solving-based online discussion

A total of 112 topics contained 517 response messages; 612 codes were obtained after coding, in accordance with the coding scheme in Table 1. Since sequential analysis focuses on observing the sequential approach of consecutive behaviors (one specific behavior follows a certain behavior), we calculated the frequency of each behavioral category immediately following another behavioral category. As shown in Table 3, each row represents the initial behavior; each column is the code of the behavior that follows immediately after a row-behavior has occurred. The numbers in the table represent the total number of times (total frequency) a column behavior follows immediately after a row behavior (for example, the number 60 in row 2, column 3 means that "P3 occurring immediately after P2" happened 60 times). To continue the deduction on each sequential relationship and determine whether they reach statistical significance, we conducted a sequential analysis on the data listed in Table 3 (Bakeman & Gottman, 1997).

Results were organized into Table 4. When the z -value of a sequence was larger than +1.96, it means that the degree of continuity reached statistical significance ($p < .05$), and we deduced a behavioral transfer diagram based on this table (as shown in Figure 1).

Table 3. Frequency transition table

	P1	P2	P3	P4	P5
P1	3	118	2	0	0
P2	6	178	60	34	5
P3	3	49	6	5	1
P4	0	17	7	0	2
P5	0	4	0	0	0

Table 4. Adjusted residuals table (z-scores)

	P1	P2	P3	P4	P5
P1	0.04	3.91	-5.08	-4.11	-1.86
P2	-0.70	-4.67	6.21	5.85	0.51
P3	1.35	0.36	-1.33	0.00	-0.03
P4	-0.83	-0.49	1.66	-1.50	2.59
P5	-0.31	0.63	-0.78	-0.56	-0.26

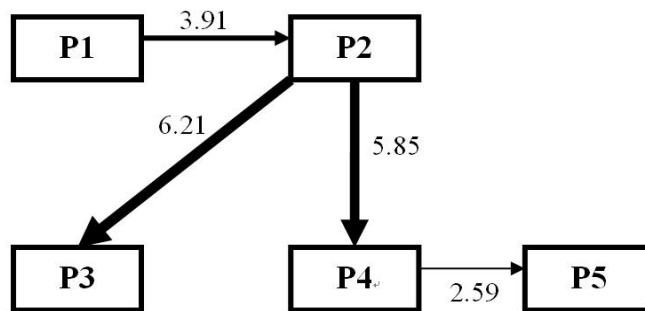


Figure 1. Behavioral transfer diagram of problem-solving-based discussion

Figure 1 presents all sequences in Table 4 that have reached a level of significance. The values specified in the figure represent the z -value of each sequence, the thickness of the arrow represents the level of significance, and each arrow points in the direction of the transfer. Data shown in Table 3 and Figure 1 provided the pattern of behaviors that occurred during online discussions. From the data, we derived the following pattern of behavioral transfer.

The sequences that reached significance during online problem-solving discussions are P1→P2, P2→P3, P2→P4, and P4→P5. P1 (propose or clarify problem) behavior was most frequently followed by P2 (propose solutions), and P2 was often followed by two different paths. P2→P3 (compare and comment) was more frequent, and P2→P4 (organize and form conclusions) also occurred. P4 is most frequently followed by P5 (irrelevant messages).

From the above, we can see the sequential approach of students' online discussion. We found that the sequential pattern derived from students' discussions was basically similar to the procedural approach of problem-solving models proposed in past research (Mayer, 1992; D'Zurilla & Goldfried, 1971). Problems were initiated, solutions were then proposed, and comparisons or conclusions were given to the proposed solutions or collected information.

To a certain degree, the approach also verified the pattern of the theoretic model; this also indicated that, even though there was no teacher guidance, students' behavioral patterns in the online discussions still complied with the theoretical sequence of problem solving to a certain level.

However, this research also discovered limitations of the students' self-monitored problem-solving discussions. Ideally speaking, the depth of the discussions may be higher, and more interactions of discussion behaviors may occur during higher quality problem-solving discussions. For example, after comparing and commenting on others' opinions (P3), the solution proposed initially should be refined to a certain level, new solutions of other dimensions may be proposed (P3→P2), and other participants may be inspired to propose organized conclusions, which would facilitate the choice of the best answer (P3→P4). Furthermore, opinions or comparisons at a more profound level could arise after a person proposed a conclusion (P4→P3), or new solutions of different dimensions could be derived (P4→P2). Moreover, in the process of in-depth discussion, new problems could be established in stages P2, P3, or P4 (P2→P1, P3→P1, P4→P1) to form a dynamic discussion model of greater depth. However, we did not detect any of the above behavioral sequences reaching a level of significance in this study.

From observing the sequential pattern discovered, we noted limitations of students' discussion as follows: after proposing solutions, it is possible that most students only carry out brief discussions or stop the discussion directly after a conclusion is made, and the discussion can even end before really even beginning or reaching conclusions. The reason for this can possibly relate to learners' often directly viewing online resources as the *answers* to problems without in-depth cognitive processing or discussion (Wallace & Kupperman, 1997; Chang & McDaniel, 1995). In such situations, the depth of discussion is likely to be insufficient; nevertheless, learners' capacity to conduct meaningful analysis of the information collected from the Internet is important (Land & Greene, 2000). In general, learners may experience bottlenecks, such as insufficient information or inadequate deduction (Krajcik et al., 1998). When this occurs, teachers' assistance will be needed. To promote in-depth discussion, the behavioral sequential pattern derived from this empirical observation (without teachers' interception) will provide important information for teachers' interception and guidance, which is another objective of this research.

We suggest that teachers can observe and intervene to promote the sequences that were lacking but could improve the discussions' depth (stated above as P2→P1, P3→P1, P4→P1, P3→P2, P3→P4, P4→P3, and P4 → P2). When students' discussions are lacking these sequences, it is time for teachers to intervene and post articles as guidance. As shown in Figure 2, the solid arrows represent the discussion's behavioral pattern found in this research without any form of teacher interception, and the dotted arrows represent the enhanced sequences that teachers could intervene in the discussions. Actual practice will depend on the teaching scenarios and students' background. In the following section, we have also provided suggestions for designing online problem-solving discussion activities:

1. Arrange discussion procedures into stages. Ask students to carry out discussions step by step following the prescribed order: P1→P2→P3→P4. In such an arrangement, students do not skip through discussions and go straight to making conclusions. Rewards (i.e., with reward credits or points) may also be used to encourage rethinking and backtracking (i.e., P3→P2 or P4→P3), which will promote the proposal of new solutions or derivation of new problems; in turn, new knowledge as well as a greater depth of discussion will be formed through the dialogues.
2. Teachers provide timely guidance and feedback. Teachers check on students' discussions and interactions regularly, as well as guide students into the enhancing paths (represented by the dotted lines in Figure 2). For example: teachers may post messages to collect more online information, ask new questions, or guide students into secondary thoughts or the establishment of new problems.
3. Automatic guidance/feedback system: the intelligent agent technology is capable of playing the role of automatic feedback and guidance (Aroyo & Kommers, 1999); its function is capable of leading the discussions through optimized sequences represented by the dotted arrows, which can be embedded into the online learning systems to provide timely guidance. For example, the data-mining technique is capable of providing relevant information or prompts and helps students refer to more relevant information during discussion, which leads to more extensive and in-depth discussion.

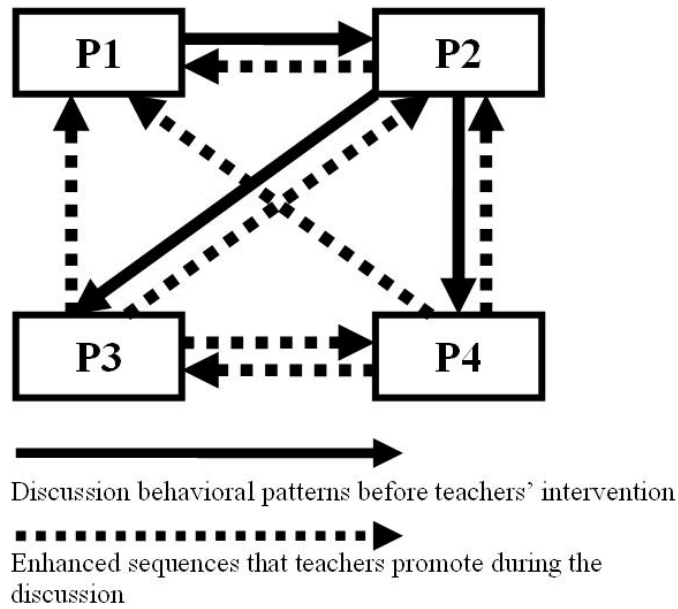


Figure 2. Students' online problem-solving discussions with **teachers'** intervention

Analysis of knowledge construction level in problem-solving discussions

In order to understand the depth of knowledge construction from students' discussions, a total of 112 topics were produced after coding via the scheme in Table 2. We derived a total of 510 codes after deleting the messages that were irrelevant to knowledge construction. The frequency and percentage of each code are shown in Figure 3.

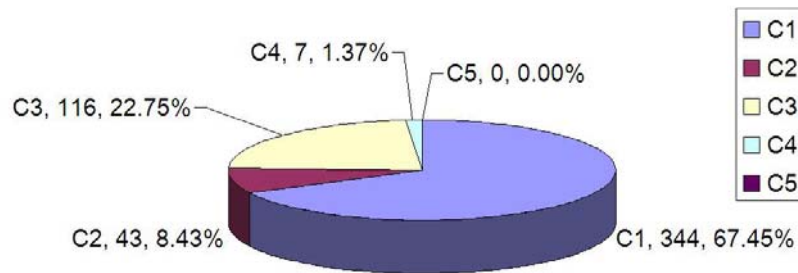


Figure 3. Percentage of problem-solving online discussion knowledge construction codes

From the distribution of the codes, we find that knowledge construction in the process of problem-solving-based discussions concentrated mostly in C1 (sharing/comparing information, 67.45%), C3 (negotiation of meaning/co-construction of knowledge, 22.75%), and C2 (discovery and exploration of dissonance or inconsistency among participants, 8.43%). This result shows that it is hard to achieve the C4 and C5 levels of knowledge construction, which is similar to other research conducted according to Gunawardena, Lowe, and Anderson's coding system (Gunawardena, Lowe, & Anderson, 1997; Jeong, 2003). Jeong (2003) also used the IAM to explore the state of knowledge construction from general online discussion activity; the teacher assigned the discussion topic, and,

instead of problem-solving-based discussion activity, the students discussed the topic freely. The percentages were C1, 93.7%; C2, 2.4%; C3, 1.9%; C4, 1.0%; C5, 1.9%. If we compare our results with Jeong's results, C2 (discovery and exploration of dissonance or inconsistency among participants) and C3 (negotiation of meaning/co-construction of knowledge) had higher and more notable percentages in our outcome. It is possible that students in the problem-solving teaching activities have a scenario for problem solving; therefore, more comparison and searching were needed. This also indicates that the problem-solving online discussion activity is more helpful in achieving higher levels of knowledge construction for students, as compared to general discussion activity with topics assigned by teachers.

In addition to information sharing and comparison (C1), this research also found that C3 was the second highest, and C3 was higher than C2. This reflects that the student focuses more on further exploration of knowledge during the process of problem solving, in addition to information sharing and comparison, which also indicates that utilization of this learning activity will inspire students to further explore knowledge.

As for the limitations of knowledge construction from the students' discussion, however, C4 (testing and modification of proposed synthesis or co-construction) and C5 (agreement statement(s)/application of newly constructed meaning) are the hardest levels to achieve. In particular, C5 was not present in this research, and this finding conforms to the results of behavioral sequence analysis derived in this research. From the sequential analysis, we also found that students did not derive new problems from thorough discussion (e.g., P2→P1, P3→P1, or P4→P1).

In order to further improve the level of students' knowledge construction, teachers can try to intervene and guide students to achieve levels C4 and C5 of knowledge construction. For example, to promote students' discussion to level C4 of knowledge construction, teachers can post messages that encourage students to link experience and relationships between knowledge already learnt and the current topic. As for promoting students' discussion to C5, teachers can guide students with supplemental new information to derive new problems; alternatively, teachers can raise new problems and allow students to form new knowledge via problem solving.

Table 5. Extraction of an actual discussion example (Student no. S003)

Problem topic: What are the possibility and impact of tax levy for internet shopping in Taiwan?					
Message #	Author	Content	Time	P-code	C-code
#7201	S003	I believed that everyone has heard about the news a while ago that the government is trying to levy tax on Internet shops. I don't want to ask whether this policy is "correct or wrong," but I would like to know what everyone's viewpoint is on possibility of executing this policy? In addition, I would also like to ask you guys about what do you think the level of impacting e-business is if this policy is put into practice?	2005/5/17 23:02:31	P1	C1
#7202	S045	The following is a news report I for-warded: <i>(the news described about statement from government and attitude of response from 2 major e-commerce sites, content of news forwarded is omitted)</i>	2005/5/17 23:12:52	P2	C1
#7203	S008	As for tax levy against Internet shopping, I personally think the symbolic meaning is greater than practical meaning. Since there are too many ways to get way with legal bound, you can complete the transaction with direct mail or leaving contact numbers to each other without giving credit or auction; alternatively, the seller can sell with a different account to achieve zero increase of income "on the table," therefore, there will be no tax to levy.	2005/5/18 12:59:14	P2	C1

In order to further explain intervention points that teachers can provide and how to guide through these places, we have quoted a section of students' discussion and the rater's coding (Table 5). The problem was posted by student S003, and two students posted responding messages. The problem was, "What are the possibility and impact of a tax

levy for Internet shopping in Taiwan?” S045 then responded with a message that forwarded an online news report. The report described a statement from the government and the attitude of response from each major e-commerce site, but there was no personal comment from S045; thus the message only acted as supplemental information for an answer. Although the third respondent, S008, intuitively addressed his own ideas for possible aspects of influence and shop owners’ response, he neither analyzed or commented about the information from S045 nor provided any new information as evidence.

From this section of discussion content, both respondents have not analyzed more information in depth or made comparisons between each possible aspect of impact of a tax levy for Internet shopping (i.e., the P3 aspect); moreover, few points of possible impact were presented, and a conclusion was not formed (i.e., the P4 aspect). Thus the discussion only stops at P2 (i.e., provide solutions, opinions, or relevant information for supplementation). In addition, the knowledge construction stops at the phase of providing opinions or sharing information (C1) without the in-depth phases of construction (e.g., C2, C3, C4, or C5). In such cases, teachers can refer to our suggestions and post relevant articles to promote greater depth of problem solving and knowledge construction. For example, teachers can post the following message: “Student S008 or other students that are interested in this problem can refer to the abundant information provided by student S045 for further analysis, propose different opinions, or try to summarize possible phases of the practical impact of a tax levy. In addition, you may refer to the policy of a tax levy for Internet shopping in other countries and think about what the meaning of a tax levy is and why it would be applied. Is it possible to derive other impacts out of e-commerce?” In this way, teachers can encourage more students to offer further discussion and analysis about information already posted by their colleagues (P2→P3). It also reminds students to adequately sum up many opinions and list out practical phases of impact as conclusions from such discussions (P2→P4, P3→P4). As to knowledge construction, it also motivates students to address different opinions (C2) and explore the knowledge on a tax levy against Internet auction (C3), which even guides students to extend their thoughts on the impact out of e-commerce and derive new knowledge topics for discussion (C5). It is possible for this guiding message to improve the quality of problem solving and knowledge construction in online discussion at the same time; thus we suggest that teachers refer to the results of this research, diagnose limitations of students’ discussion processes, and provide timely messages such as those mentioned above to promote the depth of students’ discussion.

Conclusion

The purpose of this research was to observe the process of students’ problem-solving discussions without teachers’ intervention and guidance. By combining methods of sequential analysis and content analysis, the behavioral pattern and the level of knowledge construction from students’ discussions were explored. Under the utilization of problem-solving discussion activities, we have discovered that even without teachers’ guidance, the behavioral pattern of students’ online discussions still complied with the problem-solving theory to a certain level. As for students’ knowledge construction, the result is also more in-depth than the discussion activity without utilization of a problem-solving strategy (general online discussion activity with fixed topics assigned by teachers).

However, we have also discovered insufficiency and limitations to students’ problem-solving discussions without teachers’ intervention. In view of this, this research also proposed relevant suggestions that serve as a reference for teachers when intervening in students’ discussion or designing online discussion activities. In the sequential aspect of problem-solving discussion behavior, we have found behavioral sequences that can possibly promote more profound discussion (e.g., P2→P1, P3→P1, P4→P1, P3→P2, P3→P4, P4→P3, and P4→P2). The teachers can diagnose the status of students’ discussions and intervene in a timely fashion according to various limitations of the discussion, as well as post articles to promote the above-mentioned discussion behavioral sequences, which are more difficult for students to extend by themselves. In addition, the use of an intelligent agent for automatic information acquisition and provision can also possibly achieve an effect of promotion. In the aspect of knowledge construction, teachers can post articles to encourage students to link new and old knowledge (C4) or inspire new ideas or thoughts from the topic and form new knowledge (C5). This research expects that these discoveries can allow us to try combinations of sequential analysis and content analysis, which will help us further understand the process and limitation of discussion behavior, and provide a reference to teachers for designing online discussion activities.

However, this research is limited by focusing on the learning method of students’ raising and solving problems by themselves; the exploration focused only on the general speculative pattern of the entire student group’s problem solving discussion behavior. Because there is no further comparison and analysis of problem’s knowledge type (i.e.,

concept knowledge, principle knowledge, or critical knowledge), and processes for problems with different knowledge types may differ (Gijbels, Dochy, Bossche, & Segers, 2005), further research can be carried out on the difference in processes between problems with various knowledge types or between various learning activity types (i.e., learners' open-ended problems or specific problems assigned by teachers). Although teachers' intervention for online discussion might achieve different results based upon teachers' teaching styles, if a massive specimen of teachers' guidance in online discussion can be collected, different patterns of intervention and guidance can possibly be deduced and explored for differences among each pattern. These are helpful to us for finding limitations that teachers have when they guide and propose more practical suggestions. Other topics, such as exploration of the relationships between the students' discussion process and learning performance, differences in discussion behavior between students with high and low achievement, possible reasons that influence sequential progress, types of online discussion training that teachers can provide prior to a problem-solving discussion activity, and the available role and result of assistance from an automatic guidance of intelligent agent technology, are topics that this research can discuss in the future.

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