A Framework for Behavior Analysis of an Essay Writing for Understanding Learners' Thinking Process

Wasan Na CHAI, Taneth RUANGRAJITPAKORN, Nattapol KRITSUTHIKUL & Thepchai SUPNITHI
Language and Semantic Techonolgy Laboratory,
National Electronics and Computer Technology Center,
Pathumthanee, Thailand
{wasan.na_chai,taneth.rua,nattapol.kri,thepchai.sup}@nectec.or.th

Abstract: In this paper, we propose a writing supporting tool to train users' cognitive skill and to monitor their action in the tool for behavior analysis. The tool is to ask users to declare their thought and logical relation of sentences in their writing. This helps users to start thinking about their thought by focusing more on idea and strategy. By detecting users' action to the tool user interface, we can study and analyze users' behavior during the writing process that reflects their thought perspective including content understanding and planning. From an experiment, we found that users who obtained high rating from written essay have common solid action patterns as providing content, selecting the type, and assigning relationship respectively, and they generally spend less time in every action. On the other hand, users who produce an essay with low rating share fewer common patterns, and the patterns are sporadic while they need to redo the actions several times. The results also suggest that the thinking about an intention of a content and relationship of sentences gives the better essay rating than not.

Keywords: Behavior analysis, writing monitoring, cognitive training tool, metacognition

1. Introduction

As writing is a way of communication in terms of conveying own thinking to the receiver with explicit media for a solid proof (Keith Oatley, 2008), it can be used to analyze and criticize for a writer to improve their skill. Writing involves several cognitive aspects including creativity, critical thinking, strategic thinking, and memorizing (Bean, J. C., & Melzer, D., 2021). Several studies have proposed to train a writing skill for cognitive development (Kellogg, R. T., 2008). The result of those studies indicate that writing is a good method to train cognitive skills including creativity, sharpening memory, planning, and sorting out understanding. The writing has two major components which are content or idea and strategy. The content part is the transfer of knowledge or ideas through the analytical process of the writer communicating to the receiver. The strategy aspect is to plan on how to transmit the ideas so that the content is highly connected, trustworthy, and convincible (Brown, 1987) (Wong, 2005). A written output such as an essay is a traceable evident that reflects writer's thinking via words, style, and logical connection within and of sentences (Stallard, 1974). Therefore, detecting learner behavior in activities of writing an essay can help identify thought processes and planning.

In the past, we developed a tool to train learners' cognitive skill via a writing supporting tool (W. Na Chai, 2017) (W. Na Chai, 2019). By asking a learner to provide content and its related information in a sentence level, learners should halt their running thought and focus more on idea and strategy for writing as well as thinking about their own thought. The training is to understand one own thought and control cognitive performance as metacognitive skill (Mahdavi, 2014). Thus, metacognition is one of the higher-order thinking skills that can be used to clarify students' thinking or planning processes in activities such as writing (Stewart, 2015).

To improve the tool further, we aim to monitor activities that learners conduct during their training in the tool. We aim to study and analyze behavior regarding activities of writing an essay based on the tool for cognitive training. The finding from analysis can reveal the relation between learners' thinking process and their behavior. This can help instructors to understand learners more clearly and design a training method for personalized learning. Moreover, by comparing the rating results of essays and behavior, we can learn the suitable actions to improve the tool further.

2. Framework for Behavior Analysis of an Essay Writing

This section is to describe a framework that we use as a tool to analyze learner's behavior towards thinking process. The framework is initially a tool to assist learners to focus on thinking process while writing an essay by asking users to declare their thoughts via annotation method. The tool thus helps users to realize their thought and gives them a chance to train their metacognitive skill. To enhance the tool further, we apply a method to monitor users' activity on the framework. From observation of the users, we found that users tackled the tasks given from the tool differently and their activity may corelate to the training results. Thus, in this work, we attempt to monitor and record users' actions for analyzing how their behavior may relate on how they think and their thinking process. Functions of the tool remains the same for users to write an essay while users' task is to provide the following.

- Writing content in a sentence level
- Selecting a type of a content from a predefined list of content type
- Assigning a relation of the current sentence to the previous sentences based on selected content type

The aforementioned tasks are conducted via the framework. In this work, we develop and add a monitoring function to detect typing and mouse-clicking on the user interface of the tool and to record them as a log for analysis. An overview of the upgraded framework is given in Figure 1.
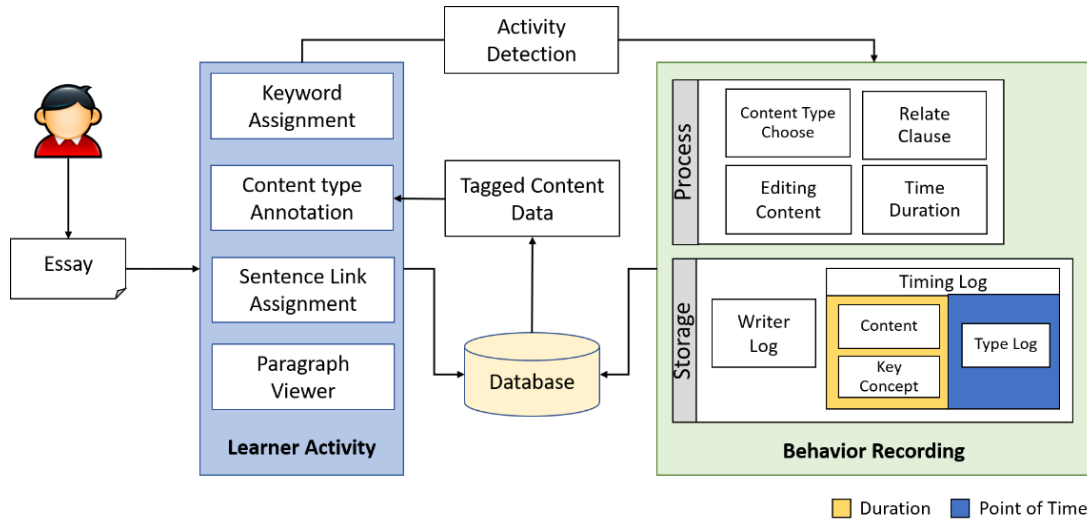

Figure 1. An overview of the upgraded framework of training thinking process via writing and behavior analysis

2.1 Tool Activities

By keeping the objective to train users on thinking process in writing an essay, the tool is designed to provide a web-based user interface for users to provide the writing content and information related to the content. In the tool, a user is asked to split up their thought and input the content for single sentence in each row. The mandatory required information related to the content in the tool includes 'what intention the content is for', and 'which other sentence is related to the intention'. The former is called 'content type' and we provide a list of types for user to select in a form of a dropdown list in the user

interface. The latter is for a user to assign a sentence ID if the working sentence is linked to the previous sentence regarding the selected content type. A user interface of the tool for a learner to provide the content and related information is illustrated in Figure 2.

Figure 2. An example of tool user interface for a learner

The user interface is designed following the concept of a thinking sequence. From left to right, a user is asked to provide content, to select a content type, and to assign sentence ID for linking sentence, respectively. The design is based on the idea that a user should think about what to mention, what kind of content, and the thinking is related to another or not in a sequence. We expect that thinking in such a manner will improve systematic thinking and may allow a user to increase a chance to think about their thoughts more thoroughly as well as their strategic thinking on convincing the reader.

2.2 Behavior Data Collection

For the task of behavior analysis, we develop a monitoring system to record users' action towards the tool. Initially, the tool was designed to collect the content and related information provided by a user. In this work, actions regarding the given tasks mentioned in the previous sections is recorded. We expect that recorded actions can be used in analysis to help us to understand users for personalized learning and improve their training results. Furthermore, we may find a thinking process of the users by grouping the behavior of the users. In this section, we explain the monitoring method and a generated action log.

We design the tool to record every action throughout the process of essay writing that a user conduct on the tool. There are two main data for the tool to detect and record including the action to the task and timing of the action. The tasks are 1) typing a content (T), 2) select a content type (C), and 3) to assign related sentence ID (R). The timestamp of an action for both starting time and ending time. With the record of action and time, we can realize action order and how long a user spend time in an action. The details of detection and record is summarized in Table 1.

Table 1. *Generated Data from Detecting User's Actions via the tool*

Detection type	Interacting with Input type	Recoding information	Description
Timestamp	Typing in Writing panel	• Starting time • Ending time	Calculation for a duration of writing content
	Clicking Dropdown of content type	• • Starting time Ending time	Calculation for a duration of selecting a content type from the list
	Selecting the content type	• Starting time • Ending time	

	Clicking Dropdown of relational sentence	• Starting time • Ending time	Recording time to relation between sentence
Order of Action	Writing panel, Dropdown of content type and Dropdown of relational sentence	• Order of action	Recording an order of actions based on time and duration

Since the action can be redone freely in a row panel, we generate a log of conducted actions of each sentence row until a user move to another sentence row panel. Users also allow to rework on the finished sentence row after working on another sentence, but the rework is recorded and regarded as a separate record to prevent complex data management. After a user submits the writing as finished, a log is generated for a learner user to review their endeavor. In a log, not only recorded actions are provided but also the input contents and related information are given. A log is also useful for instructors and training coach for analysis and providing guidance. An example of a log is given in demonstrated in Figure 3.

Figure 3. An example of an action and content log

3. Results

In this section, we aim to test the framework and analyze the behavior of users to examine their actions based on the framework specification. We asked 15 participants who are Thai native and at least studying in undergraduate degree in any major. The assigned task is for participants to write a short essay (about 10-20 sentences) within 3 hours using the framework. The topic of the essay is unlimited but is advised to be a topic that a user is excel with. The participants were trained on how to use the framework for 2 hours prior to the experiment period. The participants were informed that the framework has the action monitoring function, and they all gave a verbal consent for their actions towards the framework to be monitored and recorded.

For data collection, we collect their personal information including age, highest education level, and degree. The behaviors for analysis were recorded based on the given detail in Table 1. In terms of essay assessment, we assigned three coaches to give scores for the essays in three aspects including soundness of the content, accuracy of the selected content type, and accuracy of the given relation regarding content connectivity. The three aspects were to be rated for '0' and '1', where '0' represents unacceptable, and '1' is acceptable from overall. The ratings in each aspect from coaches were considered as voting, and the majority rating was chosen to represent the rating of an essay for that aspect. For sum of all three aspects, maximum score is 3 and the minimum is 0. We then split the participants into two groups based on the obtain summary score. Thus, the first group is those having over 1.5 sum score to represent the participants who have concise thinking process in writing, and the second group is for those having 1.5 sum score and below. As a result of grouping, the first group (G1) contains five

4

members, and the second group (G2) has 10 members. The groups were a base for comparison of their behavior in writing an essay via the framework. For statistics, there are 15 essays from 15 participants. There were 193 sentences and average sentences written per participant were 12.87 sentences, while minimum is 11 sentences, and maximum is 15 sentences per person. The language of an essay can be written in both Thai and English, but all participants chose to write in Thai by their free will.

As we collect the actions of writing an essay on the framework, their actions were recorded regarding action sequence, and timing of actions. Hence, we can create the patterns of the actions per sentence of each participant, and the duration spent for each action. From all participants, we found that there were 42 behavior patterns in total and frequency of each pattern as shown in Table 2.

Table 2. *Behavior patterns of participants in writing an essay based on the framework functions. (T = typing, C = selecting a content type, and R = selecting a relation of content)*

No.	Behavior Pattern	Frequency of G1	Frequency of G2	Summary
1	T | C | R	50	33	83
2	T | R | C	15	27	42
3	T | C | R | C	4	5	9
4	C | T | R	3	2	5
5	T | C | T | R	0	5	5
6	R | T | C	0	4	4
7	T | C | R | T	1	2	3
8	C | R | T	0	2	2
9	C | T | R | T | C | R	0	2	2
10	T | T | C | T | C | R	0	2	2
11	T | T | C | R | T	0	2	2
12	T | R | C | C	0	2	2
13	T | C | T | C | R	0	2	2
14	T | C | R | T | C	1	1	2
15	C | R | T | T	0	1	1
16	C | T | T | R	0	1	1
17	C | T | T | T | R	0	1	1
18	C | T | R | C | T	1	0	1
19	C | T | R | C | R	0	1	1
20	R | T | C | T | C	0	1	1
21	C | T | R | R	0	1	1
22	C | T | R | T | C	1	0	1
23	C | T | R | T | R	0	1	1
24	C | T | R | T	1	0	1
25	T | T | C | T | R	0	1	1
26	T | T | R | C	0	1	1
27	T | T | T | R | C | R	0	1	1
28	T | R | R | C | T	0	1	1
29	T | R | T | C	1	0	1
30	T | R | C | C | C	0	1	1
31	T | R | C | C	0	1	1

32	T | R | C | C | T	0	1	1
33	T | R | C | R	0	1	1
34	T | R | C | T | C | R	0	1	1
35	T | R | C | T	0	1	1
36	T | C | T | T | C	0	1	1
37	T | C | T	0	1	1
38	T | C | C	0	1	1
39	T | C | C | R	0	1	1
40	T | C | R | C | R | R	0	1	1
41	T | C | R | R	0	1	1
42	T | C | R | T | T	0	1	1

We also collect the data of duration of each action calculated from initial time and end time to show how much time they spent in each function. In a case of redo and edit of the same action of a sentence (such as do typing as first action and conducting a typing again as forth action as in the pattern#7 and #25), the times of all same actions are counted together to represent the duration. For typing action, we realize that typing speed may affect the statistic thus we use the average of a string count and time spent to represent the typing data of each individual instead of raw duration. With the average typing time per string of an individual, we can see which session students spend more or less time   To represent the data, we calculate for mean duration (mean), minimum duration (min), maximum duration (max), and standard deviation (SD) of each framework function. The duration results based on grouping are given in Figure 4 and Figure 5.
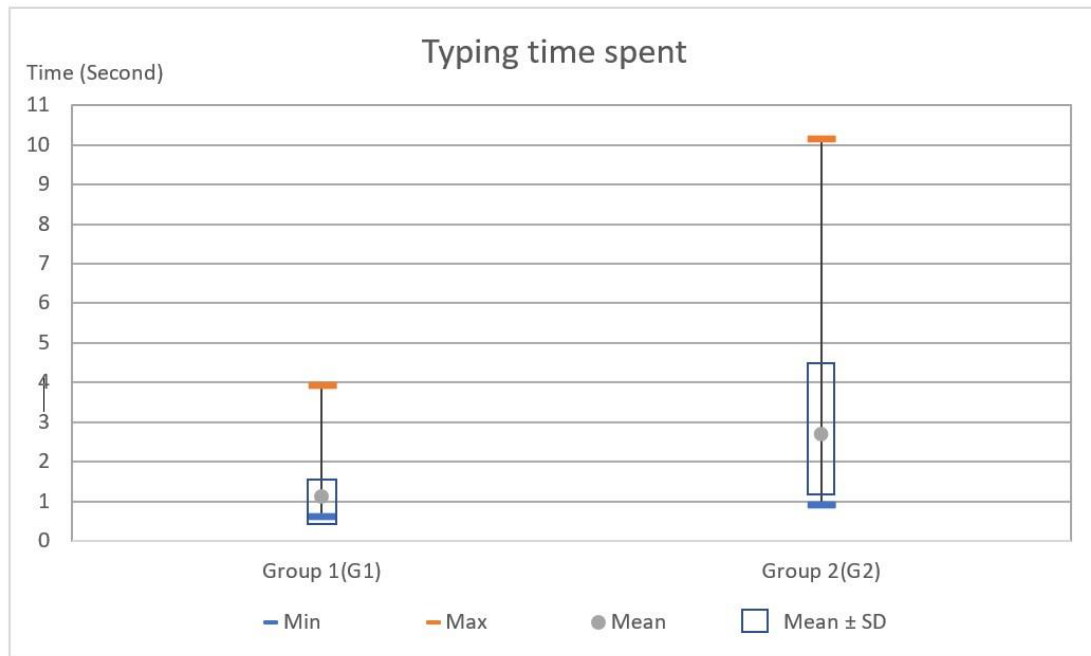

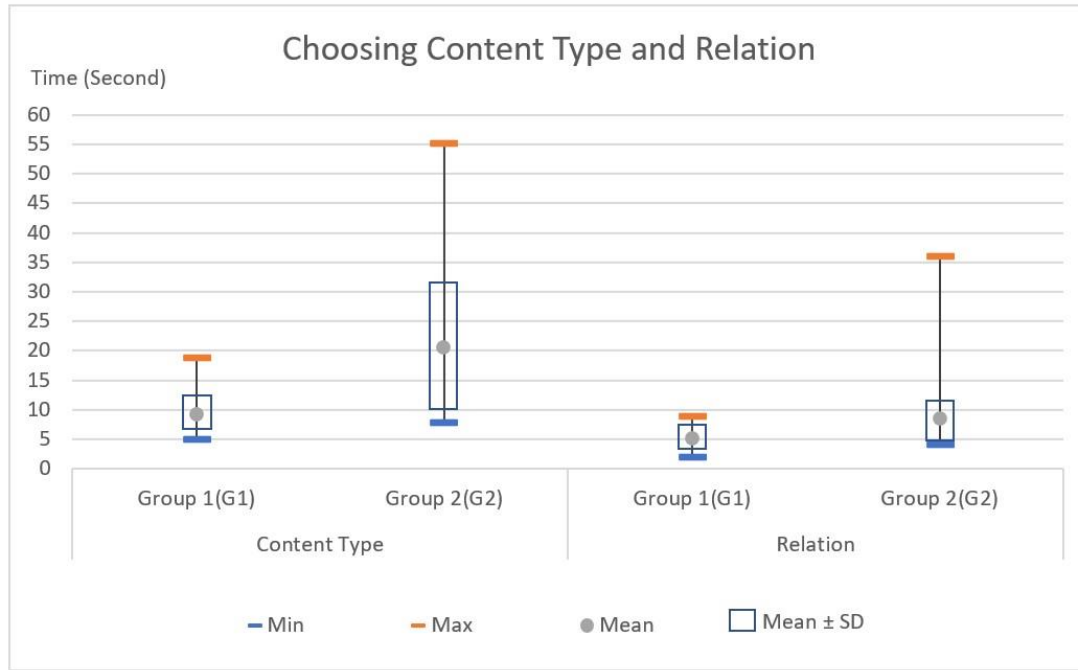*Figure 4.* Comparison graph of typing time spent between G1 and G2

6

Figure 5. Comparison graph of choosing content type and relation between G1 and G2

4. Analysis and Discussion

From the results, we can see that participants had various patterns as 42 unique patterns from 193 sentences. The distribution of the patterns as shown in Table 2 indicates that the occurrence of patterns based on a group is different and some patterns were more frequent than the rest. The list of patterns from G1 consists of 10 unique patterns while the G2 compose of 38 unique patterns, there are 4 patterns common between the two groups. We also find that the patterns from G1 mostly contain 3 actions (88.46%) indicating that there are few edit/redo actions in their endeavor. This shows that participants in G1 may have more complete and clearer thoughts before performing the writing. Regarding time spent on actions, the result shows a noticeable difference between the two groups. The G1 group had less time consumption in all functions compared to the shared patterns. This also supports the conclusion of G1 participants to have more complete and clearer thoughts since they spent less time thinking in action but rather thinking clearly before doing.

Based on the analysis, we notice that there are 2 patterns that play a majority role as frequent over 20%. These patterns are common in both groups. Especially, pattern#1 and #2 took over 43.01% and 21.76% of all patterns, respectively. Since the pattern of a sequence of typing, selecting content type, and selecting a relation of content is resembling the user interface of function order from left to right following the UI design to let a user think in a significant order, it is common for participants to follow the order subconsciously without realizing. However, a comparison between the 2 groups shows the difference in frequency of the pattern#1 and #2 is 35.4% and 4.25% whereas G1 has 64.1% and 19.23% frequency of pattern#1 and #2 and G2 has 28.7% and 23.48% respectively. This shows that participants who obtained a high rating (G1) often use the pattern#1 more than low rating participants, and this pattern of writing behavior may differentiate the result of a written essay as they think systematically.

Once combining aspect of pattern and duration, we found that the overall average time spent in writing an essay of those in G1 were shorter. The time spent on actions can be analyzed as follows. The typing time spent refers to the time a user spending in providing the content. In this case, we used the average time per sting of each individual as a base to decide which

sentence creation is short or long. We assume that the longer the time spent on typing, the more unclear the thought/idea user has. The time spent in selecting a content type represents a degree that a user understands his/her own content as to what role this sentence is for. Similarly, selecting a relation represents connectivity of thoughts from a user. For categorizing, this can be defined based on time spent and correctness (decided by coaches) into 6 types: fast and correct selection, fast and incorrect selection, normal and correct selection, normal and incorrect selection, slow and correct selection, and slow and incorrect selection. The preferred categories are those with correct rating whereas the shorter duration means how clear a user plans and think ahead, but the long duration is still admirable for thinking until the thoughts are clear and correct. However, the incorrect selection aspect is different since the faster they select may refer to not thinking about the content at all (as no plan and no strategy) or neglecting the importance of understanding own thoughts. For those in this category, they may need to be informed about the basis and importance of thinking as a groundwork towards cognitive skill training. The longer time spent but incorrect still is admirable as a user tries to spend time thinking but may not excel enough in cognitive skills to reach a correct answer, thus this group may need a lesson to improve the skills accordingly.

According to coach rating, coaches gave the impression that the essays of those from G1 were more thoughtful to readers and rationally connect throughout the content as they had a strategy to convince the readers more than those of G2. On the other hand, essays from G2 have the characteristic of a standalone sentence. Though the content in each sentence was fine, the connectivity of sentences was lacking and the assigned relations from the user were incorrect or the content of the linked sentences was not as specified. In terms of selecting the content type, the G1 specified the type correctly as they understood what they were aiming to mention, while the assigned content type from G2 often choose the common ones such as reasoning and consequence, but they were incorrect regarding the given content.

5. Conclusion and Future Work

This paper proposes to use the writing tool to include the function for monitoring actions towards behavior analysis. The actions that a user conducts are recorded and analyze for action patterns to represent how they think or strategize on convincing reader in an essay writing. The framework for an essay writing consists of tasks for a user to type the content, selecting the content type (a logical type of content), and selecting the relation to another sentence. The monitoring includes action sequence, and duration in each action.

In a summary, the results of behaviors based on the framework can differentiate the participants into two distinct types. The found patterns show the common actions of thinking process from those having decent thinking process. The findings of this study are that the writers who have clear and complete thinking process spend less time in writing, mostly act in a pattern of typing, selecting content type and selecting relation respectively, and rarely require redo/edit the typed contents. In the future, we plan to conduct an experiment on a larger scale to further learn on how thinking process and metacognitive skill play a role in writing. Furthermore, we will conduct an experiment to compare participants based on greater number of aspects including expertise domain, writing experience, and on different environment. To improve the framework, we plan to include an eye-tracking system and body temperature sensor to enhance behavior and reaction detection.

References

Oatley, K., & Djikic, M. (2008). Writing as thinking. Review of General Psychology, 12(1), 9-27.
Bean, J. C., & Melzer, D. (2021). Engaging ideas: The professor's guide to integrating writing, critical thinking, and active learning in the classroom. John Wiley & Sons.

Kellogg, R. T. (2008). Training writing skills: A cognitive developmental perspective. Journal of writing research, 1(1), 1-26.

Brown, A. (1987). Metacognition, executive control, self-control and other mysterious mechanism. Metacognition, motivation and understanding. Hillsdale, NJ: Erbaun.

Wong, A. T. (2005). Writers' mental representations of the intended audience and of the rhetorical purpose for writing and the strategies that they employed when they composed. System, 33(1), 29-47.

Stallard, C. K. (1974). An analysis of the writing behavior of good student writers. Research in the Teaching of English, 8(2), 206-218.

Chai, W. N., Ruangrajitpakorn, T., & Supnithi, T. (2017). A Tool for Data Acquisition of Thinking Processes through Writing. In International Conference on Computers in Education.

Chai, W. N., Ruangrajitpakorn, T., & Supnithi, T. A Tool for Learning of Cognitive Process by Analysis from Exemplar Documents.

Mahdavi, M. (2014). An overview: Metacognition in education. International Journal of Multidisciplinary and current research, 2(6), 529-535.

Stewart, G., Seifert, T. A., & Rolheiser, C. (2015). Anxiety and Self-Efficacy's Relationship with Undergraduate Students' Perceptions of the Use of Metacognitive Writing Strategies. Canadian Journal for the Scholarship of Teaching and Learning, 6(1), 4.