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A Case Study of Mathematics Educations Using WeBWorK in Hokkaido University

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Abstract

In this paper, we provide academic institutions with knowledge on ICT education for mathematics education, particularly the utilization of WeBWorK through the case study in Hokkaido University. WeBWorK is an open-source online homework system for mathematics and sciences courses. To promote ICT education for mathematics education in Hokkaido University, we began to use WeBWorK in 2017.We prepared more than 800 problems in line with the educational curriculum in Hokkaido University, and a total of more than 4,500 students were using WeBWorK in FY2021.We surveyed them about their work time, the difficulty of the problems and so on, and received 513 responses. Analyzing the results of the surveys we find that WeBWorK plays a role in improving the mathematical computational skills. On the other hand, it does not help users develop English skills, and in fact seems to be a factor that makes them reluctant to work on WeBWorK. Based on the these results we have created the Japanese version of original problems we have already created.

Keywords: E-Learning system, WeBWorK, Case study

1 Introduction

The Japanese government has set up the AI Strategy 2019 to contribute to Society 5.0 and the SDGs, and it has announced a policy that aims for all university and national institute of technology students, regardless of separation, to learn elementary level mathematics, data science, and AI in their courses as literacy education [1]. In line with this, Japan Inter-University Consortium for Mathematics & Data Science Education was formed by six universities across Japan selected by the Ministry of Education, Culture, Sports, Science and Technology (MEXT). The Consortium aims to establish and disseminate an educational system that enables students to master mathematics, data science, and AI at higher education institutions nationwide. A model curriculum was developed as an educational standard to which each educational institution should refer [2].

In this model curriculum, Calculus and Linear Algebra are set as required courses. On the other hand, it is not enough number of faculty to teach lectures. In addition, the educational environment for Linear Algebra and Calculus varies from class to class even in a university. A stable educational environment that is not dependent on classes and lecturers should be created.

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In response to this problem we have begun a trial of WeBWorK, an e-learning homework system, in Hokkaido University to improve the educational environment for mathematics courses in Japan. However, the Open Problem Library (OPL) built into WeBWorK does not have many available problems due to differences in the problem quality and the curriculum. Therefore, we created original problems in line with the Japanese curriculum and have been using them in mathematics courses of Hokkaido University since 2019.

2 What is WeBWorK

2.1 System of WeBWorK

WeBWorK is an open-source online homework system for mathematics and sciences courses [4]. WeBWorK is supported by Mathematical Association of America (MAA) and National Science Foundation (NSF) and comes with the Open Problem Library (OPL) of over 37,000 homework problems. The problem stored in the OPL are categorized by more than 30 "Subject" such as Calculus (single variable), Calculus (multivariable), etc.

Figure 1: The categories of the problems

We can also register "Chapter" and "Section". For example, in Fig. 1 we set "Limits and continuity" as the Chapter and "Rules of limits - basic" as the Section under the category "Calculus (single variable)".
The problems in WeBWorK are written in a dedicated language called "PG language", which is based on the Perl language. The specifications of the PG language are also compiled in a WeBWorK wiki [5], and instructors can create their own original problems.
Since WeBWorK is an open-source system, it can be downloaded for free. There is also no cost to host your server. For reference we simply describe the server performance of WeBWorK in Hokkaido University. There are two servers for WeBWorK, and they are built as a virtual machine on the Intercloud system of the Hokkaido University Information Initiative Center. Server construction, WeBWorK construction, and general server management tasks are outsourced to an external vendor. The performance of the servers is as follows:

- webwork.sci.hokudai.ac.jp
  It has 4 core CPU, 12G memory and 100G disk.

- webwork2.sci.hokudai.ac.jp
  It has 2 core CPU, 6G memory and 100G disk.

WeBWorK servers being implemented in Hokkaido University support following two authentication linkages. The first server “webwork.sci.hokudai.ac.jp” supports shibboleth authentication and the users containing the instructors and the students can log in to WeBWorK by using the login information of ELMS, which is the information system for education in Hokkaido University. On the other hand, the second server "webwork2.sci.hokudai.ac.jp" supports GakuNin. GakuNin is a multi-institutional authentication collaboration system provided by the National Institute of Informatics. Therefore, if the university to which the users belong participates in GakuNin, the users can log in to Webwork using the login information of their own university's authentication in the second WeBWorK server.

2.2 How to Use WeBWorK for Instructors

The server administrator can create a new course, and one instructor account is created for each course by default. After logging into the course, the instructor need to complete the following initial setup.

I. Register for student accounts:
The instructor needs to register the account on WeBWorK. Multiple student accounts may be registered at once by using a csv file.

II. Create the problem sets:
The instructor needs to make sets of multiple problems, which is called problem sets. In each problem set, the instructor can add several problems from the OPL. It is also possible to create original problems with the PG language.

Moreover, the instructor can use the following advanced setting as "Instructor tools" in the problem set:

- The instructor can change number of attempts (including unlimited) / change dates of open and close / show or hide the hints / change the allocation of the points.
- The instructor can obtain the student grades as a csv file.
- The instructor can monitor the student progress and statistical information such as average scores, average attempts and so on.

2.3 How to Use WeBWorK for Students

The students can log in to WeBWorK with the accounts created by the instructor. Once they log in to the course in WeBWorK they can see the following screen.

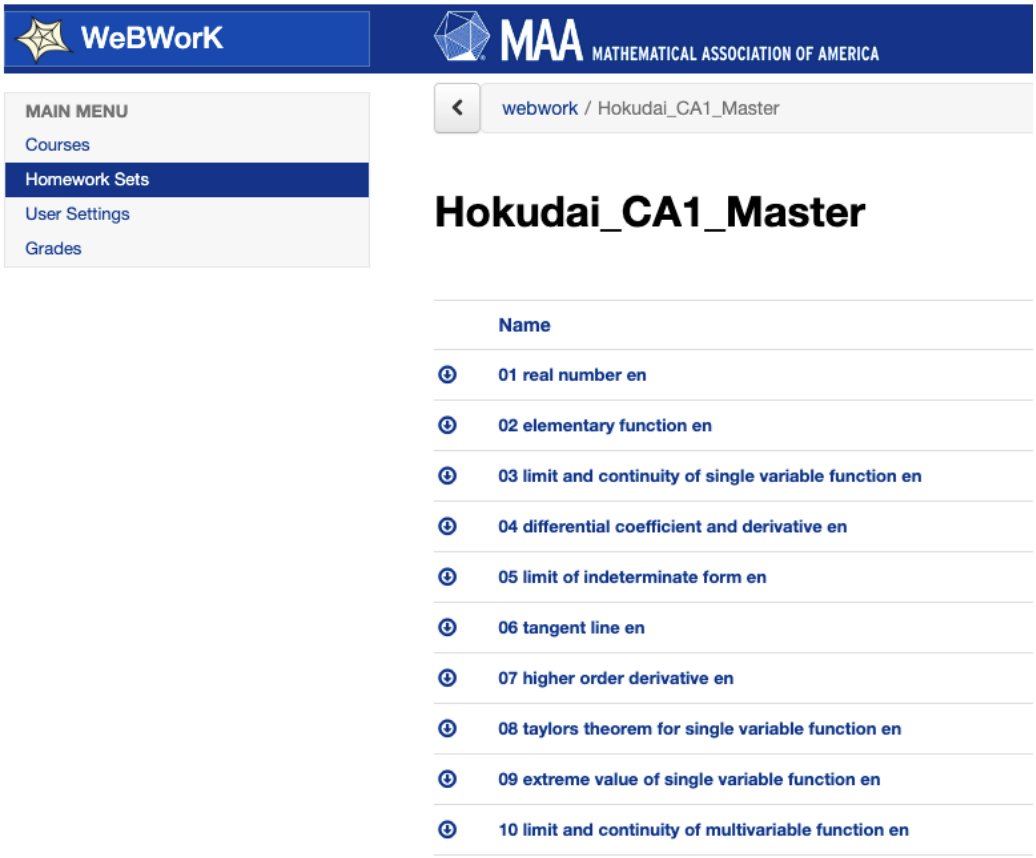

Figure 2: The top page of the course in WeBWorK

By clicking on a set of problems visible on the right side of Fig. 1, students can attempt the problem.

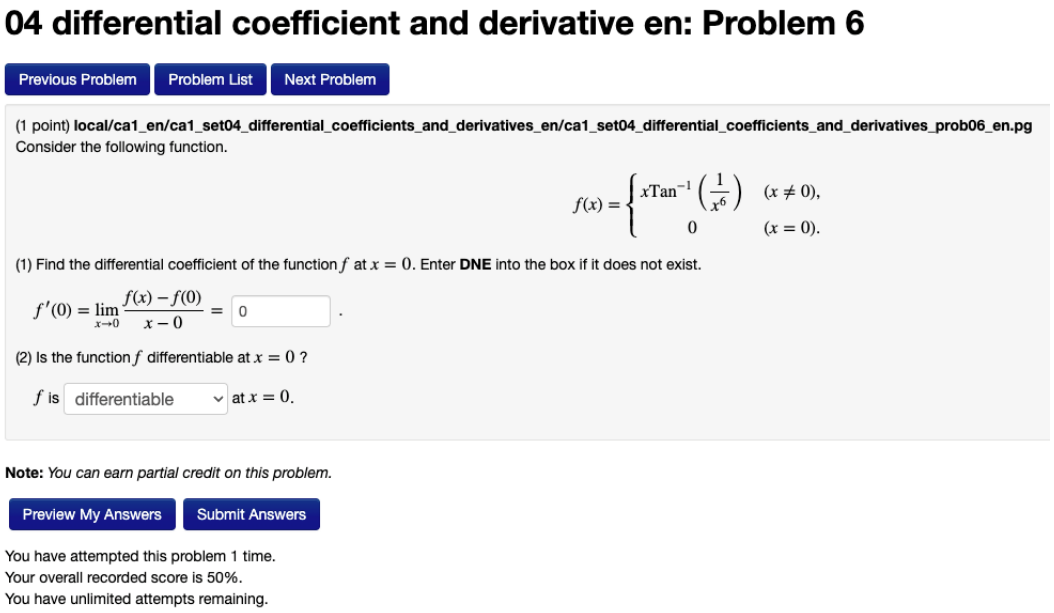

Figure 3: Answer page

After entering the answer to WeBWorK, the user can press the "Submit Answer" button in Fig. 3 to get the answer result immediately.

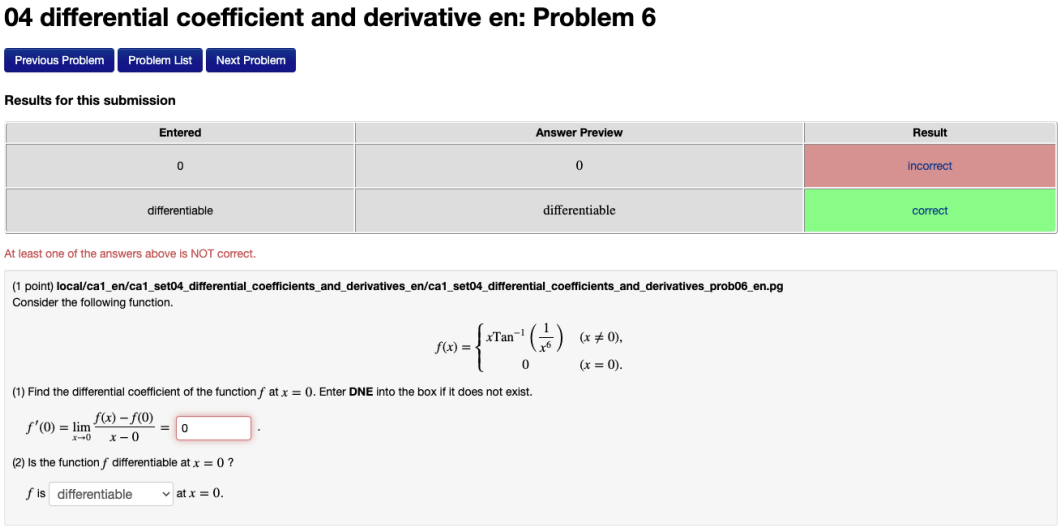

Figure 4: Answer result

3 Case Study in Hokkaido University

3.1 Original Problems

Around the winter in 2016, the Department of Mathematics, Faculty of Science, Hokkaido University began operating WeBWorK on a first scale. However due to the following factors, not many problems are available for use in mathematics education in the Department of Mathematics.

- Since there is no review process for submitting problems to the OPL, while some of the problems stored in the OPL are of good quality, others are riddled with bugs.

- Many of problems in the OPL are designed according to the curriculum of foreign universities, and few are in line with the Japanese curriculum.

Therefore, a content creation team made up of faculty members from the Department of Mathematics and Ph.D. students in the Department of mathematics formed to create an original problem collection in line with Japanese university education. More than 800 problems are prepared, mostly in the areas of Calculus and Linear Algebra. These problems have coefficients randomness. The breakdown is as follows:

- Calculus: 383 problems
  Categories: Sequences and Functions, Differential of single variable functions, Differential of multivariable functions, Integration of single variable functions, Integration of multivariable functions

- Linear Algebra: 357 problems
  Categories: Matrices, Simultaneous linear equations, Rank, Determinant, Inverse matrices, Vector spaces, Linear mappings, Linear independence, Basis, Eigenvalue and eigenvectors, Diagonalization
- The others: 99 problems
  Categories: Differential equations, Elementary statistics, Probability, Estimations

WeBWorK allows for randomization of the problems, and we made sure that the difficulty level of the randomized problems would not change significantly when creating them. For example, when creating an inverse matrix calculation problem, if randomization is performed on all matrix elements, large variations in the determinants will occur, resulting in large differences in the complexity of the answers. We designed our program to prevent the answer from becoming more complex than a certain level by making full use of elementary row operations.
The need for such ingenuity often arises when creating problems. Therefore, it is necessary to have someone with the correct mathematical knowledge to create the program.

3.2 A Case Study in Hokkaido University

Hokkaido University has introduced WeBWorK in Calculus and Linear Algebra since 2018. The number of active users has been increasing every year, with a total of more than 4,500 people using the system in FY 2021. The program has begun to be used in FY 2022 and is expected to be used by a similar number of people.

Table 1: Number of active users in Hokkaido University

	Financial Years			
	2018	***2019***	***2020***	***2021***
Calculus I	624	1,020	1,456	1,420
Calculus II	598	820	1,019	1,079
Linear Algebra I	558	1,090	1,546	1,375
Linear Algebra II	255	278	851	706
The others	189	308	327	280

Here we present some of the results of a student survey conducted in FY 2021. Since the survey was conducted in Japanese, we present the English translation of them. The total number of responses was 513. The following survey results are a preliminary analysis at this time.

Q. How many hours per week did you work on WeBWorK?

- Less than 30 minutes: 21%
- About 1 hour: 47%
- About 2 hours: 25%
- More than 3 hours: 7%

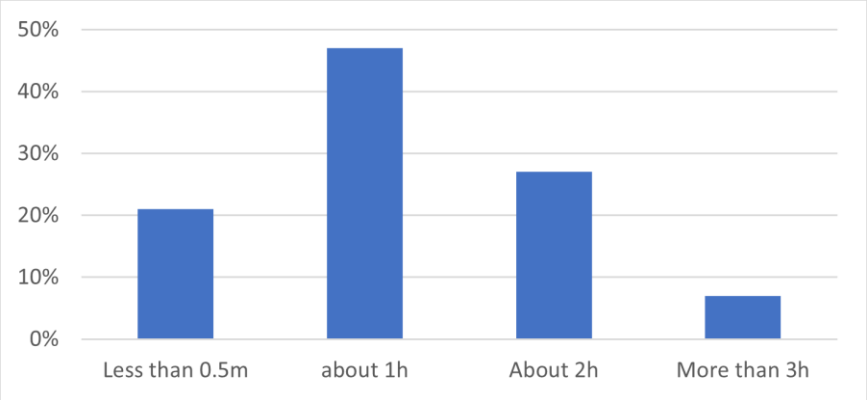

Figure 5: Time to work on WeBWorK per week

Q. How was the difficulty level of WeBWorK?

- Extremely difficult: 9%
- Difficult: 33%
- Normal: 50%
- Easy: 7%
- Extremely easy: 1%

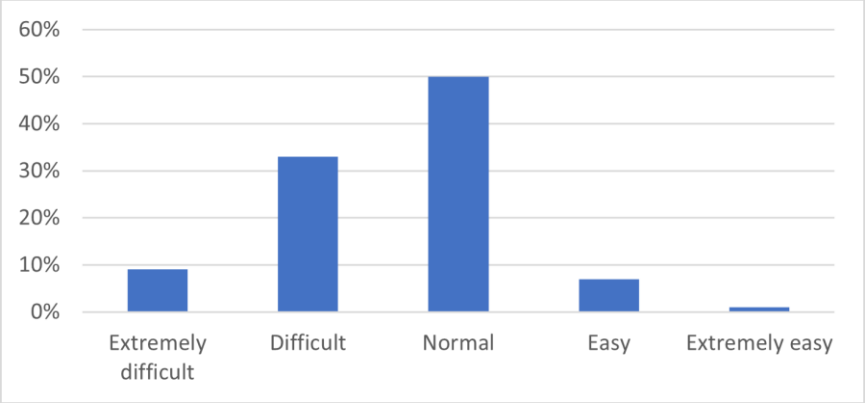

Figure 6: Difficulty of WeBWorK

Q. Did working on WeBWorK improve your computation skills?

- Strongly agree: 9%
- Agree: 66%
- Disagree: 21%
- Strongly disagree: 4%

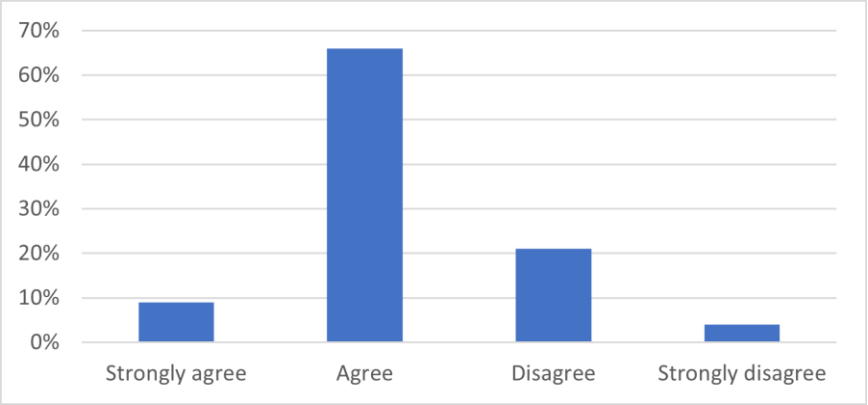

Figure 7: WeBWorK's contribution to improving computation skills

Q. Did working on WeBWorK improve your English skills?

- Strongly agree: 3%
- Agree: 23%
- Disagree: 58%
- Strongly disagree: 16%

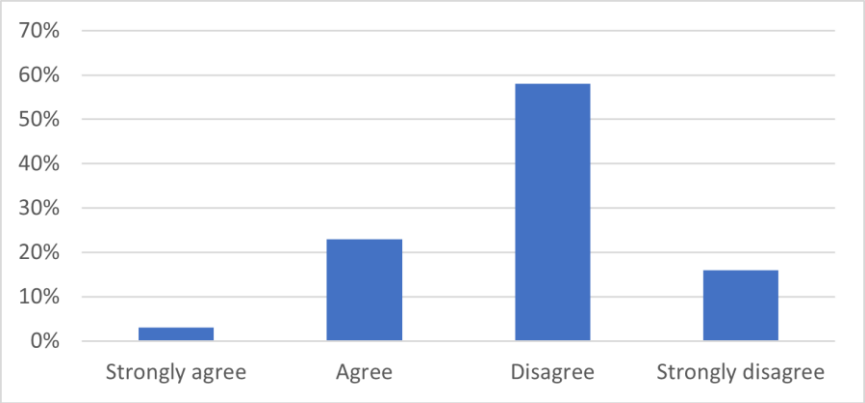

Figure 8: WeBWorK's contribution to improving English skills

Q. Free comments (Positive comments)

- I got into the habit of studying.
- I have improved my computation skills.
- I liked the fact that I can re-solve the problems over and over again.

Q. Free comments (Negative comments)

- Time-consuming to enter answers.
- I would have liked some hints.
- It was difficult for me to read the text because it was in English.

The results of the survey show the following facts.

- Although there are some differences among students, almost 80% of students use WeBWorK at least one hour per week.
- More than 90% students believe the questions are neither too easy nor too difficult. From this we think that we are successful to adjusting the difficulty level of problems.
- For many students WeBWorK helps improving their computation skills. On the other hand, many students do not feel that their English skills are not improved by using WeBWorK.

Based on these results we created Japanese version of the original problems. Since the fact that the problems are written in English is one of the barriers for students to engage in the WeBWorK, it is expected that creating problems written in Japanese will give an advantage in expanding the program to other universities. Japanese versions of the original problems have already been provided to Hokkaido University and Hokkai Gakuen University from 2021 for a trial basis.

4 Trends in E-Learning Systems at Other Universities

As far as we know Tohoku University and Kanazawa University have installed WeBWorK servers and are using them in their university education. We also provide WeBWorK courses on a class-by-class basis to the following universities on a loaned server in Hokkaido University:
Hokkaido University of Education, Muroran Institute of Technology, Hokkai Gakuen University, National Institute of Technology, Tomakomai College, National Institute of Technology, Asahikawa College.
In addition to WeBWorK, other e-learning systems for mathematics education such as "Stack" and “Möbius” are being studied. We intend to use the knowledge gained in Hokkaido University to disseminate to other universities, while keeping an eye out for future trends in educational content outside of WeBWorK.

5 Conclusion

In the last few years, the university education field would have been forced to take a variety of teaching formats due to the outbreak of the COVID-19. Under these circumstances, WeBWorK plays a certain role not only in reducing the burden on faculty, but also in promoting education for students. On the other hand, WeBWorK is only a computational drill, and students' understanding of mathematics cannot be measured by WeBWorK efforts alone. In order to test students' theoretical understanding, instructors are required to be creative, for example, by assigning report-type assignments.

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