EasyChair Preprint

№ 7345

Remedial Directed Topic Map on Personalized Scaffolding Adaptive Learning Management System

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January 18, 2022

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Abstract— The problem arises behind the mastery learning model, that is some students fail to achieve the minimum standard of completeness. The existing solutions have been ineffective in helping the study plan. The existing remedial method does not consider the previous formative test answers, but all material that has been mastered must also be tested. This remedial method did not give students more time to learn misconceptions or the material they had not mastered yet. We propose a framework for building a scaffold on a remedial learning path that is personal and adaptive to the material needs that students must learn. Initial exploration in this study aims to look the possibility in implement the proposed framework by utilizing machine learning on mastery module using neural network and knowledge-based recommendation technique to process the input of student's answers, domain expert's topic maps, and the relationship among answers to build a computer-based scaffold. This novelty of exercise learning path could be an effective remedial path for the failed student to learn just according to topics have not mastered.

Keywords—Scaffolding, Topic Map, Self-Regulated Mastery-Learning, Assessment-Based Learning, Machine Learning

I. INTRODUCTION

The COVID-19 pandemic has caused nearly all schools worldwide to close. More than 530,000 schools in Indonesia have closed, which mean that 68 million Indonesian students are forced to no longer be in class. These school closings adverse effects on academic learning because for a distance learning to be effective, it required new skills for both teachers and students. Regarding this pandemic, SDI argues that Indonesia needs a strategy to support better face-to-face teaching and improve the quality of distance learning, to restore and improve its human resources [1]. The World Bank stated that drastic action was needed to support Indonesian students' learning as part of the ongoing recovery and re-opening process. Some actions are recommended related to learning recovery to prevent the permanent impact of "learning loss" on students. The recommendations include 1. using formative classroom assessment to identify learning losses; 2. integrated use of blended-learning and technology to ensure that all students receive the support they need to become effective learners. The United Nations mentioned that preventing the learning loss from becoming a generational disaster needs to be a top priority to protect millions of students' rights and promote economic progress, sustainable development, and lasting peace [2].

In face-to-face learning, it is easier for teachers to assist students in need. Teachers need to provide scaffolding to students in need during learning activities to improve their understanding, affective, and skills [3]. Unfortunately, learning during the pandemic lacks personal assistance from teachers to students who do not understand the material. It potentially causes problems, especially for students who need assistance and need an extraordinary approach to complement and prepare tools for students and teachers related to this problem. Research projects related to scaffolding proven to be effective in science learning are, for example in physics learning, which uses the PhET simulation (physics simulation portal) to increase student's conceptual understanding and independent learning [4]. Inquiry-based learning uses an agent-based framework where students can check their understanding of science and the concept of Computational Thinking (CT) by taking formative tests managed by a mentor agent. The mentor agent assesses students' responses to multiple-choice type questions and provides feedback on correct responses along with suggested learning resources pages to read if there is an incorrect response [5]. Although this research has provided feedback for students' mistakes, it is limited to recommendations for subject matter that must be read. Simultaneously, physics lessons' characteristics require problem-solving skills that cannot be met in these studies. Problem-solving skills in physics lessons require continuous practice compared to mere theoretical reading.

The solution approach we offer is adapted to the learning process in Indonesia, which applies mastery learning model. Each student must achieve a minimum completeness score in a unit before entering the next study unit in mastery learning. There are always students who fail to achieve the minimum completeness score; unfortunately, there is no solution ineffective remedial handling. These findings indicate that the scaffolding approach can be considered for application to improve students' understanding of concepts and useful. This work plan explicitly adds a scaffolding assessment-based learning process for students who do not pass the complete learning process. This process is an opportunity to correct misconceptions or material that has not been understood to help students effectively achieve mastery adaptively according to their needs. Fig.1 is the recommendation for the mastery learning diagram presented by Thomas, 2008 [6].

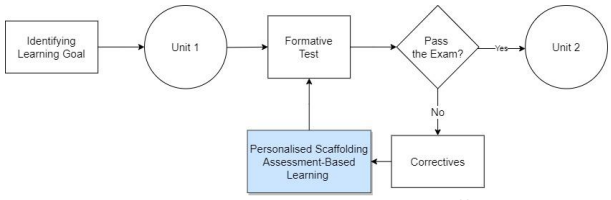

Figure 1 Mastery with Personalized Scaffolding

This study is a proactive step in responding to the World Bank's recommendation to Indonesia regarding the re-opening of schools with a proposed framework that implements computer-based scaffolding in flipped classrooms by applying assessment-based learning. Assessment-based learning method deserves to be taken considering that the assessment has a "test effect", useful for long-term retention, and practice questions can increase understanding of the subject of physics [7]. The Assessment-based learning method is the guidelines for school opening policymakers, namely schools need to conduct an assessment, a computer-based diagnostic assessment [8]; It is a rational basis that assessment-based learning is proven to increase learning completeness. This paper's composition is as follows: Section 2 contains previous research work, followed by a proposed method in Section 3, initial investigation is in Section followed by discussion in Section 5, and Section 6 is a conclusion.

II. PREVIOUS RESEARCH WORK

In preparing for returning to class after the pandemic, it is necessary to pay attention to the zone proximal development (ZPD) referring to the area between what one knows and what one does not know during learning. In this area, one needs guidance from other knowledgeable people, so that in the end, they will be able to develop their understanding [8]. The scaffolding strategy has been integrated into e-learning. One of the studies that identify and determine the attributes of a mixed learning environment that supports students' self-regulated learning ability found scaffolding to be one of the seven key attributes (authenticity, personalization, learner control, scaffolding, interaction, reflection, and calibration) [9]. Meanwhile, recent research on adaptive scaffolding is an efficient strategy to support and improve student performance when learning new concepts, and guide them progressively towards a better understanding when answering questions [10]. Other scaffolding research uses breaking a problem into smaller items or directing students to other problems similar to the current problem and helping students through the new problem. When students incorrectly answer the main questions, scaffolding items are activated according to the following four types: (a) procedural, (b) conceptual, (c) metacognitive, and (d) strategic [11].

The study's selection of objects also refers to the World Bank report, which focuses explicitly on the pandemic's Indonesian PISA test results. It appears that science is one of the subjects that need special attention. Learning science does have its peculiarities, for example, in Physics, apart from requiring practice in problem-solving skills, Physics have a close relationship among knowledge topics. The challenge in finding out which concepts are less mastered by students causes them to fail to achieve learning completeness. When students learn to build new physics concepts, they must remember previous concepts and increase students' cognitive load and impact learning outcomes. A concept map may be a solution to the problems because a concept map represents various concepts. Its relationships can also organize students' cognitive structures and are expected to encourage in-depth, integrated knowledge. Concept mapping is used as a scaffold to support adequate information problem-solving— using questioning as a facilitator for constructing students' previous knowledge structure. A domain expert will provide the initial topic map because not all students know how to benefit from a concept map [12]

Research related to machine learning is more common nowadays. Some research uses machine learning algorithms to deal with several problems, such as predicting student performance [13], predicting student performance based on learning styles [14]. So, in the future, when implementing this proposed framework, it will utilize the development of machine learning in e-learning [15] [16]. The evaluation tool for this proposed framework will emphasize the level of satisfaction and user preferences, referring to the weakness of the existing recommendation system's (RS) evaluation, which is stated in a review that RS in e-learning is based on students; however, system evaluation still focuses on measuring algorithm accuracy through Mean, Precision, Recall and F-measure rather than evaluating its impact on user satisfaction and preference levels [17].

This study offers a Remedial Directed Topic Map framework on Personalized Scaffolding Adaptive implemented in the Learning Management System (PSALMS) to be a novelty of remedial learning path. The last published research provides the exercises learning based on a sequence of students' previous answers, but they do not consider the internal connection between knowledge concepts [18]. A remedial directed topic map will be developed by paying attention to students' formative test answers, expert's initial topic map as the internal connection between knowledge concepts and the failed topic related question. This personalised remedial learning path that effectively helps students achieve learning mastery. By applying the state-of-the-art computer-based scaffolding to giving practice questions, it is expected that failed students receive the learning support they need to achieve mastery learning and increase resilience in self-regulated learning.

III. PROPOSED METHOD

Our study selected the Flipped-learning to support the re-opening of face-to-face classes after the pandemic and the World Bank direction regarding blended learning development. This framework will be applied to the learning management system (LMS) because of the wide use of LMS (Moodle, canvas, another open-source LMS) [19]. This paper is a step development of initial research idea [20]. Fig. 2 is the Flipped Classroom method proposed to adjust to the "new normal" learning conditions.

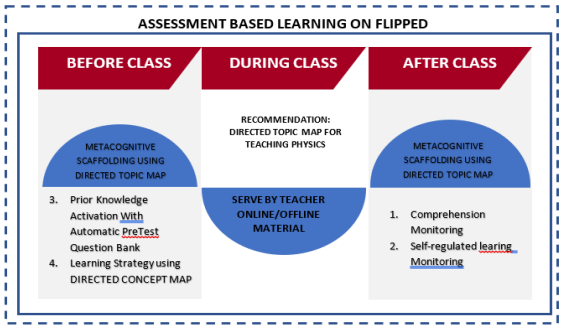

Figure 2 Assessment-based Learning on Flipped the Classroom

In the new normal state at the re-opening school, students take turns attending classes, so that it's needed to provide a system that can cover the three main learning activities. Namely, activities are before students into the classroom, the second part is when the students are in the class during the face-to-face learning, and the third part is the activities after the face-to-face class ends.

This initial research focuses on the after-class activities from our general framework PSALMS research ideas [19]. This study's primary purpose is to provide practical solutions to students' remedial problem based on real-world problems (see Table 1). The result shows that not all students exceed the minimum completeness score standard. It is necessary to develop practical computer-based tools to help students personally prepare for remedial tests. Therefore, we proposed 2 (two) main stages with three modules: The Topic module on the first stage, mastery module, and scaffolding module on the second stage, Fig. 3.

A. Topic Module and Scaffolding Module

The first stage is a Topic module, left side of Fig 3. There are two inputs at this stage: a topic map (topic knowledge) based on information from domain experts and the single-labelled teacher's questions. The domain expert's topic map is used at the topic module to examine teacher's questions based on various inputs, such as keywords, certain meta-keywords related to the questions to identify whether the questions need to be assigned and classified multi-label Topic. This process involves cleaning and preliminary processing the available questions in the dataset for further processing using a classification algorithm; the questions are classified and labelled appropriately if they are multi-label questions and stored back in the database. At first, each question is manually classified on one Topic by the Teacher.

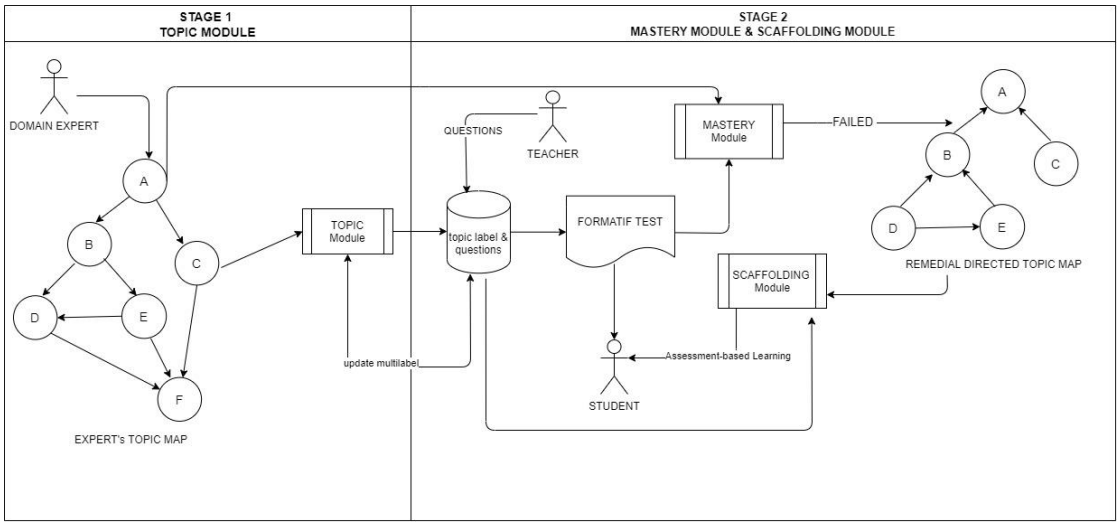

Figure 3 Remedial Directed Topic Map on Personalized Scaffolding Adaptive Learning Management System

A second stage, there are two modules, namely the scaffolding module and the mastery module. The scaffolding module helps provide recommendations based on question queries provided to students as scaffolding for students preparing to re-test. The scaffolding module extracts information from the mastery module and the question database to provide coherent questions according to the personal remedial path. First, the personalized question request is forwarded to run a recommendation algorithm. The association rule algorithm, Apriori, is used to mine and extract the appropriate problem patterns from the repository of questions and then test the relationship's accuracy with the questions. To validate the data of the identified questions will using recall, f1-score, and precision using matrix factorization to observe the questions' suitability and estimate the recommendation result's accuracy.

B. Mastery Module

The focus of this paper is the initial investigation related to the mastery module. The illustration in Fig 4 shows the flow of the mastery module process. The purpose of the mastery module is to extract students who do not meet the minimum completeness standards taken from the data of the formative test. The formative test is a test given at the end of a topic unit.

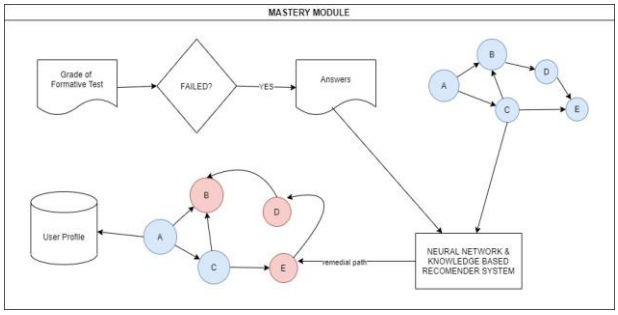

Figure 4 Mastery Module

After obtaining the data, a remedial learning path is designed for students who failed based on the wrong and correct answers from the formative test results. These answers will be correlated into an expert topic map to obtain any topics that had not been mastered, causing this student failed using knowledge-based technique [18]. This personal information remedial learning path may be constructed using neural network algorithms [21] . The user information repository is formed with the students' topic map profiles and stored in a database to be used to the scaffolding module.

Therefore, the PSALMS framework is expected to provide personal recommendations for self-regulated learning and gradually overcome material misunderstandings until mastery. The objectives of this proposed work are, (i) update for multilabel classification of practice questions under the related topics to remedial students that have not been mastered; (ii) based on the knowledge topic that students did not master and the need for practice questions on a particular topic, a new query of practice question as a personalized scaffold was formed; and (iii) by formulating classification and personalization, it allows personal recommendations that are accurately diagnosed and given to students to reinforce self-regulated learning.

General proposed framework is, if the student score fails to achieve the minimum completeness score, their test answers will be applied to the expert topic map to building an effective remedial learning path acts as an adaptive scaffolding. It will be personal guidance to direct students to retrace the previous Topic's misconceptions and using practice questions only on material that had not been mastered coherently as a form of assessment-based learning.

IV. INITIAL INVESTIGATION

In this paper, the researchers use real-world data as a study case. The data were taken from the formative test results for Physics, Newton's laws, which was conducted online with Moodle as its LMS. The number of students in this class was 23 students; the test questions were 10 (ten) questions and were given 40 minutes to finish. Subject materials and practice questions were delivered synchronously as much as 4 x 40 minutes and asynchronously within two weeks.

The initial topic map, obtained from experts, and to build a sequence on the topic map used a relation table as in Table 1. Table 1 and a collection of topics on Newton's laws indicate the topic map's order is obtained as in Fig 5. The test result obtained by 23 students on Newton's laws can be seen in Table 2.

Fig 6 is the position of the question topic on the initial topic map by the expert. The figure shows that the formative test question topics are spread out on the domain expert's initial topic map. Table 3 is the initialization of the Topic for each question made by the Teacher.

Table 1 Example of PERT table to built relation between the Topic

No	Present State	About	Previous State
1	equilibrium	equilibrium, in physics, the condition of a system when neither its state of motion nor its internal energy state tends to change with time	-
2	net force	The net force is defined as is the sum of all the forces acting on an object. Net force can accelerate a mass. Some other force acts on a body either at rest or motion. The net force is a term used in a system when there is a significant number of forces.	equilibrium
3	inertial reference frame	Within the realm of Newtonian mechanics, an inertial frame of reference, or inertial reference frame, is one in which Newton's first law of motion is valid. An inertial frame of reference is one in which the motion of a particle not subject to forces is in a straight line at a constant speed.	force
4	inertia	Inertia is the resistance of any physical object to any change in its velocity. This includes changes to the object's speed or direction of motion. An aspect of this property is the tendency of objects to keep moving in a straight line 4at a constant speed when no forces act upon them.	First Newton Law

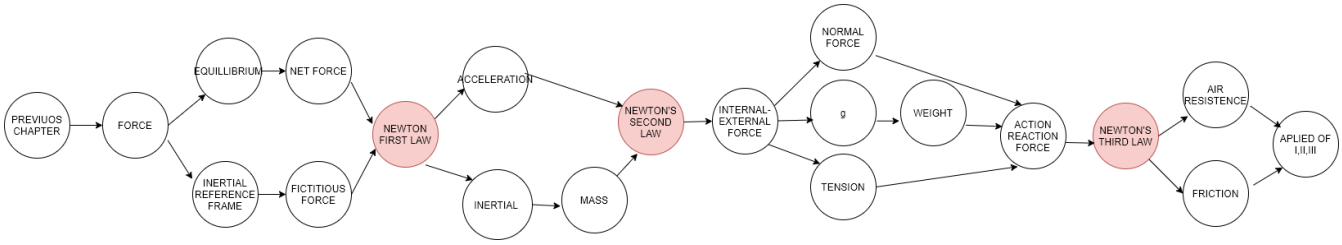

Figure 5 Topic Map Dynamic of Motion

Table 2 Students Grade and Answer Form Formative Test

Student	Grade	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
S01	30	1	1	0	0	1	0	0	0	0	0
S02	30	1	1	0	0	1	0	0	0	0	0
S03	40	1	1	1	0	1	0	0	0	0	0
S04	50	1	1	0	0	1	0	1	0	1	0
S05	50	0	1	0	1	0	1	1	0	0	1
S06	60	1	1	1	0	0	0	1	0	1	1
S07	60	1	0	0	0	1	1	1	0	1	1
S08	60	0	1	0	1	1	0	1	0	1	1
S09	60	1	1	1	1	0	1	0	0	1	0
S10	70	1	1	1	1	0	1	0	0	1	1
S11	70	1	1	1	1	0	1	0	0	1	1
S12	70	1	1	1	1	1	0	1	0	0	1

Student	Grade	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
S13	70	1	1	1	1	1	0	0	1	1	0
S14	70	1	1	0	1	1	1	1	0	0	1
S15	70	0	1	1	1	1	1	1	1	0	0
S16	70	0	1	1	1	1	0	1	0	1	1
S17	80	1	1	1	1	0	1	1	0	1	1
S18	80	1	1	1	1	1	0	1	0	1	1
S19	80	1	1	1	0	1	0	1	1	1	1
S20	80	1	1	0	1	1	1	1	1	0	1
S21	90	1	1	0	1	1	1	1	1	1	1
S22	100	1	1	1	1	1	1	1	1	1	1
S23	100	1	1	1	1	1	1	1	1	1	1

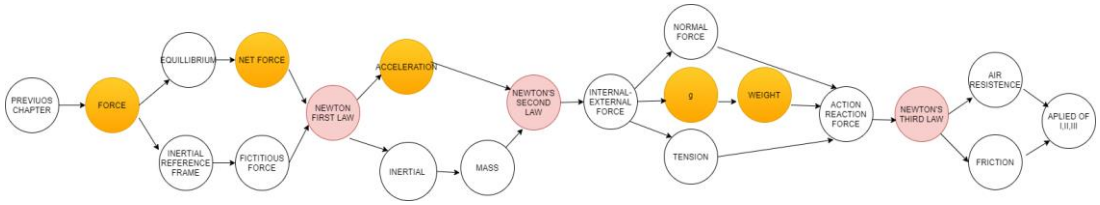

Figure 6 Question Topic Position on Initial Topic Map Based on Single Topic by Teacher

Table 3 Single Topic defined by Teacher

	T0 (Previous)	T1 (force)	T2 (Net Force)	T3 (Acceleration)	T4 (Gravitation)	T5 (Weight)
Q1	0	0	0	0	0	1
Q2	0	0	0	0	1	0
Q3	0	0	0	1	0	0
Q4	0	0	1	0	0	0
Q5	0	0	1	0	0	0
Q6	0	1	0	0	0	0
Q7	0	0	1	0	0	0
Q8	0	0	0	1	0	0
Q9	1	0	0	0	0	0
Q10	1	0	0	0	0	0

V. DISCUSSIONS FOR FURTHER WORKS

This Section will discuss several aspects related to the initial investigation of this research. Based on data are presented in Table 2, If the complete score is 70, it can be observed that students who fail to achieve the minimum completeness score in the table. For example, namely: Student 1 (S01) with a score of 30, Student 4 (S04) with a score of 50, and Student 6 (S06) with a score of 60, see Table 4. Table 3, which refers to all the topics of questions, Table 4 shows which topics cause these students to fail. For example, Question 4, Question 6, and Question 8; it turned out that these three students made the same mistake on the question items. Meanwhile, suppose we pay attention to the Topic (concept) on that question from Table 3. In that case, we see that these questions contain the Topic Net Force for Question 4, the topic force for Question 6, and topic acceleration for Question 8, which can be seen in Table 4.

Table 4 Student's Failed Topics

Question	T0	T1	T2	T3	T4	T5
Q4	0	0	1	0	0	0
Q6	0	1	0	0	0	0
Q8	0	0	0	1	0	0

In the initial topic map made by experts, we can observe that the sequence of lessons in this unit is Topic Force followed by Net Force then acceleration, as presented in Fig 7.

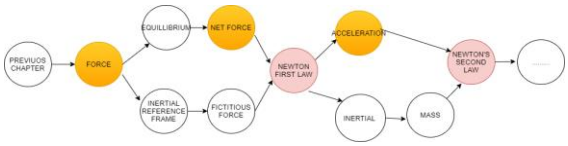

Figure 7 Position Failed Topic

Table 5 will observe another student, S09, S10 and S11 they have a similar answer. Poorly, S09 is a failed student. If we combine S09 answer with the topic map, we will know the topics which caused S09 failed.

Table 5 Example of one student who failed

Student	Grade	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
S9	60	1	1	1	1	0	1	0	0	1	0
S10	70	1	1	1	1	0	1	0	0	1	1
S11	70	1	1	1	1	0	1	0	0	1	1

Based on Table 2 and Fig. 6, we will notice, just two topics caused S09 to fail. Based on Fig.8, this proposed framework will be an effective scaffolding for the failed students because this remedial learning path directs forward to the Topic who mastered yet and gives them an adaptive question for fulfilling, they needed.

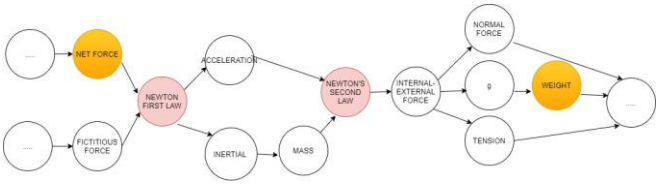

Figure 6 Personal Map for Student 9 (S09)

The inputs which are students answers, the relationship between the Topic and the questions as well as the initial topic map of the expert domain can retrace which material must be re-studied by students preparing for the formative remedial test so that students do not need to learn all the materials but focus on the material which causes them to fail in mastery.

We observed failed topics for students S05, S08 S15 in Table 6, especially on questions Q1, Q6 and Q8. The Topic for those questions, namely Weight, Force and acceleration.

Table 6 Not Matches Path

Student	Grade	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
S05	50	0	1	0	1	0	1	1	0	0	1
S08	60	0	1	0	1	1	0	1	0	1	1
S16	70	0	1	1	1	1	0	1	0	1	1

They have a similar path on Q1, Q3, Q6 and Q8; when S08 and S16 doing wrong but S05 correctly answered Q6 regarding Force. So too S16 correctly answered Q3 regarding Acceleration when S05 and S08 have a false answer.

This is something out of our thought before. There are several possibilities related to this problem, one of which is hidden relations between topics [22], to solve this problem we can try using Deep Neural Network who use of multiple layers in the network [23]

VI. CONCLUSION

In this paper, the preliminary investigations regarding PSALMS have been discussed. The discussion-section found that test answer, topic maps, and topic-labelled questions can be used to build an effective learning path remedy. The Failed Student will be directly forward to the Topics causing failed and learn with assessment-based learning. With the ideas presented as an initial investigation, it is expected to provide adaptive scaffolding solutions that can specifically recommend learning materials for a unit. The adaptive scaffold modelling approach with assessment-based learning using directed topic maps has advantages and challenges. The main challenge is developing the scaffolding model on the cognitive knowledge students have had comprehensively. We suggest a Deep Neural Network Algorithm solve the hidden correlation problem between Topics. The proposed Topic Module needs more investigation whether using a multi-label classification provided by the topic module can help with hidden relational concept problems with update the questions profiling. The proposed PSALMS model is expected to overcome preparation for returning to school after the pandemic, especially for remedial problems. Choosing a suitable machine learning algorithm for designing remedial directed topic maps is a basic challenge to solve.

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