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A Framework for Dynamic Sequential Behavioral Pattern Detecting and Automatic Feedback/Guidance Designing for Online Discussion Learning Environments

Huei-Tse Hou
National Taiwan University of Science and Technology
Taiwan

1. The Trend and Bottlenecks of Online Teaching in the Era of Web 2.0

The new era of Web 2.0 focuses on a high degree of interactivity (Musser & O' Reilly, 2006). Changes in Internet applications also stress online knowledge-construction and knowledge-sharing. In order to develop students' critical-thinking and problem-solving skills, "project-based learning" (Marx et al., 1997; Blumenfeld, et al., 1991; Blumenfeld, et al., 1994; Thomas et al., 1999) is a popular choice for facilitating students' knowledge-construction. With the rapid expansion of online teaching technologies, efforts to provide students with interactive online project-based learning are receiving greater attention. However, past studies indicate that the extent of learning based on online project-based learning – especially analyses and discussions regarding online data — is limited (Wallace & Kupperman, 1997; Chang & McDaniel, 1995). Furthermore, since the new style of digital teaching is still in its experimental phase, teachers are finding that its actual implementation is not going as well as expected (Becker, 2001; Cuban, 2001; Cuban et al., 2001; Guha, 2001; Sung et al., 2005).

Given the limited experience that teachers have in utilizing online interactive teaching strategies, disappointing student performances may discourage teachers from utilizing online interactive teaching strategies in the first place. Therefore, in-depth investigations and diagnoses of the bottlenecks that occur in students' online interactions coupled with the formulation of relevant strategies for teachers to provide guidance and feedback are crucial.

Solely examining learning performance does not allow us to fully understand the bottlenecks in learners' online interactions and data analyses. Rather, we must conduct process-analysis focusing on learners' online interactions. Issues pertaining to learners' knowledge interactions include aspects of knowledge-construction, knowledge-sharing, and knowledge-transfer that are relevant to studies on knowledge-sharing and knowledge-transfer (Nonaksa & Takeuchi, 1995; Gilbert & Gordey, 1996; Davenport & Prusak, 1998; Hendriks 1999). Indeed, there are many factors that influence knowledge-sharing (Bock et al., 2005; Kankanhalli et al., 2005; Wasko & Faraj, 2005; Hsu, et al., 2007) and that are related to the organization character (Yang, 2007; Yang & Chen, 2007; Bock et al., 2005). Therefore, exploring knowledge-sharing and interaction in online learning communities may help us

understand the limitations of online knowledge interactions.

In the digital learning environment, knowledge-interaction is mostly implemented in asynchronous forums. Such practice for the purpose of promoting knowledge-sharing and knowledge-construction has received greater attention in studies that examine their educational benefits (Vonderwell, 2003; Bodzin & Park, 2000; Henri, 1992). Teaching methods that utilize online discussions can incorporate different types of interactive learning strategies that have been widely discussed and that form the bases of diverse online discussions and learning activities, including problem-solving (Gagne, 1980; Mayer, 1985; Hatch, 1988; Sternberg, 1996; Gagne & Briggs, 1979; Henna et al., 1995; Hou et al., 2008, 2009), peer-assessment (Topping, 1998; Falchikov & Goldfinch, 2000 Cizek, 1997; Shepard, 2000; Lin et al., 2001; Sung et al., 2005; Hou et al., 2007), peer-tutoring (Annis, 1982; Cohen et al., 1982; Greenwood et al., 1988; Miller, 1995; Fantuzzo et al., 1992), and role-playing (Kirs, 1994; Bell, 2001).

Utilizing these strategies, a teacher can specify questions and themes, arrange different discussion rules, and provide appropriate guidance in order to enhance the quality of student discussions and facilitate knowledge-internalization and externalization (Hendriks, 1999). Many studies also indicate that the design of the discussion mechanism has strong influences on the quality of the online discussion (Patricia & Dabbagh, 2005; Hewitt, 2003; Vonderwell, 2003; Swan, at el., 2000; Vrasidas & McIsaac, 1999). As mentioned earlier, shallow discussions and narrow data analyses may be related to the design of the discussion mechanism (including rules of the discussion, strategies such as guidance and intervention, and content of feedback). One way to address this issue is to conduct observations of knowledge-sharing during actual discussions based on the above interactive teaching strategies and to examine the subsequent behavioral patterns. Theoretically sound strategies can then be provided to teachers. This is precisely one of the important tasks of research designed to improve the quality of online educational discussions in the Web 2.0 era.

2. Apply Sequential-Analysis to Detect Online Discussion Patterns

There have been many studies about online asynchronous discussions (Hewitt, 2005; Fahy et al., 2001; Sudweeks & Simoff, 1999; Gunawardena et al., 1997; Newman et al., 1995; Levin et al., 1990). In addition to the analysis of social interaction patterns, related coding schemes have also been formulated for the analysis of the content of interactions (e.g., Gunawardena et al., 1997). While a content analysis of the discussion would help facilitate understanding of the subject matter, the following limitations still exist:

(1) Qualitative or quantitative content analysis alone does not allow us to infer the sequential correlations between discussion behaviors. Nevertheless, these kinds of correlations are crucial to the understanding of the overall behavioral patterns in discussions as well as its implications and bottlenecks.
(2) We can only understand a certain aspect of discussion content patterns by content analysis. The validity of the analysis must also be considered (Rourke et al., 2004). The abstractive nature of certain codes in some coding schemes may also limit the coding accuracy (Marra et al., 2004).

Therefore, in order to have a deeper understanding of students' knowledge-related discussions and interactions, more appropriate analytical methods are required. Compared to other methods, "lag sequential analysis" (Bakeman & Gottman, 1997) allows better

inference of the overall sequential patterns in online discussions. Furthermore, it has already been adopted in related studies (Jeong, 2003; England, 1985; King & Roblyer, 1984; Hou et al., 2007; Hou et al., 2008, 2009, in press). Ordinary quantitative content-analysis methods mainly yield data such as the frequency and proportion of different coded contents and focus more on understanding discussion content. However, for further exploring the behavioral patterns in different types of coded discussion behaviors, ordinary quantitative content-analysis methods are not able to provide sequential patterns of students' overall online discussions through statistical testing. As such, we cannot assess, for instance, what kind of discussion immediately follows another or whether the continuity of each type of discussion sequence reaches statistical significance. Sequential patterns of this type allow cross-referencing with prescriptive theory models (e.g., models of problem-solving or instructional design) that indicate differences between theories and actual practice, that allow us to infer possible causes of issues in online discussion patterns (e.g., why a learner carelessly makes a conclusion or terminates a discussion), and that suggest the timing of interventions and guidance by teachers or intelligent agents.

This kind of analytical method can not only analyze online interactive operation behavioral patterns e.g., users' browsing, responses, and posts, but it can also be combined with content analysis to reveal the sequential content patterns in users' online discussions. The specific calculation steps, as detailed by Bakeman and Gottman (1977), are as follows:

(1) Calculation of the frequency transition matrix. First, we calculate the frequency of transitions between each behavior code and create a frequency transition table that represents the frequency of inter-code transitions. The Table 1 is an example; the rows represent the starting behaviors, the columns represent the follow-up behaviors, and the numerical values represent the total frequency of having a certain behavior right after another. For example, the number "60" in row-2/column-3 means that behavior P2 is followed by behavior P3 60 times.

	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 1. Example of Frequency Transition Table (Lag=1)
*Source: Excerpt from Hou, H. T., Chang, K. E., & Sung, Y. T. (2008). Analysis of Problem-Solving Based Online Asynchronous Discussion Pattern. Educational Technology & Society, 11(1), 17-28.

(2) Calculation of the sequential transition conditional probability. From the above sequential frequency transition table we can calculate the conditional probability of different types of inter-code transitions and determine the sequential transition conditional probability matrix, which helps us infer expected-values.

(3) Calculation of the sequential transition expected-values. From he above sequential frequency transition table and the sequential transition conditional probability matrix, we can calculate the expected-values of inter-code transitions that will help us to infer

the Adjusted Residuals Table and to formulate a diagram of transition that allows follow-up analysis.

(4) Calculation of the Adjusted Residuals Table. We can infer the adjusted residuals by the above data and examine each sequence to see if the $p<0.05$ level of significance is reached. A Z-score greater than +1.96 indicates that the sequence reaches the level of significance ($p<0.05$). Table 2 is an example, boldface represent sequences (P1->P2, P2->P3, P2->P4, and P4->P5) that reach the level of significance.

	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

Table 2. Example of Adjusted Residuals Table (Z-scores) Lag=1
*Source: Excerpt from Hou, H. T., Chang, K. E., & Sung, Y. T. (2008). Analysis of Problem-Solving Based Online Asynchronous Discussion Pattern. Educational Technology & Society, 11(1), 17-28.

(5) The creation of a behavioral transition diagram: The significant sequences from the above z-score table are depicted in the diagram of sequential transitions (e.g., Figure 1) in which the coded behaviors are represented as nodes that are linked together with arrow heads, the thickness of which represents the level of significance. The z-scores are also shown in the diagram. Figure 1 depicts the transitions of significant sequences in Table 2 and provides analyzers and teachers a visual presentation of discussion-patterns, thereby facilitating the analysis of patterns and bottlenecks in students' discussions.

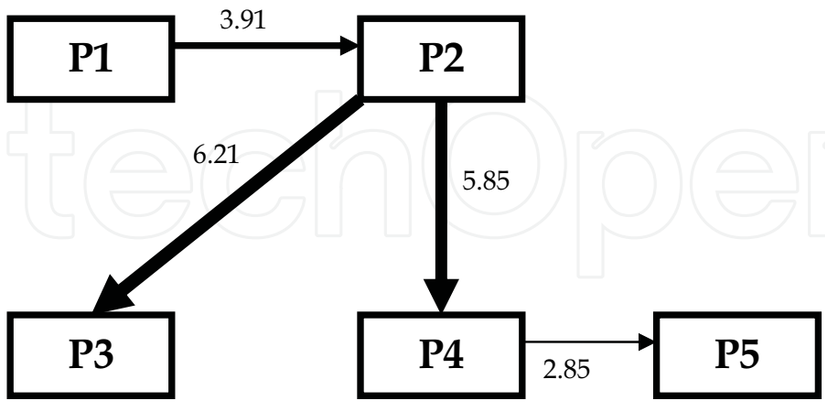


Fig. 1. Example of the Behavioral Sequence Transition Diagram
*Source: Excerpt from Hou, H. T., Chang, K. E., & Sung, Y. T. (2008). Analysis of Problem-Solving Based Online Asynchronous Discussion Pattern. Educational Technology & Society, 11(1), 17-28.

As for the actual analysis researches, Hou et al. have used the mixed-method approach, which includes quantitative (e.g., quantitative content analysis, sequential-analysis, and correlations analysis) as well as qualitative (e.g., learners' attitudes and protocol analysis) approaches to analyze the behaviors of learners who engage in different types of online learning discussions (Hou et al., 2007; Hou et al., 2008, 2009, in press).Although the above methods enhance research validity and provide teachers, researchers, and system developers with relevant suggestions, they still have limitations: they allow for neither the dynamic detection of real-time limitation patterns of discussion nor provide instant feedbacks. Without real-time diagnosis and intervention, the depth of discussions can be hindered, leaving teachers with insufficient analytical tools to instantly evaluate the content of student discussions/performances and to intervene accordingly. If real-time discussion analysis tools can be introduced to the discussion system, teachers will be better equipped to provide effective feedback that instantly improves the quality of discussions.

Since sequential-analysis allows for the inference of behavioral patterns and their visualized graphs from online operations and discussions and is statistically sound for examining behavioral continuity, teachers and researchers can be provided with real-time analytical data as long as the method is built into an online forum. As such, teachers will be able to evaluate students' discussions, and researchers will be able to use the data to analyze and develop feedback strategies. Researchers will even be able to design an automatic diagnostic feedback system that better assists teachers. Introducing this kind of tool would satisfy both educational and research purposes and facilitate knowledge-sharing in the digital learning environment.

To summarize, our research purpose is to apply the calculations of sequential-analysis to design a framework for a knowledge-sharing forum that allows for the analysis of sequential discussion behavioral patterns. This would not only provide teachers with a real-time, visualized diagnosis of sequential-patterns in learners' online discussions operations (including posting, answering, and reading articles), but it would also allow detailed or random analyses of students' discussions through customized or existing content-analysis coding schemes and generate graphs of sequential-behavioral patterns based on the content of discussions. These two types of patterns (i.e., operation sequential-behavioral pattern and content sequential-behavioral pattern) provide teachers and researchers with real-time, dynamic references for designing a feedback/guidance mechanism. The system also enables the configuration of an automatic feedback mechanism through which teachers can provide students with pre-designed feedback when certain behaviors occur.

3. The Knowledge-sharing Environment Combined with Automatic

The framework and function of the knowledge-sharing environment based on automatic sequential-analysis are explained below.

3.1 System Framework

Most of today's online educational discussion forums have basic features such as article-posting/replying. Some are further equipped with more advanced features such as topic-search, highlights, and mail-notification. However, only a few are equipped with the tool of discussion behavior/process analysis. In our study, we wish to have the sequential-analysis calculations discussed in Section 1 (Bakeman & Gottman, 1997) built into the forum and to

develop modules such as dynamic feedback rule-base as well as the interfaces for automatic and manual behavior-coding and feedback-design in order to create a knowledge-sharing forum with automatic analysis and feedback. The framework is depicted in the following diagram:

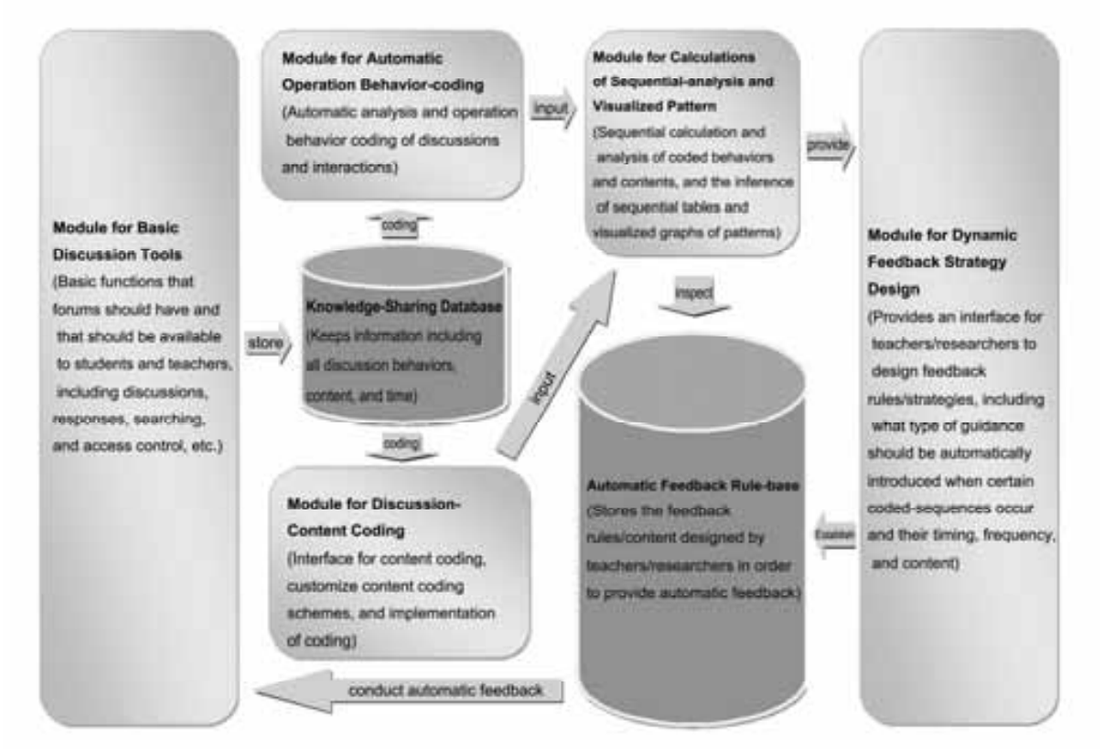


Fig. 2. Framework of Knowledge-sharing with Automatic Sequential-analysis

As shown in Fig. 2, our framework consists of five modules and two databases. In the system, teachers can use different interactive-learning strategies and specify online educational discussion activities that students need in order to participate in a specific forum. The module of basic discussion tools includes the public forum, group-discussion forums, topic-search, configurations of the highlight section, and configuration of automatic replies and mail-forwarding. The entire discussion process, including the time, frequency, content, and users' operations, is recorded in the knowledge-sharing database.

To facilitate our understanding of discussion behaviors, sequential-analysis is implemented based on two main categories of data: interactive behaviors (such as posting/answering/browsing articles) and content of discussions (detailed coding of discussions based on a given coding scheme). In regards to interactive behaviors, the system utilizes the built-in, automatic operation behavior coding module to code all users' operations. As for the content of discussions, the system provides the user (researcher or teacher) with a module of discussion content coding that allows the user to utilize a coding interface in order to code based on his/her own coding schemes or existing ones proposed in previous studies (Hou et al., 2008; Gunawardena et al., 1997).

Both types of codes are then outputted to the sequential-analysis calculation and pattern

visualization module for instant processing. The yielded sequential transition table is subsequently converted into a sequential-diagram of patterns in operation and content. The analyzer or teacher can then browse the data and give instant feedback. Furthermore, the teacher can simultaneously view the behavioral patterns and either intervene or adjust the rules of discussions, thereby reaching the goal of dynamic real-time assessment. On the other hand, the teachers or researchers can also use the module for dynamic feedback strategy design to design the rules and content of automatic feedback. For example, when sequential-pattern "A->B" of knowledge-construction occurs and is followed by sequential-pattern "D->E" of the operation behavior, the system automatically announces guidance-message "C". Teachers or researchers can design this kind feedback rules by having the rules and guidance-messages stored in the automatic feedback rule-base. When learners' operations or discussions match a certain pattern, the system automatically searches the automatic feedback rule-base and announces appropriate guidance-messages, thus greatly improving the quality of knowledge-sharing.

The above system not only allows teachers to conduct dynamic assessments but also assists researchers in long-term strategic analysis. However, various theories of interactive-learning strategies and knowledge-sharing still need to be considered when designing the optimal guidance strategy. Moreover, dynamic, empirical observations of the system are needed before better automatic-feedback strategies that assist teachers and enhance knowledge internalization/externalization can be formulated.

3.2 System Functions

The functions of the above system modules are explained in the following table.

Module	Function	Description
A. Module for Basic Discussion Tools	A1 Configuration of Group Forum	Configuration of users, settings in different group forum sections.
	A2 Configuration of Users	Add new users or configure each user's access modules or basic information.
	A3 Configuration of the Highlight Section	Selection and related configurations of articles in the Highlight Section.
	A4 Teacher Control Panel	Configuration allowing the teachers to delete articles and manage discussion-rules.
	A5 Configuration of Links with e-Learning Platforms	Configuration of links with other online learning platforms that allow learners or teachers to access/upload materials.
B. Module for Automatic Operation Behavior Coding	B1 Configuration of Operation Behavior Types	The analyzer chooses the types of operation behaviors for automatic analysis and assigns code names.
	B2 Operation Behavior Coding Report	View, output, or print the current report of operation behavior codes.
C. Module for	C1 Coding Schemes	Add, input, or choose existing coding

Discussion Content Coding	Management	schemes to code discussions.
	C2 Interface of Coding	The coding interface allows the user to choose a forum and code a certain article or response using multiple coding schemes.
	C3 Content Coding Report	Allows the user to view, output, or print a report of content coding data for analysis.
D. Module for Calculations of Sequential-Analysis and Visualized Pattern	D1 View Sequential Tables	Choose and view the transition table of content patterns at a certain point in time for further analysis.
	D2 View Diagrams of Sequential-behavioral Patterns	Choose and view the diagrams of the sequential-transition of content/operation patterns in a certain time slot for further analysis.
E. Module for Dynamic Feedback Strategy Design	E1 Configuration of Sequential-pattern Feedback Strategies	Provides an interface allowing the teacher/analyzer to configure feedback rules/content according to a certain sequential status. The user can formulate his/her own rules and strategies and store them in the rule-base.
	E2 View Rule-base	Browse the current content of the rule-base, and view/manage relevant rules.
	E3 View Rule Tracking History	View the "hit" rate of each rule and link it to the discussion article/message for further analysis.

Table 3. Functions of the Knowledge-sharing Environment with Automatic Sequential-analysis

Table 3 indicates that this system has both educational and research values and can combine digital learning platforms with the actual practice, design, analysis, and evaluation of different types of online knowledge-sharing discussions. This process greatly facilitates in-depth analysis of behavioral-patterns in discussions. It also assists managers of online learning communities to promote interactive learning activities, knowledge-sharing, and knowledge-construction.

4. Conclusion and Future Studies

In order to improve the depth of online knowledge-construction in the highly interactive Web 2.0, the theory of knowledge-sharing/transfer as well as different instructional strategies for online discussions is taken into consideration. As such, this develops

discussion strategies that promote the depth of knowledge-construction as well as the frequency of knowledge-transfers. Efficient discussion strategies for knowledge-transfers are the key to deepening online project-based learning.

This critical topic in research on interactions among online learning communities, however, still lacks a dynamic, real-time evaluation tool that would facilitate relevant studies and educational practices.

In this study, sequential-analysis yields instant references for the analysis of knowledge-related interactions. It has thus been incorporated into our online forum in order develop a knowledge-sharing discussion framework for the real-time analysis of sequential-behavioral patterns. This framework provides flexible coding tools and feedback-configurations, facilitates teaching, and allows teachers and researchers to develop, observe, refine, and test different interaction strategies. In addition, it also serves as an important reference for the developers of intelligent discussion systems.

Future empirical analyses can enhance the validity of process-evaluation by completing the system based on the framework provided in this study. Furthermore, future studies can not only utilize the original method of sequential-analysis but also employ multi-dimensional (quantitative and qualitative) approaches that combine quantitative content-analysis, original protocol analysis, correlation analysis, performance evaluation, and attitudinal surveys. Doing so will greatly facilitate our understanding of the actual discussions and feedback occurring among teachers and students.

5. Acknowledgements

This research was supported by the projects from the National Science Council, Republic of China, under contract number NSC 97-2511-S-231-001-MY3, NSC 98-2511-S-231-002, NSC 97-2631-S-003-002, and NSC 97-2511-S-003-041-MY3.

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Advanced Learning

Edited by Raquel Hijn-Neira

ISBN 978-953-307-010-0

Hard cover, 444 pages

Publisher InTech

Published online 01, October, 2009

Published in print edition October, 2009

The education industry has obviously been influenced by the Internet revolution. Teaching and learning methods have changed significantly since the coming of the Web and it is very likely they will keep evolving many years to come thanks to it. A good example of this changing reality is the spectacular development of e-Learning. In a more particular way, the Web 2.0 has offered to the teaching industry a set of tools and practices that are modifying the learning systems and knowledge transmission methods. Teachers and students can use these tools in a variety of ways aimed to the general purpose of promoting collaborative work. The editor would like to thank the authors, who have committed so much effort to the publication of this work. She is sure that this volume will certainly be of great help for students, teachers and researchers. This was, at least, the main aim of the authors.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Huei-Tse Hou (2009). A Framework for Dynamic Sequential Behavioral Pattern Detecting and Automatic Feedback/Guidance Designing for Online Discussion Learning Environments, Advanced Learning, Raquel Hijn-Neira (Ed.), ISBN: 978-953-307-010-0, InTech, Available from: http://www.intechopen.com/books/advanced-learning/a-framework-for-dynamic-sequential-behavioral-pattern-detecting-and-automatic-feedback-guidance-desi

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Phone: +86-21-62489820
Fax: +86-21-62489821

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