Year 2023	**Summary　of　Thesis**

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A Fundamental Research on a Method for Determining the Teaching Content of Total Derivatives Utilizing Formal Concept Analysis and Rough Set Theory

1.　Introduction

It is important to teach multivariable functions and derivatives to high school and college students. Many students don't properly understand the concept of derivatives. On the other hand, most functions used in the real society are multivariable functions, thus teaching them helps students understand the usefulness of mathematics. Teaching the concept of total derivatives is necessary to deepen the understanding of concepts of both. In addition, three-dimensional images and immersive experiences provided by VR technology can enhance educational effectiveness.

Cronbach suggested that instruction should be suitable for the characteristics of the learner in order to improve educational effects. In this study, both Formal Concept Analysis and Rough Set Theory can be used to determine teaching content according to learner characteristics. Using Formal Concept Analysis, the attributes of objects are considered as concepts, and the conceptual dependency can be visualized by Hasse diagrams. Thus, it is possible to visualize the dependency relationships among the concepts of total derivatives. In Rough Set Theory, we deal with information tables in which objects described by multiple attributes are arranged in rows, and decision rules are extracted from the tables. The relationship between learner characteristics and appropriate teaching content can be analyzed through the analysis of decision rules.

2.　Purpose

In this study, we verify the educational effectiveness of a proposed method for determining the teaching content of total derivatives using Formal Concept Analysis and Rough Set Theory. In addition, considering the importance of diagrams in the teaching of total derivatives, VR materials were used in the experiments.

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3. Proposed Method

Formal Concept Analysis is carried out to analyze the dependencies among classes on total derivatives and eight groups of classes are set based on the dependencies. Next, Rough Set Theory is used to extract decision rules for determining the necessity of each class based on the proficiency level of each learner. Then, using the decision rules, the necessity of each class is determined. Finally, we consider the class group that includes the necessary classes is the best one.

4. Experiment

Two experiments were conducted to extract decision rules and to verify educational effectiveness of the proposed method. The subjects were college students and graduate students who had already studied Mathematics II.

Experiment A: All classes are practiced and decision rules are extracted and the level of understanding of total derivatives is obtained.

Experiment B: Using the decision rules extracted in Experiment A, the best group of classes was practiced and the level of understanding of total derivatives is obtained.

5. Results and Discussions

Tabulated results were subjected to statistical analysis. The results showed that, at the 95% level of significance, there was a significant difference between the results of Experiment A and Experiment B. Therefore, higher educational effects were obtained when classes selected by the proposed method were taken than when all classes were done.

Unnecessary classes can cause learners to lose concentration. Besides, if necessary ones are omitted, learners cannot catch up with the content of total derivatives. Due to these, it is important to omit appropriate classes. As a result, it can be said that the number of classes is appropriately reduced by the proposed method. On the other hand, the method requires whether or not each class is necessary, but does not mention whether or not each class is unnecessary. We speculate that if the latter is also analyzed, the best group of classes can be determined with a higher degree of accuracy.

6. Conclusion

Higher educational effects were obtained when the classes determined by the proposed method were taken than when all the classes were taken. Both Formal Concept Analysis and Rough Set Theory enable us to select classes to teach based on dependencies of classes and learner's characteristics. Verifications of the proposed method in high school students are needed.

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