On Developing an Adaptive Tutoring System with Formative Assessment for Mobile Learning

Hisashi Yokota

Abstract—**In this article, it is shown that how to generate a formative assessment using Educator's knowledge structure map, Learner's knowledge structure map and the relative distance which measures the difference between the machine generated solution and user's solution evaluated at some point. Then hoping to be used widely by many learners, an adaptive tutoring system with formative assessment is implemented as an web application.**

***Index Terms*— formative assessment, intelligent tutoring system, knowledge structure map, relative distance, web application**

I. Introduction

One of the most commonly used communication devices college students own is either a smart phone or a tablet. This means that for those of you developing educational learning system for PC have to think about developing new system for smart phones or tablets. There are iOS based smart phones and android based smart phones, and android based tablets and windows base tables. Thus there are essentially three different operating systems to choose to create educational learning systems. This becomes a burden for educational learning software developers.

Instead of developing educational learning software for each operating system, one can notice that the above problem can be solved by using web browsers. For all of these devices have web-browsers to access information provided by the web servers. Thus, any adaptive tutoring systems with formative assessment runnable on web can become adaptive tutoring systems with formative assessment for mobile learning. Furthermore, many integrated development environments for an adaptive tutoring system with formative assessment runnable on web are available. This suggests that instead of developing an adaptive tutoring system with formative assessment for each of communication devices with different operating systems, it is more useful to develop an adaptive tutoring system runnable on web with formative assessment

To develop an adaptive tutoring system with formative assessment runnable on web, we adopted ASP.NET web application (visual c#) as an integrated development environment. Since the functions such as automatic question generation, automatic determination of correctness, calculation of the relative distance which are essential part of forming an adaptive tutoring system called JCALC for windows were already developed and were reported in [7]. Note that those functions developed for JCALC are put into dynamic link library so that they can be reused for web application. So, it is a natural decision to adopt ASP.NET web application.

To develop an adaptive tutoring system with formative assessment runnable on web, it is necessary for the system to be equipped with the ability to diagnose a level of understanding of each learner by examining their inputted answer. Furthermore, it is necessary for the system to be equipped with the ability to choose the most appropriate formative assessment.

In order to equip such an ability, educator's concept map is studied in detail and utilized to diagnose a level of understanding for each student. Then by tracing the edges of educator's concept map with evaluated value, the learner's concept map is created as a subset map. Furthermore, by preparing a formative assessment for an each edge of the learner's concept map, developing an adaptive mathematics tutoring system with formative assessment becomes possible.

Finally, it is shown that how an adaptive tutoring system with formative assessment is implemented into our system called webCalc.

II. Experienced Mathematics Educator's Knowledge Structure

A. Experienced Mathematics Educator's knowledge

In an article [7], how 10 experienced educators in my school answered the question like the followings are studied:

1) If a student writes $-\sin(3x+1)$ as the answer to the question of "Find the derivative of $\cos(3x+1)$". How do you assess the student's level of understanding.
2) If a student writes $-2/(x+1)^2$ as the answer to the question of "Find the derivative of $x-1/(x+1)$". How do you assess the student's level of understanding.
3) If a student writes xe^x+x+c as the answer to the question of "Evaluate $\int xe^x dx$ ". How do you assess the student's level of understanding.
4) If a student writes $\det\begin{pmatrix}-1 & 0\\ 1 & 2\end{pmatrix}$ as the answer to the question of "Find the $(1,2)$ minor of $\begin{pmatrix}1 & 3 & 2\\ 2 & -1 & 0\\ 0 & 1 & 2\end{pmatrix}$". How do you asses the student's level of understanding.
5) If a student writes $\det\begin{pmatrix}2 & 0\\ 0 & 2\end{pmatrix}$ as the answer to the question of "Find the $(1,2)$ cofactor of $\begin{pmatrix}1 & 3 & 2\\ 2 & -1 & 0\\ 0 & 1 & 2\end{pmatrix}$". How do you asses the student's level of understanding.

This work is supported in part by the Ministry of Education, Science, Sports and Culture, Grant-in-Aid for Scientific Research in 2013-2015 with the project number 25330514

Hisashi. Yokota is with Shibaura Institute of Technology, Saitama, 337-8570, Japan +8148-687-5693; (e-mail: hyokota@ shibaura-it.ac.jp).

6) If a student writes $\det\begin{pmatrix}-1 & 0\\ 1 & 2\end{pmatrix}$ as the answer to the question of "Find the cofactor expansion of $\begin{pmatrix}1 & 3 & 2\\ 2 & -1 & 0\\ 0 & 1 & 2\end{pmatrix}$ along the 1st row". How do you asses the student's level of understanding.

For the question 1), most of my colleagues agreed that this student knows how to differentiate cosine function. But this person probably does not know how to apply the chain rule. This suggest us to put different weights for simple differentiation and differentiation with chain rule.

For the question 2), most of my colleague agreed that this student knows what to do. But this person somehow memorized the quotient rule in the wrong way. This suggest us that it is important to tell the student to memorize the quotient rule correctly as a feedback.

For the question 3), most of my colleague agreed that this student knows about the integration by parts. But the person did not apply the integration by parts correctly. So, the person's knowledge about integration is not enough. This suggest us that it is possible to tell where the learner made mistake.

For the question 4), most of my colleagues responded by saying that this student knows that the minor of a matrix is given by the determinant. But the person does not know how to find it. This suggest us to tell the learner to study the determinant as a feed-up.

For the question 5), most of my colleagues responded by saying that this student may know a little bit about cofactor. But forgetting a sign means that the person's knowledge about cofactor is not enough. This suggest us to ask the learner to solve the same question.

For the question 6), most of my colleague responded by saying that this student has no idea about cofactor expansion. This suggest us that the learner must go over the section of cofactor expansion.

B. *Experienced Mathematics Educator's Response*

The experienced mathematics educators' responses can be created by using the experienced educators' concept map. For example, consider the following question and its response:

- A learner writes $2(x^2+3x)^3(2x+3)$ as to the question of "Find the derivative of $(x^2+3x)^4$".

The experienced mathematics educators read the learner's solution $2(x^2+3x)^3(2x+3)$. Then they compared the learner's solution to the correct solution. To do so, they differentiate the given function by themselves and compare the results. In other words, they have to recall the chain rule and apply it correctly. Furthermore, they have to recall the differentiation of the power function and apply it correctly within a short period of time. With all these processes, they have noticed that the derivative of power function is essentially in the right form. Furthermore, the chain rule is applied correctly. Therefore, the experienced mathematics educators' response for the above question becomes like the following:

This learner knows how to differentiate the composite function and how to apply the chain rule. But the learner somehow made a mistake multiplying by 2 instead of multiplying by 4.

Now notice that every experienced mathematics educator used the chain rule and the derivative of the power function. Thus, every experienced mathematics educators' knowledge structure is very similar. Even though the knowledge of an individual expert consists of both a cognitive element— the individual's viewpoints and beliefs, and a technical element—the individual's context specific skills and abilities [4], experienced mathematics educators' knowledge structure can be used as the basic knowledge structure about how to solve problems. Furthermore, the response by experienced educators can be used as formative assessment.

III. Generating Formative Assessment

A. *Knowledge Score*

Now to implement the concept map into webCalc, the "knowledge score" is introduced. The marks such as 0.2 and 0.3 on edges of figure 1 are called "knowledge score" which indicates that the basic knowledge needed to obtain a correct map. Note that the knowledge scores on the top row adds up to 1, and the knowledge score added vertically adds up to the one of top scores. In other words, to be able to differentiate a composite function, the knowledge about composite function consists of 20%, the knowledge about the chain rule consists of 50%, and the knowledge about the basic rules of differentiation consists of 30%. These percentages are derived by adding the necessary knowledge needed to acquire before completing the top row knowledge.

Using [2][5], the explained knowledge structure map can be expressed in the following figure.

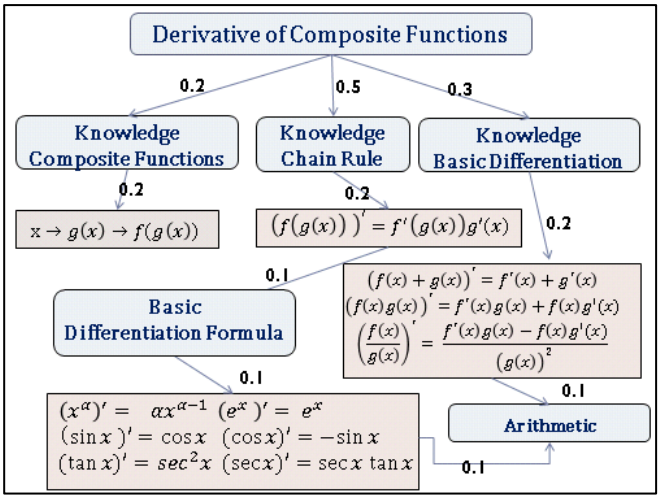

Fig 1 Knowledge Structure Map with Knowledge Score

B. *Generating Formative Assessments*

Using experienced educators' knowledge structure maps, we create formative assessments by reading each learner's inputted answer. To do so, consider the following question and its response:

- A learner writes $2(x^2+3x)^3(2x+3)$ as to the question of "Find the derivative of $(x^2+3x)^4$".

The experienced mathematics educators read the learner's solution $2(x^2+3x)^3(2x+3)$. Then they compared the learner's solution to the correct answer. Then they have

ISBN: 978-988-19252-3-7
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

noticed that the derivative of power function is essentially in the right form. Thus, the feedback part of the formative assessment becomes like the following: "You know how to differentiate the power function". Furthermore, the chain rule is applied correctly. Then the feedback part of the formative assessment becomes like "You know how to use chain rule correctly". Once a learner can answer the chain rule question correctly for five consecutive times, the feed-forward part of the formative assessment becomes like "Go on to next section". Therefore, the experienced mathematics educators' response for the above question becomes like the following:

This learner knows how to differentiate the composite function and how to apply the chain rule. But the learner somehow made a mistake multiplying by 2 instead of multiplying by 4. Since this person answered the question of chain rule, he/she can go on to the next section.

IV. Developing and Implementing Formative Assessment

Well known effective educational model for less prepared learners is one-on-one tutoring [1]. Why one-on-one is effective can be explained by many experiments. The behavior of human tutors is studied in [6] to implement into an adaptive tutoring system. There the importance of formative assessment is not mentioned. But the adaptive tutoring system created certainly includes formative assessment.

It is shown in [6] that it is possible to determine the student input is right answer or not by evaluating the correct answer generated by JCALC and a student input at certain value. This method is studied more carefully to notice that when the value of the correct answer and the student input are different, their difference or ratio has some tendency among group of students. Suppose that a displayed question is "find a derivative of $(x^3+2x^2+3)^4$" and a student input is "$(x^3+2x^2+3)^3(3x^2+4x)$". Furthermore, the correct answer generated by JCALC is "$4(x^3+2x^2+3)^3(3x^2+4x)$". Looking at the student input, anyone with calculus teaching experience judges that the student has the knowledge of derivative of composite function because he/she has took care of derivative of power function then worked inside function.

Suppose this time that the student input is "$4(3x^2+4)^3$". Then again anyone with calculus teaching experience would say that this student did not master the rule of derivative of composite functions. It is because the derivative of the inside function is taken before the derivative of the power function. This time it is not easy to design our system to judge the same way as the experienced educator. For students inputs vary many ways and it is impossible to cover all.

Now as explained in [6], the value of the relative distance rd is calculated for each performance criterion. Then by multiplying the values of each rd s, we can obtain the assessing value for a student's knowledge structure. Thus to give a formative assessment, it is only necessary to add the assessing values for each questions the learner answered.

A. Developing and Implementing Formative Assessments

To develop an adaptive tutoring system with formative assessment, ASP.NET web application is adopted as a development environment. It only because windows based software JCALC component can be used to create web application.

In the next few figures, how an adaptive tutoring system with formative assessment behaves is shown.

Figure2 shows that the top page of webCalc. Here a learner can login to set his/her login name. Then a learner can choose the subject to study. In this figure, the subject differentiation and item Polynomial is chosen.

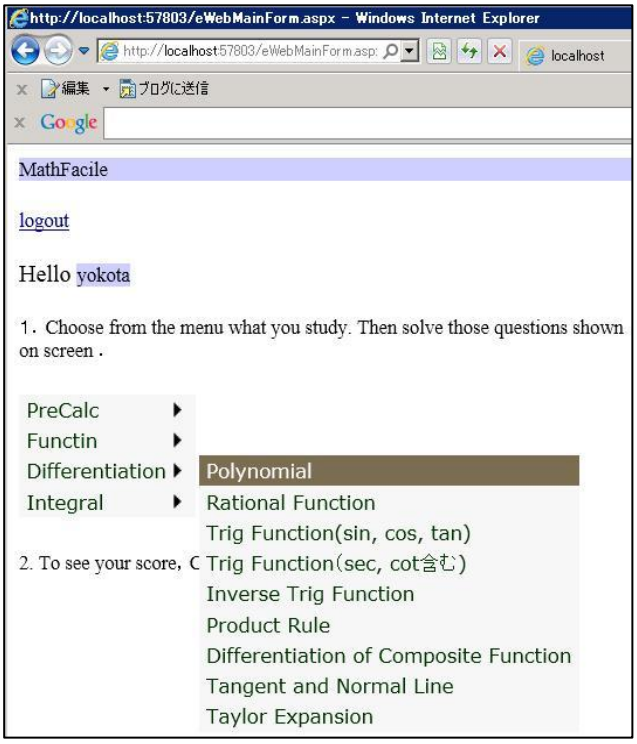

Fig 2 web application webCalc

When a learner push the Start button, the question will be shown. Then the browser shows the question and answer sheet as in Figure3. Notice that the question is automatically generated and the mathematical expression is given in nice form. Automatic generation of the question is given in [6].

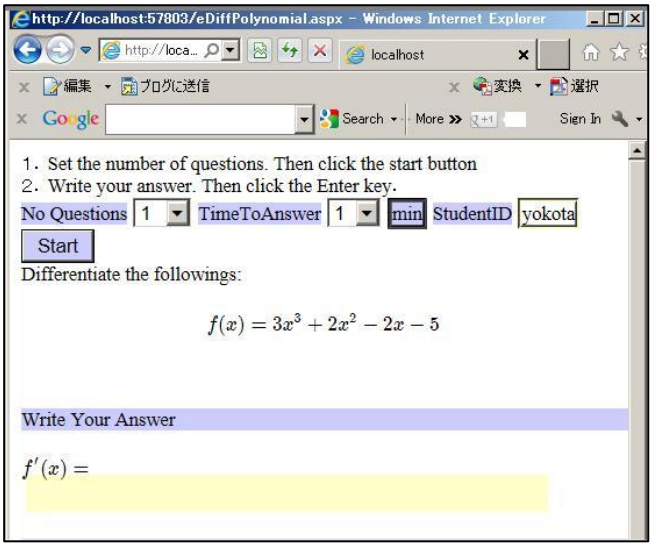

Fig 3 Snap shot of webCalc

Suppose that a learner write 9x^2 as in Figure 4. Then webCalc responds to say "your answer is no close to right

ISBN: 978-988-19252-3-7
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

answer" and then shows "sum of derivatives is the derivative of sum" to let the learner notice his/her mistakes.

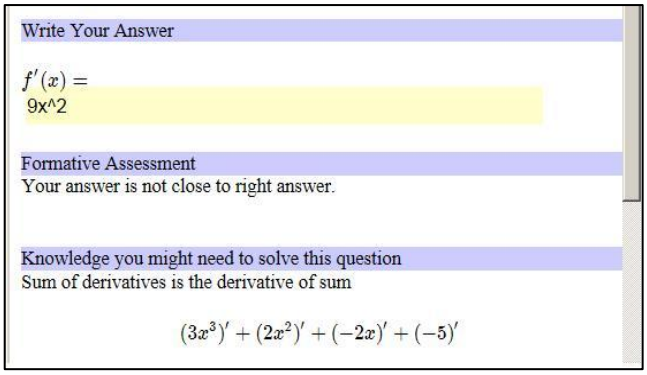

Fig 4 Formative assessment

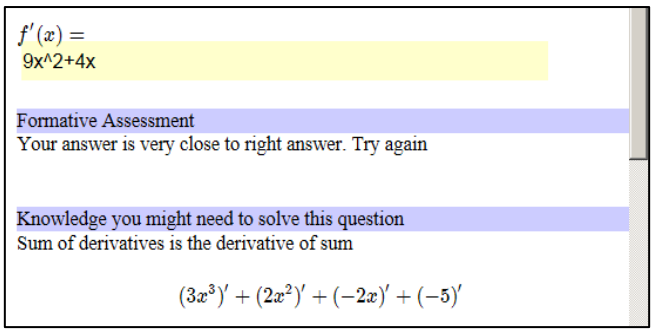

Fig 5 Another formative assessment

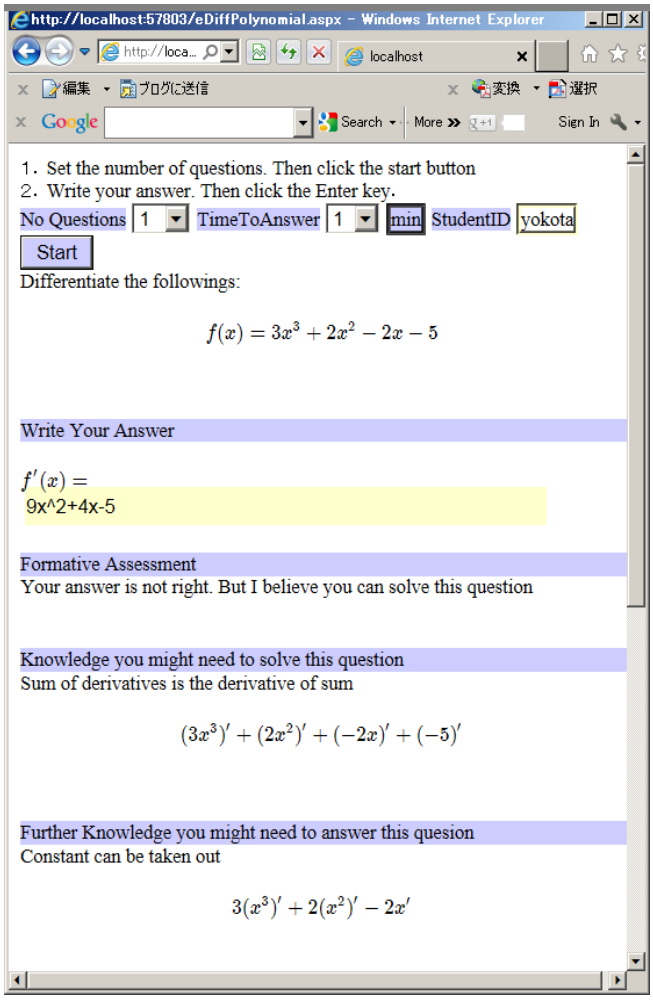

Fig 6 Some other formative assessment

In figure 5 shows the different situation. The solution written is 9x^2 + 4x. Then webCalc responds by saying that "your answer is very close to right answer. Try again". Here, the relative distance is calculated and it is decided that formative assessment should be the one above.

In Figure 6, the answer written is 9x^2 + 4x-5 which is only differ by 3 from the correct answer. Then webCalc responds by saying "your answer is not right. But I believe you can solve this question." Then further knowledge to solve this question is given as a hint.

V. Conclusion

The importance of mobile learning is getting more obvious. Yet it is not easy for educators to develop their own mobile learning system adjusted to their students. One of the major reasons why adaptive tutoring system with summative assessment is losing interest from many educators is the cost performance. The method shown here does not require any marketed software to develop an adaptive tutoring system with formative assessment. Using this method, it is also possible to transform any PC software into mobile learning software.

The system can be used by anyone to access the following URL:
http://next2.msi.sk.shibaura-it.ac.jp/webCalc1/ewebMainForm.aspx

Acknowledgment

We thank all colleagues and students participated in this project and suggested useful ideas to develop a mathematical intelligent tutoring system with formative assessment .

References

[1] R.G. Ainsworth Turning potential school dropouts into graduates: the case for school-based one-to-one tutoring. Research report 95 – 07. National Commission for Employment Policy, 35, 1995

[2] M. Alavi, D.E. Leidner, Knowledge management and knowledge management systems: conceptual foundations and research issues, MIS Quarterly Review 25(1), 2001, pp.107–136

[3] P. Bana, Artificial intelligence in educational software: has its time come? British Journal of Educational Technology, 30(1), 1999, 79-81

[4] J. Keyes, Where's the ''expert'' in expert systems, AI Expert , vol. 5, No. 3, 1990, pp. 61–64

[5] J. Rentsch, T. Heffner, Group and Organization Management 19(4), 1994, pp. 450–474..

[6] H. Yokota, An adaptive tutoring system for Calculus learning. *Proceedings of The World Congress on Engineering and Computer Science 2009*, WCECS 2011, 640-645, October 20-22, 2009, San Francisco, USA

[7] H. Yokota, On a development an adaptive tutoring system utilizing educator's knowledge structure. *Proceedings of The World Congress on Engineering and Computer Science 2011*, WCECS 2011, 19-21 October, 2011, San Francisco, USA, pp.260-264