Deep-Learning-based Analysis of the Patterns Associated with the Changes in the Grit Scores and Understanding Levels of Students

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***Abstract*—The purpose of this study is to classify the pattern of the understanding level changes for university students during class term, and analyze the relation between them and the changes in the Grid score before and after the class term. Dynamic time warping was applied for classification of the understanding level, and the decision tree was applied to analyze the relation between the changes in the understanding level and that in the Grid score. As a result, it was shown that a large variety of the patterns of changes in the understanding level, and the relations between the understanding level and Grid score cover a wide variety, too. It is necessary to take these results for conducting effective lectures.**

***Keywords*—Time series; dynamic time warping; decision tree; Grit**

I. Introduction

With the spread of information, communication equipment, the online management of student learning data for learning analysis has become popular. Furthermore, with the advent of machine learning and time series analysis, research on learning analysis and education data mining[1] has been actively conducting for improving education quality. Studies that predict students' careers and probability of dropping out of school analyze educational data as time series data using the state transition model and machine learning algorithms [2] [3]. In the knowledge accumulation approach to learning, learners reflect on their understanding levels before undertaking a task, and the teacher visualizes the students' understanding levels from the results. Accordingly, learners can improve their comprehension, and the teacher can make improvement to the contents of their lecture accordingly [4]. Regarding knowledge accumulation, it not only focuses on cognitive factors, which are measured by academic assessments such as examinations, but it also highlights the importance of non-cognitive factors such as self-adjustment capability.

Many reports have confirmed that non-cognitive factors influence not only social behavior but also academic performance [5] [6]. Additionally, they can potentially strongly impact cognitive capabilities such as academic ability and intelligence quotient [7]. The Grit score [8], which measures a learner's self-control in pursuing goals and enthusiasm in overcoming difficulties, is a particularly strong predictor of their educational achievements. This score has attracted wide attention globally in the field of education, with many reports investigating its impact on academic grades in higher educational institutions [9] and colleges [10][11]. Specifically, it has been reported that the level of perseverance measured by the Grit score is related to both a learner's English acquisition time and proficiency [12]. In the field of information technology in education, the relation between information and communication technology and students' self-efficacy and information literacy has been studied [13]. In a study for medicine Residents, higher Grit scores are reported associated with less burnout [14]. For these reasons, the Grit score has attracted widespread attention. It is also known that Grid score changes in the case of situation, and Grid score at the school base has large variance, and it is higher in the sports area than in school and life [15]. In my previous study [16], data on students' understanding levels were treated as time series data, and the effect of the understanding levels in a previous lecture on the understanding levels in a new lecture was reported using time series analysis. The study discussed the relation between maintaining the understanding level and decrease in retention of learned information over time. Furthermore, it revealed that correspondence with the levels of learning retention in the learning pyramid could improve the quality of education. Moreover, the differences in learners' grades had a significant effect on their cumulative understanding levels. Additionally, a study on students' Grit scores during clinical practice in a physical therapy training course showed improvements in the Grit score improvement and variations in their understanding levels [17]. Regarding a university-lecture setting, which involves many students, there are various factors that affect students' understanding levels. As previously mentioned, Grit scores can change, and the variations in students' motivation and understanding levels can potentially affect such changes.

It can be difficult to assess students' understanding levels in a lecture-type setting where there are more than a hundred registered students, compared to hands-on practice or seminar-type settings that offer more scope for one-on-one interactions. Therefore, it is important that lecturers are acquainted with patterns in students' understanding levels or changes in their Grit scores to conduct their lectures more effectively. Furthermore, by clarifying the relation between the understanding level and Grit score , lecturers can identify students who may need additional support or interventions and assist them accordingly. This study aims to classify the patterns found in the changes between students' understanding levels and Grit scores in both traditional lecture-type classroom and practical hands-

on settings. Dynamic time warping (DTW) [18], a time-series analysis algorithm, was used for classification. Furthermore, the decision tree algorithm was used to analyze the relation between the changes in students' understanding levels and Grit scores.

The remainder of this paper is organized as follows. Section II provides a succinct background of Grid score and DTW, and introduces the proposal analysis for students' understanding level and Grid score. Section III introduces the experimental data and discusses the results. Finally, Section IV concludes the paper and future work.

II. Method

This section provides a brief overview of certain time-series analytics and evaluation indices that are frequently used in this study, and proposed procedure for analysis of the patterns associated with the changes in the Grit scores and understanding levels of students.

A. Grit Score

The Grit score consists of the subscales "consistency in interest", which represents passion, and "perseverance in effort", which represents persistence; the average value of these scores is used as the Grit score. A high passion score corresponds to carefully working toward a single goal for a long time, and a high persistence score corresponds to displaying determination in the face of difficulties and not being satisfied till a specified result is achieved. In this study, the relation between students' understanding levels and passion and persistence scores was also analyzed.

B. Dynamic Time Warping (DTW) Model

The DTW model finds the optimal alignment between two-time sequences by the brute force approach. This technique is often used to analyze human behavior data, such as voice data or walking data. In the field of education, clustering methods such as DTW have been used to study the detection of students' Grit scores[19]. The distance between two time-series data points (x_t, y_t) is defined as follows:

$$DTW(x, y) = min \sum_{i=1}^{p} |x_t - y_t|, \quad (1)$$

Moreover, it is possible to classify multiple time-series data by applying the k-means method in DTW[20]. In the current study, DTW has been applied to determine the patterns in the changes in the understanding levels of students.

C. Proposal Analysis based Deep-Learning Regarding Students'Understanding Levels and Grid Score

In this study, the changes in students' understanding levels in different types of lecture settings were observed. Students were asked to rate their understanding levels for a day's lecture using one of these five options: 100%, 80%, 60%, 40%, or less than 20%, 0% denoted a student's absence. Next, the students' Grit score data over more than 10 lectures were collected as time series data, and DTW was applied to determine any patterns in the changes in the students' understanding levels. Furthermore, the decision tree algorithm was applied to obtain the rules that explained the changes in both the understanding level and those in the Grit score before and after the classes to visualize the relation between these changes. The process of data generation for the Grit score or the students' understanding levels are described in steps 1–4 (Fig. 1), and the process of data analysis is described in steps 5–8.

Fig. 1. Procedure of investigation (steps 1–4):The horizontal axis indicates the number of lectures, and the vertical axis indicates the understanding level. $Grit_{before}$ will be collected before the start of lecture term, and $Grit_{after}$ will be collected after the end of lecture term.

- Step1 Measure the students' $Grit_{before}$ scores on the day of the first lecture for each subject.
- Step2 Ask each student to select the option (out of five) corresponding to their understanding level after each lecture.
- Step3 Implement step 2 in all the classes and save the data on the understanding level scores as time series data.
- Step4 Measure the students' $Grit_{after}$ scores on the day of the final lecture for each subject.
- Step5 Apply DTW to the time series data obtained in step 3 and predict the patterns in the changes in the students' understanding levels.
- Step6 Classify the Grit scores obtained in steps 1 and 4 as either a "passion score" or "persistence score," compare the $Grit_{before}$ and $Grit_{after}$, and convert the increase or decrease in the scores to "up" or "down," respectively.
- Step7 Generate learning data using the students' understanding levels in each lecture as the explanatory variable and the changes (increases/decreases) in the Grit scores comprising the passion score and persistence score as the objective variable.
- Step8 Apply the decision tree algorithm to the learning data obtained in step 7 and extract the rules for the relationships between the changes in the Grit scores and understanding levels.

Based on the properties and components of the Grit score, three hypotheses regarding the patterns in the relation between the changes in the understanding levels and Grit scores are proposed.

- H_1 The Grit (especially passion) scores increase when the understanding levels are high.
- H_2 Maintaining diligent class participation results in high Grit (especially persistence) scores even if the understanding levels are low.
- H_3 The Grit (especially passion) scores decrease when the understanding levels are low.

In this study, these hypotheses were tested through analyses performed through DTW and the decision tree algorithm.

III. Results and Discussion

This section provides the detail of experimental data and discuss the results. First, the results of applying DTW to each data regarding students' understanding levels are reported as described in Step 5 of the proposed procedure. Second, the relation between changes in the understanding level and those in the Grit scores are by use of decision tree reported as explained in Step 6.

A. Experimental Data

The collected experimental data are described in this section. To obtain data for this research, a survey for six classes was conducted in 2021. In this investigation, 328 time-series data were collected, wherein participants 1, 2, and 3 were in a lecture-type setting, and participants 4, 5, and 6 were in a practical-type setting. Details of the collected data include the type of class setting and the number of students in each class, as shown in Table I.

TABLE I. Details of Each Class

	Lecture or practical	Number of students
Participant 1	Lecture	103
Participant 2	Lecture	69
Participant 3	Lecture	70
Participant 4	Practical	30
Participant 5	Practical	31
Participant 6	Practical	17

B. The Results of Applying DTW to Data of Students' Understanding Levels

The analysis results of the acquired data and the discussion are presented. First, the results of applying DTW to each data regarding students' understanding levels with different numbers of clusters (2, 3, and 4) are shown. Fig. 2 to Fig. 4 show the results of the practical-type classes, and Fig. 5 to Fig. 7 show the results of the lecture-type classes. In these figures, the horizontal axis indicates the number of the lectures, and the vertical axis indicates the understanding levels.

Considering that an understanding level of 0 indicates the absence of a student for a class, only cases wherein the understanding level was 0.2 or more have been discussed. In the case of practical-type classes, when the cluster number was two, the data were classified into groups with either red lines or blue lines. In both the group with the red lines and that with the blue lines, the understanding levels were only 1.0 in the mid and later periods, with them transitioning between 0.4 and 1.0. When the cluster number was three, the data were classified into groups with either red lines, blue lines, or green lines. In the group with the red lines, all kinds of understanding levels were included. The group with the blue lines included understanding levels between 0.6 and 1.0 while that with the green lines included understanding levels of all kinds and noticeably included absenteeism. When the cluster number was four, the data were classified into groups with red, blue, green, or yellow lines. The groups with red or blue lines resembled the groups for the cluster number of three. The group with the green lines included understanding levels between 0.2 and 0.6 and high understanding levels in the starting and later periods

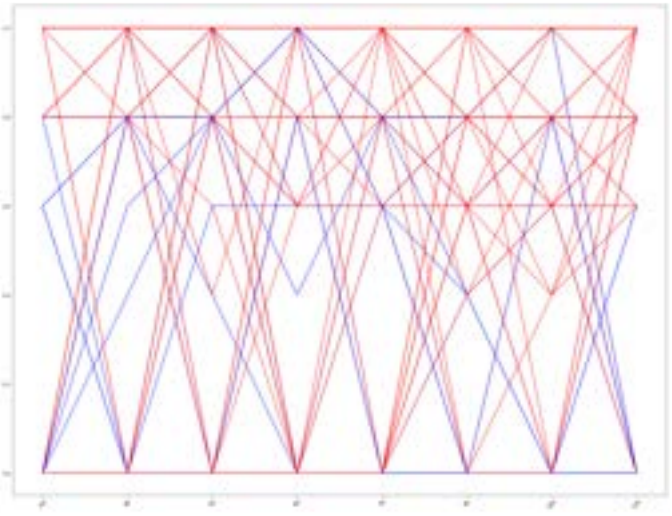

Fig. 2. Practical-type classes (number of clusters =2).

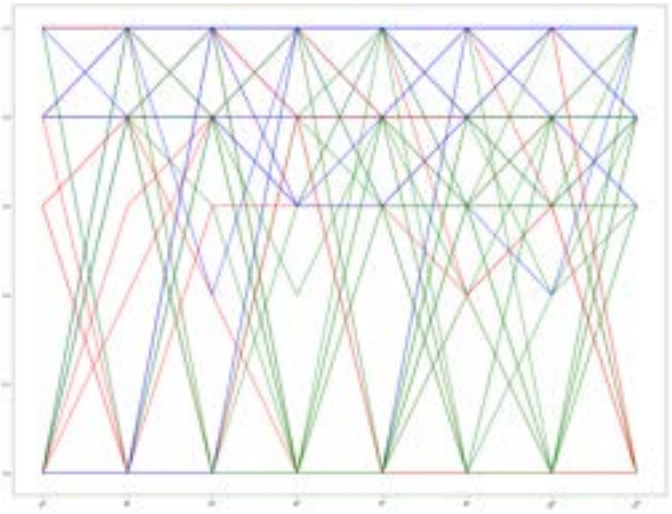

Fig. 3. Practical-type classes (number of clusters =3).

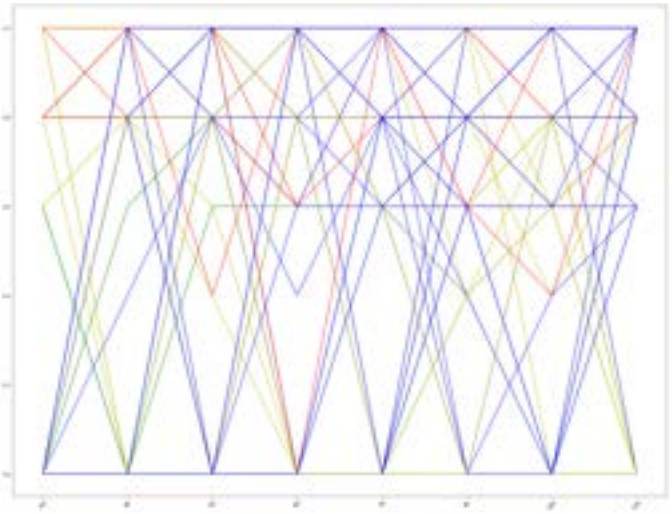

Fig. 4. Practical-type classes (number of clusters =4).

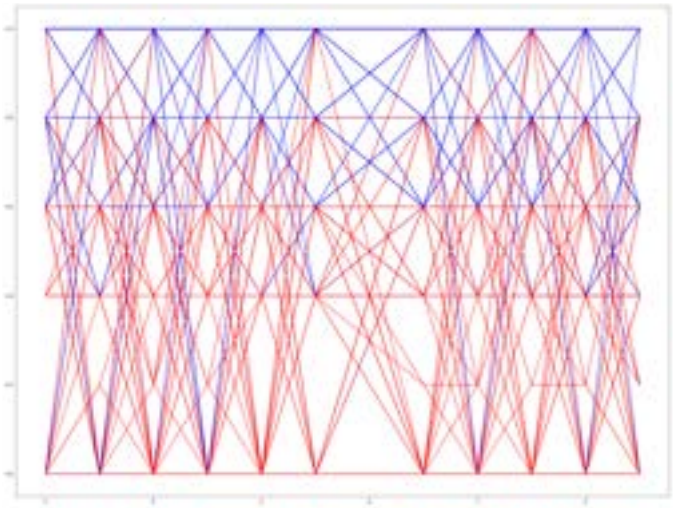

Fig. 5. Lecture-type classes (number of clusters =2).

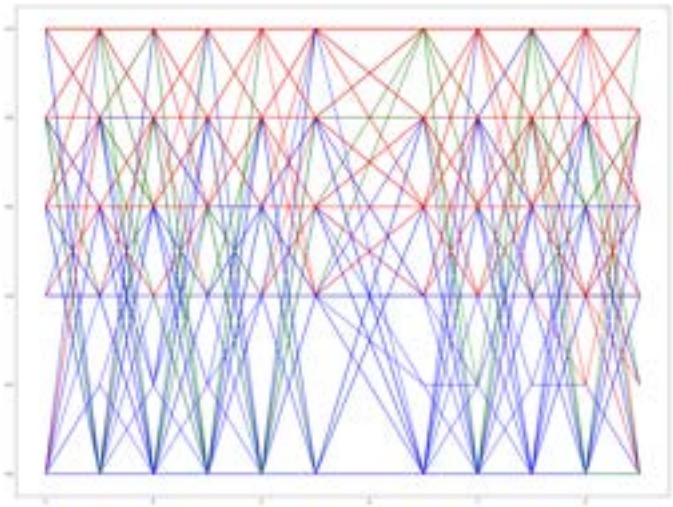

Fig. 6. Lecture-type classes (number of clusters =3).

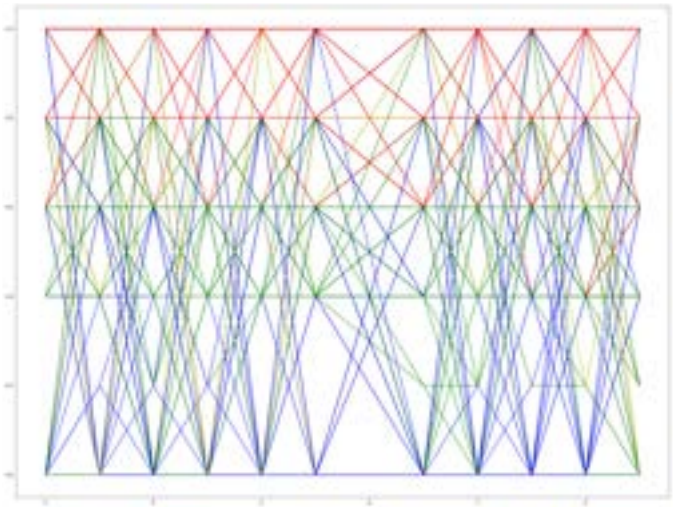

Fig. 7. Lecture-type classes (number of clusters =4).

while the group with yellow lines included low understanding levels.

Regarding lecture-type classes, when the cluster number was two, the data were classified into groups with either red or blue lines. Most of the blue lines were positioned at the upper side while most of the red lines were positioned at the lower side. Each group either contained high understanding levels or low understanding levels.

When the cluster number was three, the data were classified into groups with either red, blue, or green lines. The group with red lines included high understanding levels (more than 0.4), and the group with blue lines included various understanding levels of either other degrees or 0, indicating the presence of frequent absenteeism. The group with the green lines included understanding degrees that were both high and low. When the cluster number was four, the data were classified into groups with red, blue, green, or yellow lines. The groups with red or blue lines resembled the groups for the cluster number of three. The group with the green lines included understanding levels between 0.2 and 0.6 and high understanding levels in the starting and later periods while the group with yellow lines included low understanding levels.

C. The Relation between Changes in the Understanding Level and Those in the Grit Scores

Under the application of DTW, many trends were observed in the changes in the understanding levels. Here, the relation between more specific changes in the understanding level and those in the Grit scores will be discussed. Table II to Table V presents the rules obtained by applying the decision tree algorithm to analyze the relation between changes in Grit scores and those in the understanding level. Table II to Table III presents the results of practical type, and Table IV to Table V presents the results of lecture type.

TABLE II. PRACTICAL TYPE:RELATIONS AND SUMMARY BETWEEN THE CHANGES IN THE GRIT SCORES AND UNDERSTANDING LEVELS

Practical type:Grit
Rule 1: 10th$<$0.7, up (0.16)
Rule 2: 6th $\geq$ 0.9, 10th $\geq$ 0.7, 11th $<$0.9, up (0.13)
Rule 3: 6th $\geq$ 0.9, 10th $\geq$ 0.7, 11th $\geq$ 0.9, down (0.07)
Rule 4: 6th $<$0.9, 10th $\geq$ 0.7, down (0.04)
Rule 1: The Grit scores of 16% of the students increased even though their understanding levels in the tenth lecture were less than 70%.
Rule 2: The Grit scores of 13% of the students increased when their understanding levels were more than 90% in the sixth lecture and less than 90% in the eleventh lecture.
Rule 3: The Grit scores of 7% of the students decreased when their understanding levels were more than 90%, 70%, and 90% in the sixth, tenth, and eleventh lectures, respectively.
Rule 4: The Grit scores of 4% of the students decreased when their understanding levels were less than 90% in the sixth lecture and more than 70% in the tenth lecture.

First, the data classification results for the practical-type setting will be discussed. Regarding the Grit score, the following patterns were observed: 1) the Grit scores increased even when the understanding levels were low in the latter period; 2) the Grit scores increased even when the understanding levels were high in the middle period and low in the later period; and 3) the Grit scores decreased even though the understanding levels were high in the middle and latter periods. Concerning the persistence score component of the Grit score,

TABLE III. PRACTICAL TYPE:RELATIONS AND SUMMARY BETWEEN THE CHANGES IN THE GRIT SCORES (PERSISTENCE AND PASSION) AND UNDERSTANDING LEVELS

Practical type: Grit(Persistence)
Rule 1: 4th <0.2, up (0.16)
Rule 2: 2nd ≥ 0.7, 4th ≥ 0.2, 6th >0.9, up (0.15)
Rule 3: 2nd ≥ 0.7, 4th ≥ 0.2, 6th <0.9, down (0.11)
Rule 4: 2nd <0.7, 4th ≥ 0.2, down (0.09)
Rule 1: The Grit (Persistence) scores of 16% of the students increased even though their understanding levels were less than 20% in the fourth lecture.
Rule 2: The Grit (Persistence) scores of 15% of the students increased when their understanding levels were more than 70, 20, and 90% in the second, fourth, and sixth lectures, respectively.
Rule 3: The Grit (Persistence) scores of 11% of the students decreased when their understanding levels were more than 70% in the second lecture, more than 20% in the fourth lecture, and less than 90% in the sixth lecture.
Rule 4: The Grit (Persistence) scores of 9% of the students decreased when their understanding levels were less than 70% in the second lecture and more than 20% in the fourth lecture.
Practical type: Grit(Passion)
Rule 1: 4th ≥ 0.2, 7th ≥ 0.7, 9th ≥ 0.7, down (0.13)
Rule 2: 4th ≥ 0.2, 7th <0.7, 9th ≥ 0.7, up (0.09)
Rule 3: 4th ≥ 0.2, 9th <0.7 down (0.04)
Rule 4: 4th <0.2, down (0.02)
Rule 1: The Grit (Passion) scores of 13% of the students decreased even though their understanding levels were more than 20% in the fourth lecture and more than 70% in both the seventh and ninth lectures.
Rule 2: The Grit (Passion) scores of 9% of the students increased when their understanding levels were more than 20% in the fourth lecture, less than 70% in the seventh lecture, and more than 70% in the ninth lecture.
Rule 3: The Grit (Passion) scores of 4% of the students decreased when their understanding levels were more than 20% in the fourth lecture and less than 70% in the ninth lecture.
Rule 4: The Grit (Passion) scores of 2% of the students decreased when their understanding levels were less than 20% in the fourth lecture.

TABLE IV. LECTURE TYPE:RELATIONS AND SUMMARY BETWEEN THE CHANGES IN THE GRIT SCORES AND UNDERSTANDING LEVELS

Lecture type: Grit
Rule 1: 3rd <0.2, down (0.02)
Rule 2: 3rd ≥ 0.2, 10th <0.7, 13th ≥ 0.5, down (0.07)
Rule 3: 3rd ≥ 0.2, 9th <0.9, 10th ≥ 0.7, 13th ≥ 0.5, 13th ≥ 0.9 down (0.01)
Rule 4: 3rd ≥ 0.2, 9th <0.9, 10th ≥ 0.7, 12th <0.7, 13th ≥ 0.5, 13th <0.9 down (0.03)
Rule 5: 3rd ≥ 0.2, 9th <0.9, 10th ≥ 0.7, 12th ≥ 0.7, 13th ≥ 0.5, 13th <0.9, down (0.12)
Rule 6: 3rd ≥ 0.2, 9th ≥ 0.9, 10th ≥ 0.7, 13th ≥ 0.5, up (0.12)
Rule 7: 3rd ≥ 0.2, 13th <0.5, up (0.07)
Rule 1: The Grit scores of 2% of the students decreased when their understanding levels were less than 20% in the third lecture.
Rule 2: The Grit scores of 7% of the students decreased when their understanding levels were more than 20% in the third lecture, less than 70% in the tenth lecture, and more than 50% in the thirteenth lecture.
Rule 3: The Grit scores of 1% of the students decreased when their understanding levels were more than 20, 90, 70, and 50% in the third, ninth, tenth, and thirteenth lectures, respectively.
Rule 4: The Grit scores of 3% of the students decreased when their understanding levels were more than 20% in the third lecture, less than 90% in the ninth lecture, more than 70% in the tenth lecture, less than 70% in the twelfth lecture, and between 50 and 90% in the thirteenth lecture.
Rule 5: The Grit scores of 12% of the students decreased when their understanding levels were more than 20% in the third lecture, less than 90% in the ninth lecture, more than 70% in the tenth and twelfth lectures, and between 50 and 90% in the thirteenth lecture.
Rule 6: The Grit scores of 12% of the students increased when their understanding levels were more than 20, 90, 70, and 50% in the third, ninth, tenth, and thirteenth lectures, respectively.
Rule 7: The Grit scores of 7% of the students increased when their understanding levels were more than 20% in the third lecture and less than 50% in the thirteenth lecture.

the following patterns were noted: 1) the persistence scores increased when the understanding levels were low in the former period and increased in the latter period; 2) owing to the diligent student participation, the persistence scores ultimately increased when the understanding levels decreased and increased; and 3) the persistence scores increased even though the understanding levels were less than 20% in the former period; 4) the persistence scores ultimately decreased when the understanding levels decreased in the former period; and 5) the persistence scores ultimately increased even when there were increases and decreases in the understanding level, owing to the diligent student participation. Regarding the passion score component of the Grit score, the following patterns were noted: 1) the passion scores decreased even though the understanding levels gradually increased; 2) the passion scores increased when the understanding levels gradually increased; and 3) the passion scores decreased when the understanding levels were low in the former period.

Now , the data classification results for lecture-type settings will be discussed. Regarding the Grit score, the following patterns were observed: 1) the Grit scores decreased when the understanding levels were low in the former period; 2) the Grit scores decreased even though the understanding levels were low in the former period and high in the latter period; 3) the Grit scores ultimately increased when the understanding levels were low in the former period and high in the latter period, owing to the diligent student participation; 4) the understanding levels were low throughout, but there was diligent participation, resulting in the Grit scores ultimately. Concerning the persistence score component of the Grit score, the following patterns were observed: 1) the persistence scores increased even though the understanding levels were low in the latter period; 2) the understanding levels were low in the former period and average in the latter period, and the persistence scores finally decreased; 3) the persistence scores finally decreased, even though the understanding levels were high in both the former and latter periods; and 4) the persistence scores ultimately increased, when the understanding levels were high throughout the entire period. Regarding the passion score component of the Grit score, the following patterns were observed: 1) the passion scores decreased when the understanding levels were less than average in the middle period; 2) the passion scores ultimately decreased when the understanding levels were low in the former period and high in the latter period; and 3) the passion scores ultimately increased when the understanding levels were average in the former period and even when they were low in the latter period. The above observations revealed that changes in the understanding levels and Grit scores varied depending on the students and type of class setting. Moreover, the hypotheses described in chapter 2 were verified from the data analysis; and additionally, there were some students whose Grit score decreased even when their understanding level was high.

IV. CONCLUSION

This research has made contributions to the viewpoint of comparative study for time series data. The changes in students 'understanding levels over more than ten lectures were considered as time series data, and both lecture-type and practical-type class settings in a university were analyzed. First, changes in the patterns of students' understanding levels were analyzed through DTW. The change patterns were quite diverse; thus, subdividing them was necessary. Next, rules

TABLE V. LECTURE TYPE:RELATIONS AND SUMMARY BETWEEN THE CHANGES IN THE GRIT SCORES (PERSISTENCE AND PASSION) AND UNDERSTANDING LEVELS

Lecture type: Grit(Persistence)
Rule 1: 13th $<$0.5, up (0.08)
Rule 2: 3rd $<$0.7, 13th $\geq$ 0.5 down (0.08)
Rule 3: 3rd $\geq$ 0.7, 4th $<$0.7, 13th $\geq$ 0.5, down (0.05)
Rule 4: 3rd $\geq$ 0.7, 4th $\geq$ 0.7, 13th $\geq$ 0.5, 13th $<$0.7 up (0.06)
Rule 5: 3rd $\geq$ 0.7, 4th $\geq$ 0.7, 6th $\geq$ 0.9, 13th $\geq$ 0.7, 13th $<$0.9 down (0.01)
Rule 6: 3rd $\geq$ 0.7, 4th $\geq$ 0.7, 6th $<$0.9, 13th $\geq$ 0.7, 13th $<$0.9 up (0.1)
Rule 7: 3rd $\geq$ 0.7, 4th $\geq$ 0.7, 13th $\geq$ 0.9, up (0.08)
Rule 1: The Grit (Persistence) scores of 8% of the students increased when their understanding levels were less than 50% in the thirteenth lecture.
Rule 2: The Grit (Persistence) scores of 8% of the students decreased when their understanding levels were less than 70% in the third lecture and more than 50% in the thirteenth lecture.
Rule 3: The Grit (Persistence) scores of 5% of the students decreased when their understanding levels were more than 70 and 50% in the third and thirteenth lectures, respectively.
Rule 4: The Grit (Persistence) scores of 6% of the students increased when their understanding levels were more than 70% in the third and fourth lectures and between 50 and 70% in the thirteenth lecture.
Rule 5: The Grit (Persistence) scores of 1% of the students decreased when their understanding levels were more than 70% in the third and fourth lectures, more than 90% in the sixth lecture, and between 70 and 90% in the thirteenth lecture.
Rule 6: The Grit (Persistence) scores of 10% of the students increased when their understanding levels were more than 70% in the third and fourth lectures, less than 90% in the sixth lecture, and between 70 and 90% in the thirteenth lecture.
Rule 7: The Grit (Persistence) scores of 8% of the students increased when their understanding levels were more than 70% in the third and fourth lectures and more than 90% in the thirteenth lecture.
Lecture type: Grit(Passion)
Rule 1: 9th $<$0.5, down (0.01)
Rule 2: 3rd $<$0.2, 9th $\geq$ 0.5,13th $\geq$ 0.7, down (0.01)
Rule 3: 3rd $\geq$ 0.2, 9th $\geq$ 0.5, 9th $<$0.7, 12th $\geq$ 0.7, 13th $\geq$ 0.7 down (0.01)
Rule 4: 2nd $<$0.9, 3rd $\geq$ 0.2, 9th $\geq$ 0.7, 12th $\geq$ 0.7, 13th $\geq$ 0.7, down (0.07)
Rule 5: 2nd $\geq$ 0.9, 3rd $\geq$ 0.2, 9th $\geq$ 0.7, 12th $\geq$ 0.7, 13th $\geq$ 0.7 up (0.09)
Rule 6: 3rd $\geq$ 0.2, 9th $\geq$ 0.5, 12th $<$0.7, 13th $\geq$ 0.7 up (0.07)
Rule 7: 2nd $<$0.7, 5th $<$0.7, 9th $\geq$ 0.5,13th $<$0.7 down (0.02)
Rule 8: 2nd $\geq$ 0.7, 5th $<$0.7, 9th $\geq$ 0.5,13th $<$0.7 up (0.08)
Rule 9: 5th $\geq$ 0.7, 9th $\geq$ 0.5,13th $<$0.7 up (0.11)
Rule 1: The Grit (Passion) scores of 1% of the students decreased when their understanding levels were less than 50% in the ninth lecture.
Rule 2: The Grit (Passion) scores of 1% of the students decreased when their understanding levels were less than 20% in the third lecture and more than 50 and 70% in the ninth and thirteenth lectures, respectively.
Rule 3: The Grit (Passion) scores of 1% of the students decreased when their understanding levels were more than 20% in the third lecture, between 50 and 70% in the ninth lecture, and more than 70% in both the twelfth and thirteenth lectures.
Rule 4: The Grit (Passion) scores of 7% of the students decreased when their understanding levels were less than 90% in the second lecture, more than 20% in the third lecture, and more than 70% in the ninth, thirteenth, and, respectively.
Rule 5: The Grit (Passion) scores of 9% of the students increased when their understanding levels were more than 90% in the second lecture; more than 20% in the third lecture; and more than 70% in the ninth, twelfth, and thirteenth lectures.
Rule 6: The Grit (Passion) scores of 7% of the students increased when their understanding levels were more than 20% in the third lecture, more than 50% in the ninth lecture, less than 70% in the twelfth lecture, and more than 70% in the thirteenth lecture.
Rule 7: The Grit (Passion) scores of 2% of the students increased when their understanding levels were less than 70% in the third, fifth, and thirteenth lectures and more than 50% in the ninth lecture.
Rule 8: The Grit (Passion) scores of 8% of the students increased when their understanding levels were more than 70% in the second lecture, less than 70% in the fifth lecture, more than 50% in the ninth lecture, and less than 70% in the thirteenth lecture.
Rule 9: The Grit (Passion) scores of 11% of the students increased when their understanding levels were more than 70% in the fifth lecture, more than 50% in the ninth lecture, and less than 70% in the thirteenth lecture.

reflecting the relation between changes in the Grit score before and after students participated in classes and changes in their understanding level were acquired through the decision tree algorithm. The proposed hypotheses were verified through data analysis, and noteworthily, unexpected patterns were extracted. The analysis results clearly showed that when conducting classes, the various relations between the changes in understanding levels and Grit scores of students should be considered.

The limitations of this study are two points. The first point is about the experimental data. Since students' data used in this study limited to the one university, it is necessary to try analyzing the case of the other university. The second point is the evaluation index. Since the understanding level is subjective scale that is students evaluate themselves, objective scale has to be applied. In addition, DTW was used for clustering of time series data and other statistical methods are necessary, as the future work.

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