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MathML and JAVA Implementation in Linear Algebra

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Abstract

In our new learning environment we have developed various JAVA tools, and studied ways to display mathematical expressions effectively on the web. In this paper, we discuss how we adapt MathML and JAVA techniques to develop mathematical tools, for example matrix calculators and the Random Problem Generator (RPG), which can be used in our linear algebra class. It can be profitably used in other classes as well.

1 Introduction

Learning environments for mathematics have been dramatically developed over the last decade [2, 3]. Throughout Calculus reform[1] and the ATLAST project[2], students have been affected by the changes, and teachers of linear algebra, in particular, are expected to implement new educational environments such as CAS or the Internet. Linear algebra especially is a subject in mathematics which has had more interaction with changes in recent educational environments. Many web examples of linear algebra with advanced features have now appeared. Now students use a lot of resources from the internet for their study. But there still exists an obstacle in expressing mathematics on the web. There still remains several difficulties, such as a slow feedback and the shortage of quality responses. We may adapt the MathML and JAVA techniques with interactive linear algebra contents to overcome these difficulties.

In this paper, we discuss how we adapted MathML and JAVA techniques to develop mathematical tools. JAVA Matrix calculators and the Random Problem Generator(RPG) will be some of our examples. It can be well used in the blended learning environment, see for example [1, 6].

[1] http://mathforum.org/mathed/calculus.reform.html
[2] http://www.umassd.edu/SpecialPrograms/Atlast/

2 MathML and its implementation on the web

In this section, we introduce MathML techniques and show how we can effectively express our mathematical expressions on the web by using MathML and MimeTeX rendering program.

2.1 Introduction to MathML

MathML is an XML-based encoding method for mathematics which has been announced by W3C (World Wide Web Consortium). XML (short for eXtensible Markup Language) has emerged as the dominant data format underlying the information infrastructure of the web. Since MathML is a part of XML, MathML defines a method of representing structured data types, essentially the pointy-bracket tagging of HTML. MathML itself merely defines the common syntax and leaves it to specific areas of application to define appropriate data types. MathML is significant because it is becoming deeply embedded in the software systems and workflows that will shape the information landscape for years to come. Because of MathML, mathematics is a full-fledged part of that information landscape, and this bodes well for the scientific community [8].

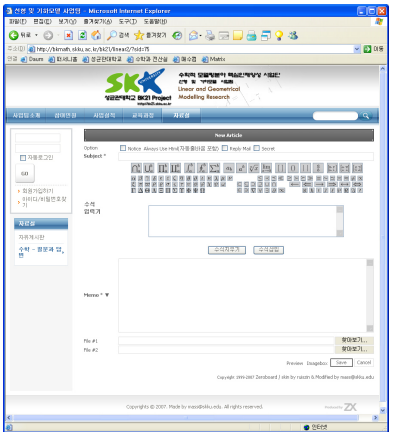
Preferentially, the rendering software is required on the web in order to produce MathML. This program read MathML and analyze it, and display a mathematical expression to the web browser. Since it has a function to be displayed to web browser, most rendering programs use the ActiveX technology. The Mathplayer program of the Design Science company is a good example. But there is a problem because most rendering programs use the ActiveX technology. The Microsoft corporation which is a major vendor of Windows XP and Vista announced to reduce the support on ActiveX applications [12]. Therefore, we expect there will be a lot of changes in the MathML technology in the future. Because of these changes, it is still not well spread out of MathML in the mathematical expression to web browser. There has been many tries to express the MathML document on the webpages[3]. But the Microsoft corporation doesn't follow the standard of W3C. Many applications(including jsMath etc) do not properly operate on Internet Explorer except for Firefox. Considering the heavy use of the Internet Explorer in Korea's educational environment, the dependability on the Internet Explorer has been a big obstacle on the wide use of the MathML in our linear algebra classes. In Korea, other platforms including the Linux and Macintosh systems are not popular for the field of education. Most students and teachers use Internet explorer for educational purposes. Due to this reason, we have developed tools for Internet explorer, but they also work in FireFox and other platforms.

2.2 MathML and rendering program with TeX

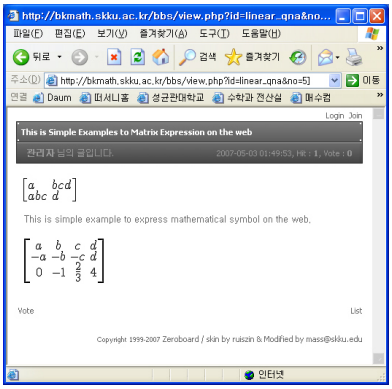
MathML has the merit of easily displaying mathematical expressions. Anyone can easily display mathematical expressions if MathML rendering programs are used. That is why many programs such as TeX, MS-Word, Maple, Mathematica adapted MathML. Among them, TeX is superb in its expression and it also has the tool called LaTeX2HTML which is very useful on the web. MimeTeX use LaTeX2HTML functions to express mathematical objects on the web, see Figures 1 and 2. Although we may encounter slow rendering of pages, and often poor alignment of mathematical expressions when we use LaTeX2HTML, but when we used MimeTeX we do not face any problem because it uses the enhanced LaTeX2HTML functions.

[3]http://www.w3c.org

If we apply MimeTeX on a bulletin board, we can make a bulletin board system (in brief, BBS) which can freely post mathematical expressions. Mathematical information which can be accumulated through this BBS can be used by KIMS (Knowledge Information Management System), e-Learning and multimedia contents etc. We have successfully used (see Figure 1 and 2) this BBS, and the two Figures can be reproduced by visiting the following URLs.



[Figure 1 : TeX input system using MimeTeX]



[Figure 2 : Result]

- http://bkmath.skku.ac.kr/bk21/linear2/?sid=75
- http://bkmath.skku.ac.kr/bbs/view.php?id=linear_qna&no=5

With this BBS, we can express mathematical expressions to web browser, but users should have some knowledge of TeX usage in order to use this system properly. So, we have to find a method that everyone can express mathematical objects on the web. That method can be found in the MathML techniques. In this process, JAVA makes a bridge on MathML and TeX render scheme by object oriented concept. In the next section, we will introduce how we implemented them on the JAVA with MathML.

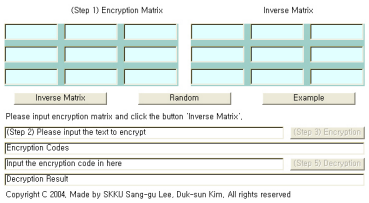
3 Java Implementations

JAVA has been used effectively for the educational purpose of mathematics. We have developed a JAVA matrix calculator with MathML.

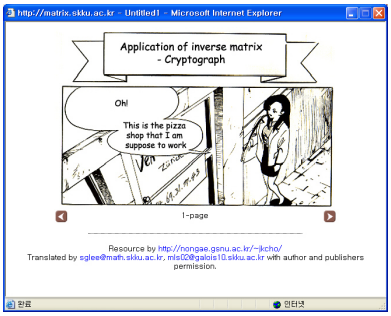
3.1 Use of JAVA Tools in Teaching of Linear Algebra

Since 1995, JAVA has carried out a lot of applications in linear algebra education. We have also developed several multimedia contents of linear algebra using JAVA and flash tools [11]. We use them in our on-line and off-line classes. We also tried to find effective ways of using them. Some of our efforts on using our JAVA tools has been helped the learning process of our students [2, 4] .

One example of our JAVA applet was on simple encryption system [10]. This example was made for students to understand about the inverse matrix [5, 10]. It was introduced with a cartoon in the ILAS Educational Homepage[9][4], see Figure 4.



[Figure 3 : The encryption applet]



[Figure 4 : Matrix JAVA tool with a cartoon ILAS Educational Portal Site]

This program used an encryption matrix and its inverse, encodes the plain text by using the encryption matrix, and decoded it by using its inverse. This program can be used wherever you can use web browser which support JAVA applications. Its URL is as follows.

http://matrix.skku.ac.kr/ilas/er/module2/Applets/Test.html

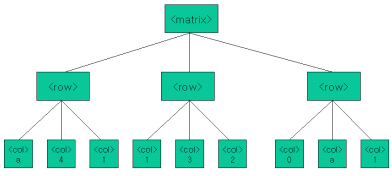
3.2 Object Oriented Programming in JAVA and MathML

Since MathML is based on the XML feature, MathML has the DOM (Document Object Model) structure which is based on the object oriented concept. JAVA is also based on the object oriented programming concept. This feature makes a strong connection between JAVA and MathML. That concept enables us to do mathematical computation.

Object oriented concepts have relevance to MathML which has important position in the expression of a mathematical object on the web. The DOM structure of test.xml is given in Figures 5 and 6.

```
<?xml version = '1.0'?>
<matrix>
        <mname>  DetMatrix </mname>
        <row>
                <col>a</col>
                <col>4</col>
                <col>1</col>
        </row>
        <row>
                <col>1</col>
                <col>3</col>
                <col>2</col>
        </row>
        <row>
                <col>0</col>
                <col>a</col>
                <col>1</col>
        </row>
</matrix>
```

[Figure 5 : MathML Expression]



[Figure 6 : the DOM Structure]

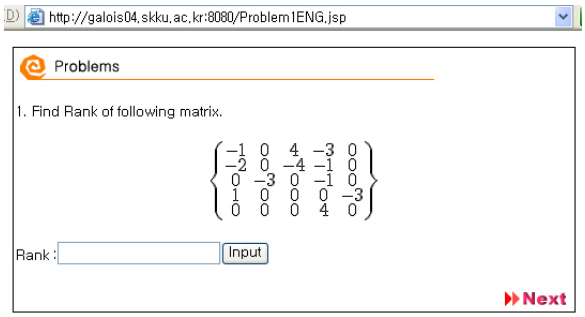
[4]http://matrix.skku.ac.kr/ilas/er/module2/index.html

MathML data which has been produced by JAVA is stored as a computable object and an expressible object on the web. Therefore, we can calculate this object and see the output on the web. The source code that shows how this process is executed is provided in Figure 7.

```
17              <p align="center"><font size="2">
18  <jsp:useBean id="cm" scope="session" class="CMatrix" />
19
20  <%
21      cm.BeanXMLLoader("/usr/local/tomcat/webapps/ROOT/test.xml");
22  %>
23
24  <%=cm.printApplet() %>
```

[Figure 7 : A part of Problem1.jsp]

BeanXMLLoader function [11] reads a MathML file (test.xml) and it will appear using the printApplet function on the web as shown in Figure 8.

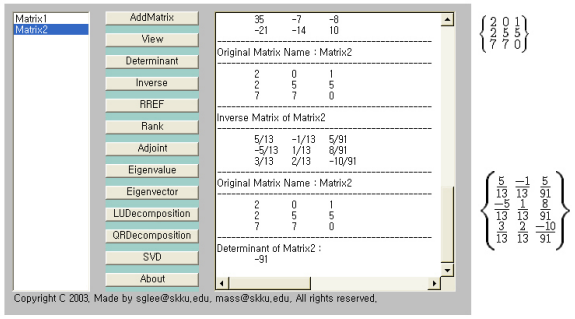


[Figure 8 : MathML Loading Example[5]]

In this system, a matrix is loaded and the result of the evaluations is stored in this system. When a student types his or her answer in this box, it returns whether it is right or not.

3.3 Development of JAVA matrix calculator with MathML

The following matrix calculator has been developed and its logic is based on matrix decomposition theories [11]. It help us to find the determinant, inverse matrix, REF (Row Echelon Form), RREF (Reduced Row Echelon Form), rank, adjoint matrix, eigenvalues and eigenvectors, see Figure 9.



[Figure 9 : JAVA Matrix Calculator : English Edition]

[5]http://galois09.skku.ac.kr/Problem1ENG.jsp

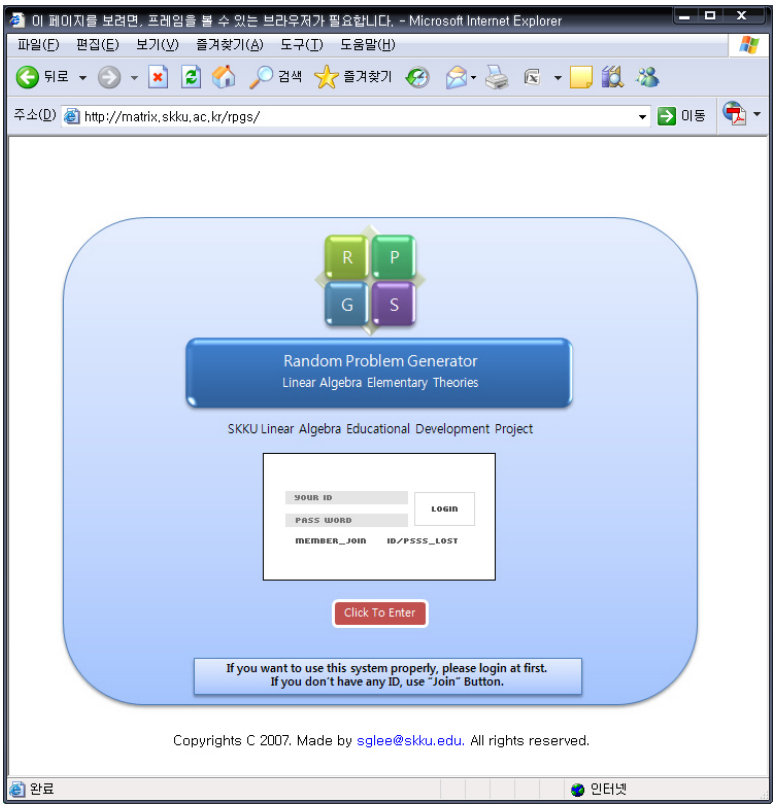
It has new features as follows. It can deal with rational and complex numbers. In rational number case, we can use 7/3, 10/7 forms and when we input complex numbers, we can use 3+4i, 7-2i forms. It is able to compute matrices of size up to 15×15 with complex numbers in this UI (user interface). But we have made the engine module which can evaluate matrices with size up to 1000×1000. This can be accessed at the following URLs.

- http://matrix.skku.ac.kr/newMatrixCalENG11/Test.html
  [English Edition]
- http://matrix.skku.ac.kr/newMatrixCalKOR11/Test.html
  [Korean Edition]

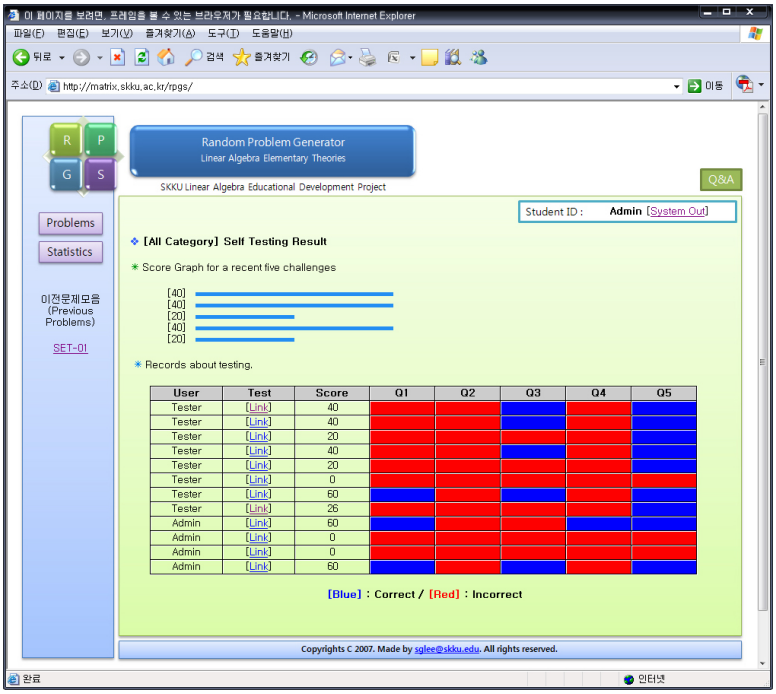
4 Development of Random Problem Generator

We have developed a RPG(Random Problem Generator) system, and have tried to apply it in our classroom. The RPG system can be viewed at the following URL. (Figure 10)

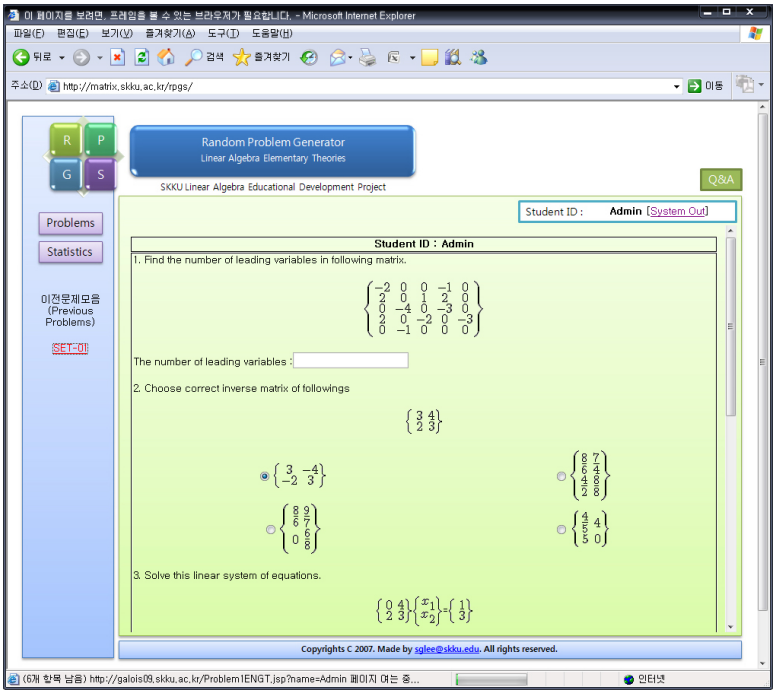
- http://matrix.skku.ac.kr/rpgs



[Figure 10 : Random Problem Generator]



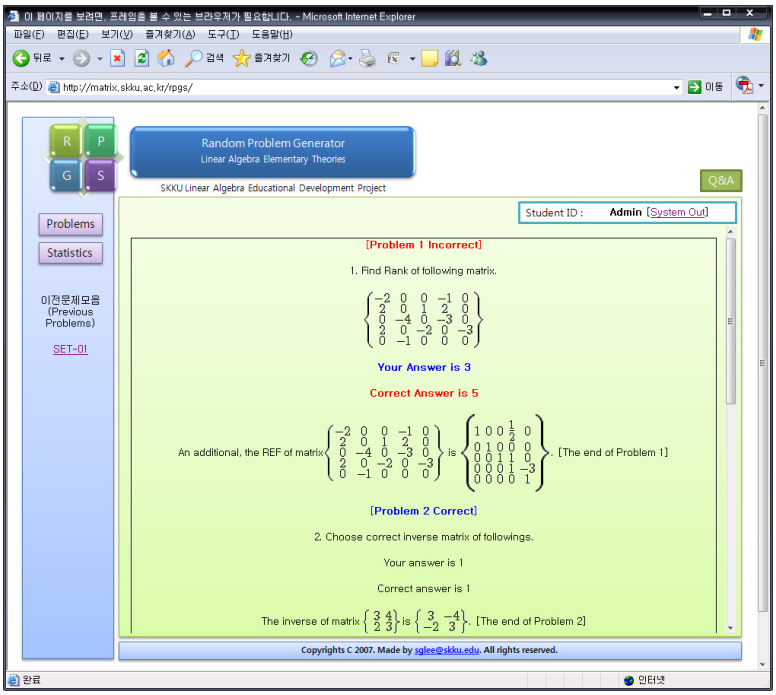
[Figure 11 : Statistics]



[Figure 12 : The randomly generated problems]

Each student will receive a different problem to solve in Figure 12. Each of the delivered problems can be well programmed with given criteria. Some examples of responses from the system are given

in Figure 13. Finally students can show their achievement in this system using by the statistics in Figure 11.



[Figure 13 : Responses about the answer]

The RPG system is built by JAVA and MathML with object oriented concepts. This system is effectively used to develop the "Item Pool / Item Bank" system and it improves the interactive multi-media contents from earlier prototypes. In the next section, we will discuss how we use our tools in a new learning environment.

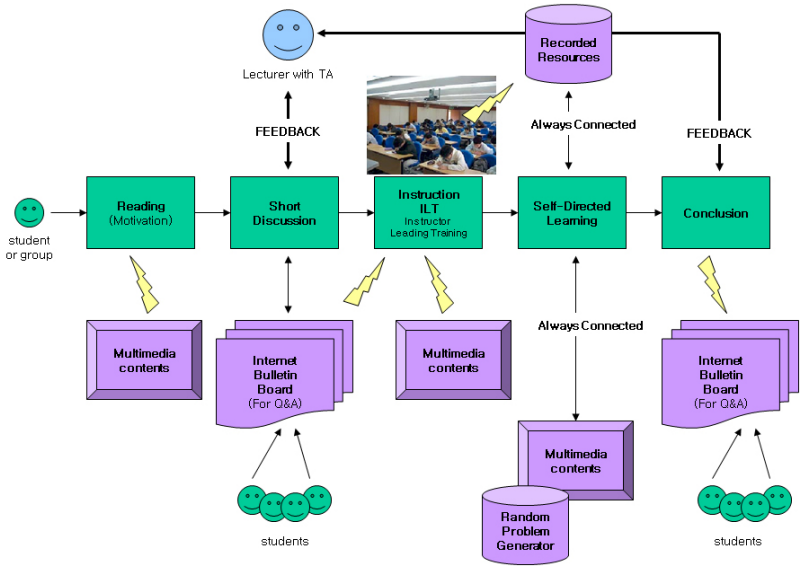
5 Further Issues : Blended Learning of Linear Algebra

In Korea, high speed internet is available to everyone almost everywhere [2, 7] . The cost of unlimited use of it per month is about a price of a couple of meals. So, all students do not hesitate to use such learning environment in college level mathematics education (blended learning of the linear algebra). The RPG system using JAVA and MathML techniques can be added to our linear algebra lecture to improve student interactions [2, 6, 7]. Now we shall discuss the blended learning of linear algebra which was introduced in [6, 7]. If you have opened e-mail communication route with your students, we can say you are already in blended learning environment. In our class of linear algebra, we may think a learning process is as indicated in Table 1. It provides examples of things that can be done with the blended learning class for the instructors and students.

	Instructor / TA	Students
Reading (Motivation)	- Offer reading materials. - Offer updated web references.	- Read materials before the class - Get enough motivation - Make questions
Short Discussion	- Give some concepts to discuss - Guide the process of discussion	- Write what they think - Follow the feedback
I L T Instructor Leading Training	- Go throughout materials face to face contact. - Possibly leave the record of off-line lecture.	- Off-line learning process - Students can resolved all unanswered problem question.
Self-Directed Learning	- Guide the learning process. - Keep in contact with students.	- Self-directed learning, self-testing, mastery learning, level and type based on individual learning with contents, lecture note, web materials, RPG, BBS
Conclusion	- Finalize FEEDBACK process - Evaluation of participation	- Achieve student's own goal of each lecture.

[Table 1 : The Activities in the Blended Learning Course]

In the blended learning environment, the RPG system has many advantages such as self-directed learning, self-testing, mastery learning, level and type based individual learning. The following diagram (Figure 14) shows how the RPG system can be used in the blended learning of linear algebra.



[Figure 14 : The Process of our Blended Learning]

Because of more personal interaction, most students found better motivation in the blended learning classes. Their performance and satisfaction have also been improved. In the blended learning course, we could try to more diverse problems with better motivated students and can have a wonderful results from there. We are satisfied with the blended learning education of linear algebra [4]. Table 2 provides the results of a teaching evaluation that shows the change. Since then, most of the

evaluation from the students who were in the mathematics classes were higher than 90 points (the average in math was less than 83 points which made a high record for the entire school). That indicates that students satified this class and it shows that RPG is important in the linear algebra classes.

< Example >

< Teaching evaluation, 2006> Score: 97/100

Course	Number	No of Students who answered	Score
Linear Algebra	GEDB003	41/ 55	97/100

<Number of students for each Questionnaire >

Course No.	Answer	Q.1	Q.2	Q.3	Q.4	Q.5	Q.6	Q.7	Q.8	Q.9	Q.10	Total
GEDB003	S. Agree	22	24	20	17	16	16	19	15	19	21	188
GEDB003	Agree	14	11	13	13	14	18	15	18	12	10	138
GEDB003	Average	6	6	8	8	11	6	6	6	9	9	73
GEDB003	Bad	0	0	0	3	1	2	1	2	1	1	11
GEDB003	Worse	0	0	0	0	0	0	0	0	0	0	0
GEDB003	No Answer	1	1	1	1	1	1	1	1	1	1	10

[Table 2 : The teaching evaluation for the Blended Learning class with RPG.]

6 Conclusion

We have developed various JAVA matrix calculators for our linear algebra class, and have studied effective ways to display mathematical expressions on the web. With these efforts we were able to develop Random Problem Generator (RPG) with MathML using our JAVA matrix calculators. These new tools have adopted in our linear algebra blended learning classes in addition to our self-directed learning innovations. In this paper, we have introduced how we use our new Random Problem Generator (RPG) and how it has the behavior of students in their learning process.

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