DEVELOPMENT OF A STUDENT REFLECTION SUPPORT SYSTEM BY AUTOMATIC CLASSIFICATION OF SENTENCES OF REFLECTION ON LEARNING USING A CUSTOM MACHINE LEARNING MODEL

Kohei Maruyama¹, Yasuhiko Morimoto²

¹The United Graduate School of Education Tokyo Gakugei University (JAPAN)
²Center of Information and Communication Technology, Tokyo Gakugei University (JAPAN)

Abstract

It is becoming increasingly important not only in higher educational institutions but also in primary and secondary schools for students to learn proactively and autonomously. With this type of learning, it is essential for students to constantly reflect on their learning in order to adjust tasks and progress to the subsequent learning. However, when students reflect on learning, they often stick to the facts and their impressions of various activities. Thus, it is necessary for teachers to grasp the individual situation of each student, ideally through reading sentences of reflection on learning written by the student, and to facilitate reflection on learning appropriately. One promising direction is technologies such as artificial intelligence and machine learning that could be used to facilitate learning by analyzing large amounts of accumulated data. The purpose of this study is to develop a system that facilitates student reflection on learning by using a custom machine learning model. This model automatically classifies written sentences of reflection on learning with a focus on the different phases of reflection. We then facilitate further reflection on learning by grasping the situation from the classification result. In this paper, we describe the design and development of the system functions.

Keywords: reflection on learning, learning record data, learning analytics, text classification, machine learning, e-learning systems.

1 INTRODUCTION

It is becoming increasingly important not only in higher educational institutions but also in primary and secondary schools for students to learn proactively and autonomously. With this type of learning, known as reflective learning [1], it is essential for students to constantly reflect on their learning in order to adjust tasks and progress to the subsequent learning.

When students reflect on learning, they often write notes in their handouts or notebooks about “what I learned in today’s class” or “what I noticed and thought important” after the class. However, there are as many different ways of reflecting on learning as there are students. For example, some students might stick to the facts and their impressions of various activities, while others might reflect on learning more deeply about the tasks they perform and the future prospects these open up. Thus, it is necessary for teachers to grasp the individual situation of each student, ideally through reading sentences of reflection on learning written by the student, and to facilitate reflection on learning appropriately.

However, this can be easier said than done. Therefore, teachers would benefit from some sort of support system to help them grasp the individual learning situations of students.

In recent years, with the development of technology such as machine learning and artificial intelligence, efforts to use analysis results of a large amount of collected and accumulated data are attracting attention. An example of such an effort is text classification (or categorization) using a machine learning method [2], where other new text documents can be classified according to labels by constructing a machine learning model that gives single or multiple labels to original text document data [3].

In light of the above, if we can construct a machine learning model to classify sentences of reflection on learning by using some of the features of the written reflections, it should be possible for teachers to grasp the individual situation of each student more easily. Moreover, by enabling these individual situations to be grasped, it should also be possible to facilitate the promotion of appropriate reflection on learning.
The purpose of this study is to develop a system that supports students to reflect on their learning by means of a custom machine learning model. Specifically, we constructed a custom machine learning model that automatically classifies written sentences of reflection on learning into three distinct phases. Then, we facilitate further reflection on learning by grasping the phase from the classification result. In this paper, we describe the design and development of the system functions.

2 APPROACHES TO FACILITATE STUDENT REFLECTION USING SENTENCES OF REFLECTION ON LEARNING

In the proposed approach, we first need to grasp the situation of each student’s reflection on learning from their own written reflections (Requirement 1). Second, teachers and facilitators need to facilitate further reflection on learning on the basis of the situation that has been grasped (Requirement 2).

2.1 Phases of Reflection on Learning

The promotion of metacognition is considered effective to facilitate reflection on learning [4]. Metacognition encompasses “metacognitive activities” as an activity component consisting of a “metacognitive monitoring” phase and a “metacognitive control” phase [5] [6]. The metacognitive monitoring phase includes contemplations such as “the reader will have difficulty understanding this text unless I make some changes” or “what is the cause of this unintelligibility?” The metacognitive control phase includes thinking such as “let me change the order of the sentences” or “I should use numbering here” [7].

From the above, metacognition is considered to stimulate reflection on learning, and a cognitive awareness phase occurs when asking oneself questions such as “what did I think and why did I think so”. There is also a phase in which precepts of learning are made and tasks are identified in order to adjust the prospects of the subsequent learning. These phases essentially agree with the phases of reflection on learning that Morimoto (2017) pointed out in empirical research [8]. Additionally, it is thought that written sentences of reflection on learning will be different according to the phases.

Therefore, we propose here three phases of reflection on learning (Fig. 1). The first is “recalling the facts”, where one recalls “what I did and how well I did it today.” The next phase is “reflection with cognitive awareness”, where one considers “what I thought and why I thought so at that time.” The last phase is “reflection about precepts of learning”, where one considers “what should I do next, and how should I do it, as precepts of learning”. In these phases, some students reflect on learning that reaches the phase of “reflection about precepts of learning”, while others remain at the phases of “recalling the facts” or “reflection with cognitive awareness”. Thus, it is necessary for teachers to facilitate student reflection on learning depending on the phases. For example, if a student is at the phase of “recalling the facts”, teachers should help the student move up to “reflection with cognitive awareness”, and if a student is at the phase of “reflection with cognitive awareness”, they should help them move up to “reflection about precepts of learning”.

![Figure 1. Phases of reflection on learning.](image)

2.2 Automatic Classification of Sentences of Reflection on Learning Using a Custom Machine Learning Model

We focused on automatic text classification with a machine learning model to grasp the situation of individual students’ reflection on learning from their own written reflections. In general, for constructing machine learning models that classify text documents, it is necessary to create training datasets in
advance by tagging each text document. It would be helpful in such cases to construct a machine learning model that can be learned by any algorithm.

From the above, we assume it should be possible to grasp the situation of reflection on learning by constructing a machine learning model that classifies written reflections on learning on the basis of the phases of reflection on learning. The key idea here is to create training datasets with a tag that identifies the phases. Then, we construct a machine learning model that trains written reflections on learning and phases of reflection on learning. This makes it possible to grasp the situation of reflection on learning easily by visualizing the classification results of the machine learning model (Fig. 2).

![Figure 2](image.png)

**Figure 2.** Concept of classification of sentences of reflection on learning.

We came up with classifications of written reflections on learning corresponding to phases of reflection on learning, as listed in Table 1. Our aim is to construct a machine learning model that classifies the sentences by these three classifications. From this, it becomes possible to grasp the individual phase of each student.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Description</th>
<th>Example sentences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sentences about facts</td>
<td>Sentences that mention facts, actions, and impressions about what you did.</td>
<td>I observed plants today. I learned that plants have leaves for photosynthesis, and the front and back of the leaves have different colors.</td>
</tr>
<tr>
<td>Sentences about cognitions</td>
<td>Sentences that mention what you thought and why did you think so at that time through eliciting metacognition and self-inquiry.</td>
<td>I wondered why the colors are different on the front and back of the leaf even though it is the same leaf. Also, I wondered why there are green plants and plants that turn red when the season changes.</td>
</tr>
<tr>
<td>Sentences about percepts of learning</td>
<td>Sentences that mention how you should approach the next phase of learning through making precepts of learning.</td>
<td>Next time, I would like to think more about the mechanism of photosynthesis. Also, I would like to find out which plants are growing around my house, not just around the school.</td>
</tr>
</tbody>
</table>

### 2.3 Facilitating Student Reflection by Prompting

We also focused on prompting as a means of helping teachers facilitate reflection on learning by using the classification results of written reflections on learning. Prompts have been defined as “recall and/or performance aids, which vary from general questions (e.g., “What is your plan?”) to explicit execution instructions (e.g., “First calculate 2 + 2”) and are regarded as an important technique [9]. In addition, in Web-based learning environments, prompts that promote metacognition are important because
spontaneous metacognitive activity will be inadequate [10]. The expected learning effect varies depending on the type of prompt to be performed and its timing [11].

From the above, we assume it should be possible to facilitate student reflection on learning by providing prompts that elicit metacognition and promote reflection on learning according to the classification results.

Therefore, we suggested prompts to promote reflection on learning depending on the phases of reflection on learning, as listed in Table 2. We assume that providing these prompts will make it possible to facilitate student reflection on learning depending on the classification results based on the phases of reflection on learning.

**Table 2. Prompts to promote reflection on learning depending on phases of reflection on learning.**

<table>
<thead>
<tr>
<th>Phases</th>
<th>Prompts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recalling the facts</td>
<td>What kind of things did you think at that time? And what did you think was important?</td>
</tr>
<tr>
<td>Reflection with cognitive awareness</td>
<td>What do you think you should do to progress to the subsequent learning?</td>
</tr>
<tr>
<td>Reflection about precepts of learning</td>
<td>None (due to move on to the subsequent reflection on learning)</td>
</tr>
</tbody>
</table>

In this study, our aim was to construct a machine learning model that classifies sentences of reflection on learning by the phases of reflection on learning and to develop a student reflection support system by providing prompts to promote reflection on learning by using the classification results. The intended flow of the system we developed is shown in Fig. 3.

**Figure 3. Usage concept of Student Reflection Support System.**

(1) Students write sentences of reflection on learning in our system after learning activities or classes.
(2) Our system classifies the written sentences with the machine learning model.
(3) Our system visualizes the situation of reflection on learning of each student on a dashboard using the classification results.
(4) Teachers grasp the individual situation of reflection on learning by referencing the dashboard and the written sentences.
(5) Teachers facilitate student reflection on learning appropriately according to the individual situation by using prompts to promote reflection on learning.
(6) Or, our system directly provides prompts to promote reflection on learning using the classification results according to the individual situation.
3 DESIGN OF SYSTEM FUNCTIONS

Our system features three primary functions: one to grasp the situation of reflection on learning, one to facilitate student reflection on learning, and one to register and view sentences of reflection on learning. These functions are described in detail below.

3.1 Function 1: Automatically Classify Sentences of Reflection on Learning (Corresponds to Requirement 1)

Function 1 automatically classifies registered sentences of reflection on learning by means of a custom machine learning model in order to determine which phase of reflection on learning the registered sentences belong in. As a construction procedure of the machine learning model, we created training datasets of sentences of reflection on learning in accordance with the classifications in Table 1 and then constructed a custom machine learning model using the datasets. This function enables automatic classification by applying a process of the classification to the model and obtaining the classification results from it.

3.1.1 Creating Datasets of Sentences of Reflection on Learning

We created training datasets for constructing the machine learning model by labeling sentences of reflection on learning on the basis on the classifications in Table 1. We used 216 entries consisting of 2,262 sentences (1st period: 75 entries / 781 sentences, 2nd period: 74 entries / 726 sentences, 3rd period: 67 entries / 755 sentences) written by university students after a lecture on the use of ICTs in education. These sentences were written in response to the topic “Describe what you learned in today’s class” as a reflection on learning. Table 3 shows the theme of each lecture. The classification accuracy is typically low when training datasets are created by one tagged entry that contains multiple sentences [12], so we tagged each sentence instead of each entry with reference to Table 2 in order to improve the accuracy, as shown in Table 4.

<table>
<thead>
<tr>
<th>Period</th>
<th>Theme</th>
<th>Example of tagged sentences (translated from Japanese)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st period</td>
<td>The use of ICTs in objectivism and how to improve it</td>
<td>I learned that we should not seek only “efficiency” in order for children to learn more proactively.</td>
</tr>
<tr>
<td>2nd period</td>
<td>The use of ICTs in constructivism</td>
<td>I learned that “dialogue” is required in class and that the three types of dialogue are with peers, with teachers, and with oneself.</td>
</tr>
<tr>
<td>3rd period</td>
<td>How to use ICTs for fostering students’ ability to think, to make decisions, and to express themselves in active learning</td>
<td>I thought that if teachers don’t use ICT in a class or if there is not enough dialogue, students will get bored.</td>
</tr>
</tbody>
</table>

Table 4. Breakdown of created training datasets.

<table>
<thead>
<tr>
<th>Labels</th>
<th>Number</th>
<th>Example of tagged sentences (translated from Japanese)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sentences about facts</td>
<td>1,171</td>
<td>I learned that we should not seek only “efficiency” in order for children to learn more proactively.</td>
</tr>
<tr>
<td>Sentences about cognitions</td>
<td>765</td>
<td>I thought that if teachers don’t use ICT in a class or if there is not enough dialogue, students will get bored.</td>
</tr>
<tr>
<td>Sentences about percepts of learning</td>
<td>326</td>
<td>I want to be able to conduct a class that fosters student thinking and promotes dialogue among peers.</td>
</tr>
</tbody>
</table>

3.1.2 Construction of Custom Machine Learning Model

We constructed a machine learning model that classifies sentences of reflection on learning by using the training datasets.
As a machine learning algorithm, we used the Google Cloud AutoML Natural Language, which can train a custom model to recognize content that we care about in text [13]. AutoML Natural Language is a machine learning service integrated in the Google Cloud Platform that enables supervised learning to be performed, which involves training a computer to recognize patterns from labeled data. The model trained by AutoML Natural Language outputs (predicts) a series of numbers that communicate how strongly it associates each label in that sample. If the number (predicted value) is high, the model has high confidence that the label should be applied to that document. By using REST API or Python libraries from the server side, we can use the model to classify text data and obtain predicted values as classification results [14].

The procedure for creating a custom model using AutoML Natural Language includes “creating datasets”, “training models”, and “evaluating results”.

(1) Creating datasets: To use AutoML Natural Language, we needed to prepare datasets labeled with the category labels we want the model to use. The datasets must supply at least 20 and no more than 100,000 source text documents containing the content needed to train the custom model. In addition, they must supply at least two and no more than 100 unique labels. The datasets must apply each label to at least ten documents. In this study, we used the datasets created earlier with “sentences about facts” as a “FACT” label, “sentences about cognitions” as a “COGNITION” label, and “sentences about percepts of learning” as a “FORWARD” label.

(2) Training models: Model training can be done using AutoML Natural Language UI from a Web browser. We uploaded the datasets as a csv file using the UI and created our custom machine learning model through the training. In this training, AutoML Natural Language used the items from the dataset to train the model, test it, and evaluate its performance.

(3) Evaluating results: Tables 5 and 6 show the evaluation results of the quality and accuracy of the created model.

<table>
<thead>
<tr>
<th>Evaluation metrics</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average precision</td>
<td>0.787 (78.7%)</td>
</tr>
<tr>
<td>Precision</td>
<td>73.2%</td>
</tr>
<tr>
<td>Recall</td>
<td>64.1%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Predicted label</th>
<th>Recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>COGNITION</td>
<td>55.3%</td>
</tr>
<tr>
<td>FACT</td>
<td>77.2%</td>
</tr>
<tr>
<td>FORWARD</td>
<td>57.1%</td>
</tr>
</tbody>
</table>

In Table 5, the average precision shows how well the created model performed. The closer to 1.0 this score is, the better the model performed on the test set. Our model’s average precision was 78.7%. The precision shows, from all the test examples that were assigned a label, how many were actually supposed to be categorized with that label. Our model’s precision was 73.2%. The recall shows, from all the test examples that should have had the label assigned, how many were actually assigned the label. Our model’s recall was 64.1%. Table 6 shows the model’s performance on each label as a confusion matrix. In an ideal model, all values on the diagonal will be high, and all other values will be low. This shows that the desired categories are being identified correctly. If any other values are high, it gives a clue into how the model is misclassifying test items. Our model identified the “FACT” label at a rate of 77.2%, “COGNITION” at a rate of 55.3%, and “FORWARD” at a rate of 57.1%.

These results demonstrate that our model had an overall accuracy of 78.7% on average and 55% or more identification accuracy for each label in the test data. Since the true label “COGNITION” was
misclassified as “FACT” at a rate of 38.2%; it is therefore necessary to verify the accuracy of the model using actual data.

3.2 Function 2: Visualize Situation of Student Reflection (Corresponds to Requirement 2)

As a system function to help teachers facilitate student reflection, Function 2 visualizes the situation of each student’s reflection on learning on the basis of the classification result provided by Function 1. Specifically, Function 2 visualizes both the registered sentences and the phase of reflection on learning at which each student is by showing a highlight based on the classification result. Table 7 shows the correspondence between classification result and highlight color.

With reference to Table 7, it seems clear that teachers can easily grasp the situation of each student’s reflection and what kind of facilitation is necessary by checking the visualized highlight color and the registered sentences. Thus, teachers will be able to facilitate reflection on learning appropriately by using Table 2’s prompts.

Table 7. Correspondence of classification results and highlight color.

<table>
<thead>
<tr>
<th>Classification result</th>
<th>Highlight color</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FACT</td>
<td>Red</td>
<td>A necessary situation of facilitating reflection with cognitive awareness.</td>
</tr>
<tr>
<td>COGNITION</td>
<td>Yellow</td>
<td>A necessary situation of facilitating reflection with precepts of learning.</td>
</tr>
<tr>
<td>FORWARD</td>
<td>None</td>
<td>No facilitation necessary.</td>
</tr>
</tbody>
</table>

3.3 Function 3: Provide Prompts for Facilitating Student Reflection (Corresponds to Requirement 2)

As another system function for enabling the system itself to facilitate student reflection, Function 3 provides prompts to promote reflection on learning depending on the phases of reflection on learning on the basis of the classification result provided by Function 1. Specifically, Function 3 displays the prompts on a Web browser modal window after a student has registered sentences of reflection on learning. Function 3 also promotes student reflection by reading the provided prompt and having the student add further sentences reflecting on learning. Table 8 shows the prompts provided according to the classification result.

Table 8. Prompts providing according to classification result.

<table>
<thead>
<tr>
<th>Classification result</th>
<th>Prompt</th>
</tr>
</thead>
<tbody>
<tr>
<td>FACT</td>
<td>What kind of things did you think at that time? And what did you think was important?</td>
</tr>
<tr>
<td>COGNITION</td>
<td>What do you think you should do to progress to the subsequent learning?</td>
</tr>
<tr>
<td>FORWARD</td>
<td>None (due to move on to the subsequent reflection on learning)</td>
</tr>
</tbody>
</table>

4 DEVELOPMENT OF STUDENT REFLECTION SUPPORT SYSTEM USING MACHINE LEARNING MODEL

We developed a student reflection support system with Functions 1, 2, and 3 as a Web application. The development languages used were PHP, Python, and MySQL on the server side and HTML, CSS, and JavaScript on the client side. To enable cooperation with the machine learning model, we used the Python libraries of Google Cloud. Specifically, we apply the process of automatic classification after wrapping sentences of reflection on learning input from the browser. Then, we obtain the classification results in JSON format.

In our system, two use cases are supported: one used by students and teachers and one used by students only. When used by students and teachers, teachers grasp each student’s situation and facilitate appropriate reflection by checking the results of classification (Functions 1 and 2). When used by students only, the system (not the teachers) grasps each student’s situation and facilitates
appropriate reflection by providing prompts (Functions 1 and 3). The flow of use for our system is as follows.

1 Students write sentences of reflection on learning in our system after learning activities or classes. At this time, students write in a text input form and click the “confirm” button to register the sentences (Fig. 4).

2 Our system classifies automatically by calling the machine learning model (corresponds to Function 1). At this time, our system wraps the registered sentences on the server side and applies the process of classification to the model in Google Cloud.

3 Our system obtains the classification result and visualizes it along with the registered sentences on a teacher’s page that displays a list of sentences of reflection on learning registered by students (corresponds to Function 2). At this time, our system visualizes using the highlight colors (Table 7) by referencing the label with the highest predicted value among the three labels.

4 Teachers grasp the situation of each student’s reflection on learning by looking at the page listed in both the registered sentences and highlight color (Fig. 5). At this time, teachers grasp what kind of facilitation is necessary by looking at the page.

![Figure 4. Screen for inputting sentences of reflection on learning by students.](image)

1 Then, teachers facilitate reflection on learning appropriately by using the prompts in Table 2.

2 Or, our system provides the prompts in Table 8 according to the classification results (corresponds to Function 3) (Fig. 6).
This function is enabled when used by students outside the classroom or at the student’s home. Specifically, after the sentences of reflection on learning are registered, Function 1 automatically performs the classification. Then, Function 3 displays the modal window with the prompt on the basis of the classification results. Students can add further sentences of reflection on learning to an additional text input form as directed by the displayed prompt.

5 CONCLUSION

We constructed a custom machine learning model to automatically classify written reflections on learning on the basis of the phases of these reflections in order to grasp each student’s individual situation. We also developed a student reflection support system with functions for the system and teachers to facilitate student reflection appropriately by using the classification results.

Our system has two key advantages:

**Advantage 1:** Teachers are able to facilitate appropriate reflection on learning for each student because it is easy for them to grasp the situation of each student by using the classification results based on the phases of these reflections.

**Advantage 2:** Students are able to learn proactively and autonomously by being continuously assisted with the appropriate reflection on learning anytime and anywhere because the system automatically provides this assistance on the basis of the classification results.

On the other hand, there are two issues that occur while using our system:

- Even if teachers can grasp the situation, the effort to facilitate remains, and the effectiveness of the facilitation depends on the actual action they take.

- Even if the system provides prompts that facilitate reflection on learning, students may misunderstand the prompts or just blindly follow the phrasing. Because of this, there is a risk that students will not learn as proactively and autonomously as hoped.

In the case of the latter issue in particular, if students do not have a strong engagement in learning, they may fall into passive learning. Addressing these issues is a future avenue of research.

In the near future, we will evaluate the automatic classification by our machine learning model and investigate the effectiveness of the proposed system in detail.

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