Visualisation of Knowledge Map based on STACK Answer Data

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Abstract: With the development of e-learning, learning management systems (LMS) are increasingly being used to support both self-study and on-campus courses. Some are open-source platforms that allow tutors or course designers to freely create their own courses. Most are equipped with an automatic scoring system to provide students with instant feedback after they submit their answers. A typical example is one of the most popular LMS called Moodle, and the scoring system running on it named STACK, which specialises in mathematics. This system uses an answer-analysing mechanism called the Potential Response Tree (PRT) to predict the answers that students may reach and provide specific feedback after the test. We created a knowledge map for the course and linked it to the questions and answers to the tests. With this solution, the learner can obtain more direct recognition of his/her knowledge acquisition level and the entire construction of the course. This study aims to develop a plugin running on Moodle in collaboration with the STACK scoring system. It allows teachers to establish a knowledge map for the course and provide graphic feedback after students take their tests.

Keywords: STACK, knowledge map, Moodle plugin

1 Introduction

Since the process of digitalisation, the use of online systems has covered several fields, including education. E-learning is a teaching method that utilises online systems. The common idea of e-learning is based on a large learning management system (LMS) with an online test feature, in which every student and teacher have their own accounts.

With the development of e-learning, people expect more convenient features in LMS, beyond simply providing teaching materials and submitting assignments. Automatic scoring is one of its most important requirements. Although general automatic scoring systems are designed only for multiple-choice questions or text-based fill-in-the-blank questions for online testing, systems that automatically evaluate the correctness of mathematical expressions have been studied for approximately 20 years in the field of science and mathematics, including STACK [Sa13], Numbas [Nu23], Möbius [Mo23], WeBWorK [We23], and m-rater [Fi17], which are the most representative automatic

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scoring systems for mathematics (math e-learning systems). Most of these systems can provide feedback based on students' answers and are expected to be useful for student learning. If a course has an online test, depending on the correct or incorrect answers to questions on the online test, it would be more useful for self-study if one could view the parts of the course content that have been mastered and those that have not yet been mastered.

Knowledge maps are used to achieve this goal. This knowledge map is based on that proposed by Howard [Ho89] and, more specifically, by Nakamura [NKN18, Vi23] in the field of learning. The details are described in next section; however, in this study, we aim to visualise the knowledge elements of the knowledge map that are acquired or unacquired based on the results of online tests, thereby aiding learning. This study aims to develop a Moodle plugin for STACK to realise this because STACK is one of the world's most widely used open-source math e-learning systems, as it runs on Moodle, also an open-source LMS.

2 Knowledge map for STACK

2.1 Brief review of STACK

STACK is an online assessment system for mathematics and STEM, developed by Sangwin et al., designed to enable students to answer questions with a mathematical expression, such as a polynomial, a matrix, and so on [Sa13]. It runs on Moodle as a question plugin. The answer to this question is assessed using the STACK scoring system, and the result is returned as not only correct or incorrect, but also partially correct with some feedback comments. This was attributed to its answer analysis mechanism, the Potential Response Tree (PRT) [Po23].

With the PRT, each possible answer can be assigned a specific score and feedback. Even if the answer is wrong, students are expected to use feedback as a hint to respond to the error and advance their learning by rethinking the question and solving it again. However, it would be helpful for students to identify the knowledge that is missing and the position of that knowledge in the content they learn throughout the course so that they can consider guidelines for their learning, and for the teacher to assess the students' level of understanding.

2.2 Knowledge map

The use of knowledge maps is considered an effective method to check the position of knowledge within the content studied throughout the course. The knowledge map here is a knowledge network diagram that represents all knowledge elements to be learned throughout the course and the relationships between these knowledge elements.

First, we selected the knowledge map as the link between the feedback for the question and the content of the course from the KIT Mathematics Navigation Site developed by the Kanazawa Institute of Technology [NKN18, Vi23]. This site is a simple online course for college mathematics without online test features. All the contents of this site lead to this knowledge map, which presents the relevance of knowledge for the course.

We aimed to link the online test to the knowledge map and represent the results of the online test and understanding of the course using the knowledge map. STACK's PRTs can be used to identify whether the student who answered the question was knowledgeable. By visualising the results using a knowledge map, it is expected that it will be possible to graphically grasp the students' own level of mastery of the overall knowledge of the course. It was also possible to quantify their level of mastery.

3 Development of Moodle plugin for visualising knowledge map

3.1 Development policy and installation of plugin

As we needed to create different interfaces between the teacher and student, we split the plugin into two parts: the teacher and student sides. The teacher's side is primarily for management, and the student's side for viewing and confirming actions. The two blocks were developed using the same structure. The front end was developed with HTML+CSS+JavaScript using the bootstrap framework, whereas the back end was developed with PHP. Ajax was used to transfer data between the front and back end. The source code of the plugin is publicly available and can be downloaded from Github [Gi23].

3.2 Defining knowledge map

The entrance of the block plugin performs differently depending on whether a knowledge map was prepared for this course. If no map was prepared, the entrance was displayed with a single link to set up the knowledge map. If a map was already prepared for the course, the entrance was displayed as presented in Fig. 1. Knowledge maps can be visualised by preparing an Excel file that defines the information on knowledge elements and links that represent their relationships. Alternatively, knowledge elements and link information can be defined by specifying knowledge elements and link information individually in the configuration window presented in Fig. 2. The knowledge maps were individually defined by the teacher based on course information.

Only nodes with sizes larger than a certain threshold were displayed with their name labels. Placing the mouse on a node or link highlights the item and its labels. The knowledge map, along with all the other graphs in this study, was drawn using Echarts.js[Li18], which is an open-source visualisation package.

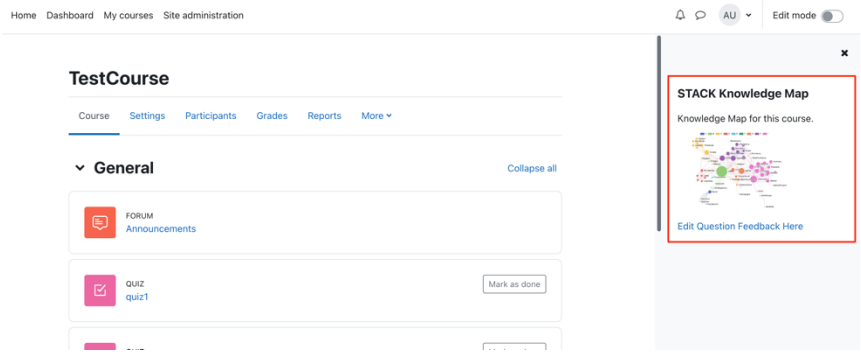

Fig. 1: Entrance for knowledge map in the block-plugin of Moodle

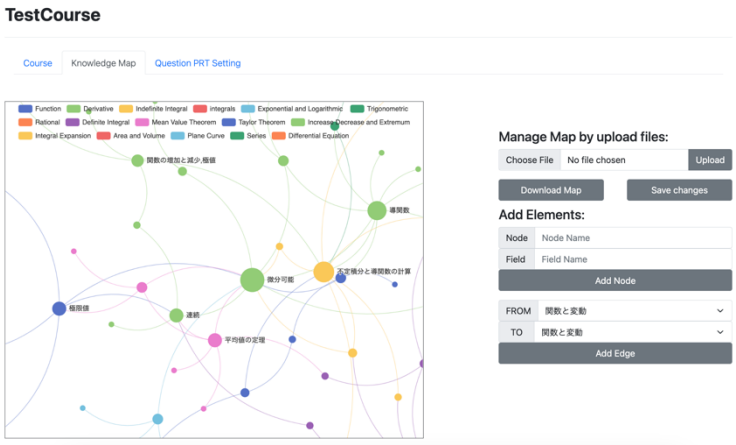

Fig. 2: Setting knowledge map page

3.3 Linking PRT information with knowledge maps

The most important task of this plugin is to link the defined knowledge map with the information from the PRT results of the online test, as presented in Fig. 3.

The plugin automatically imports the answer data for the questions in the course. As this plugin needs to work along with the PRT results of STACK, only questions of the STACK type can be displayed in the left panel of this window. The procedure for defining the relevance of the information in the PRT to the knowledge map is as follows:

1. Select question's PRT node from the right panel.
2. The nodes or elements in the knowledge map of the course can be selected from the first drop-down box to be added to the map.

3. Further, it can be deleted by the second drop-down box.
4. Set the status of the node, which denotes whether the student has commanded this knowledge element to solve the question, by setting it with “Learnt” or “Failed.”
5. The “Learnt” nodes are in a dark purple colour and the “Failed” nodes are in a light colour with dotted outline.

Teachers need to perform this correspondence work on all PRT nodes of all questions, which is expected to be a difficult task.

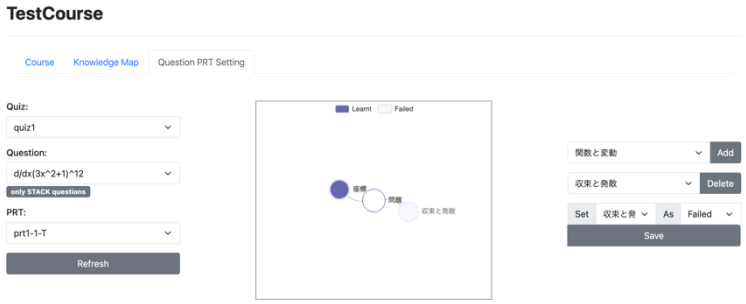

Fig. 3: Setting the status of knowledge element using question information

3.4 Displaying learning progress

The learning progress page will present the student’s overall mastery level of this course based on all test results. For every quiz that the student attempted, the final result submitted was counted as the final status performed by the student in this quiz. Fig. 4 presents an example of a student’s learning progress. Every node in this map has a special transparency depending on the mastery level.

Suppose there are 4 questions related with a knowledge element “E,” which implies that one needs to master E to solve these questions. According to the answers submitted by a student, we know that he correctly understood and used E in three questions, however, failed in one question. For each answer, if E scores “Learnt” for the answer, it will be counted as 1; otherwise, it will be counted as 0 for ”Failed.” Thereafter, the mastery level of E would be calculated as 75%. If a knowledge element is never used in any question, its mastery level will be set to 0 by default, and its node in the map will be set to white. The progress bar above the map reflects the overall mastery level of the entire course, calculated as the sum of the mastery levels of all nodes divided by the number of nodes. Furthermore, the density of the nodes of the individual knowledge elements in the knowledge map provides a visual indication of the level of mastery of the knowledge map as a whole–that is, the course as a whole.

Conversely, since this value stands for the overall mastery level, and is calculated by the feedback of every question, it requires the teacher to be careful in preparing the tests, and a question with a simple PRT cannot perform well. The questions and tests should be sufficient to cover every knowledge element in this course; otherwise, 100% will never be achieved, as the knowledge element not used will be counted as 0 by default.

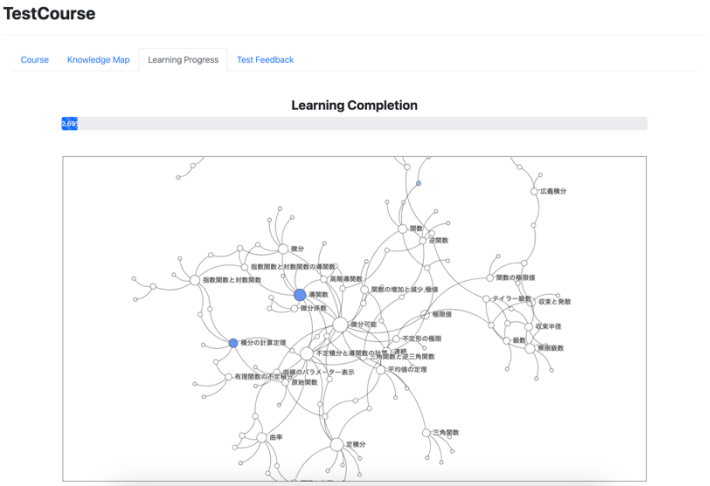

Fig. 4: Displaying learning progress

3.5 Feedback for students

On the feedback page, students can select a quiz and confirm the final answer they submitted with graphic feedback. As Fig. 5 reveals, when a student selects a quiz, the score of the last attempt he/she submitted for this quiz, along with the timestamp at which he completed it, is displayed. If a student did not submit any attempt for this question, “Null” will be displayed in the window and he/she cannot continue to select any question. After selecting the question in the quiz, the answer submitted for this question in the last attempt is displayed below along with graphic feedback on the right side, to remind the student (Fig. 5).

The white node at the centre is the question, and the nodes connected to it indicate the knowledge elements required to solve it. The density of the nodes indicates the mastery level of the knowledge element; the darker the colour, the higher the degree of mastery. This feedback allowed the students to assess the knowledge required for each question and the degree to which they had mastered it.

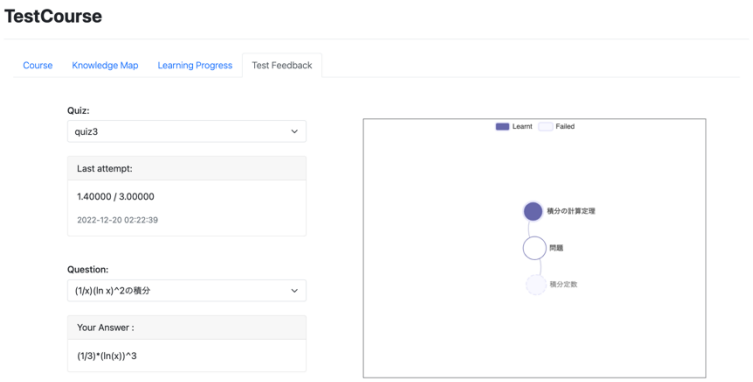

Fig. 5: Feedback page

4 Conclusions and Future Work

This study proposes a visualisation plugin for a knowledge map running on the online test system Moodle, aiming to provide learners more understandable feedback about the test they attempt and a more direct recognition of the knowledge acquisition level of the course. The teacher can use this plugin to set up a knowledge map for their courses and prepare graphic feedback for questions to build a visual relationship between the test and the course content. Students can use this plugin to view the construction of the entire course content, confirm their knowledge acquisition level, and view graphic feedback of the tests they attempted.

We used the plugin and verified its operation with trial data, however, did not use it in real courses. Therefore, we did not obtain specific feedback regarding its usability. This study is a work-in-progress and it is expected that the use of the plugin in real courses will soon become possible.

In future work, the first and most important topic is how to use it to refine the course and test design. This appears to be the reverse of our research, however, may be the most meaningful usage of this plugin. At the end of the previous section, we discussed that a question with a simple PRT cannot perform well. Further, we mentioned that a poor course design may lead to a result in which the progress map cannot be fulfilled. Attempting a test, although it may only be homework, is the most general method to confirm one's study progress, including identifying misunderstandings or weaknesses. If the tests cannot reach this goal or focus too much on the same part, it will cause neglected areas in one's knowledge construction. Thus, designing an effective test, along with providing feedback, plays an important role in education. Before designing the PRT for a question, this plugin can be used to sort out the knowledge elements required. With the reduction in one or more nodes, possible incorrect answers can easily be predicted. The mistake type that one

may reach is more likely to be covered in the feedback.

5 Acknowledgement

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