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2016

Mathematica-based e-Learning/Assessment System for College Mathematics

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- What is ‘MATH ON WEB’ ?
- Effectiveness
- The structure of ‘question data’
- Moodle plugin
- MeLQS project

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What is ‘MATH ON WEB’ ?

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Summary of ‘MATH ON WEB’

- Target : College Mathematics (Linear Algebra and Calculus)
- **Consists of 2 systems: WMLS and WASM**

  WMLS : Web-based Mathematics Learning System

  WASM : Web-based Assessment System of Mathematics

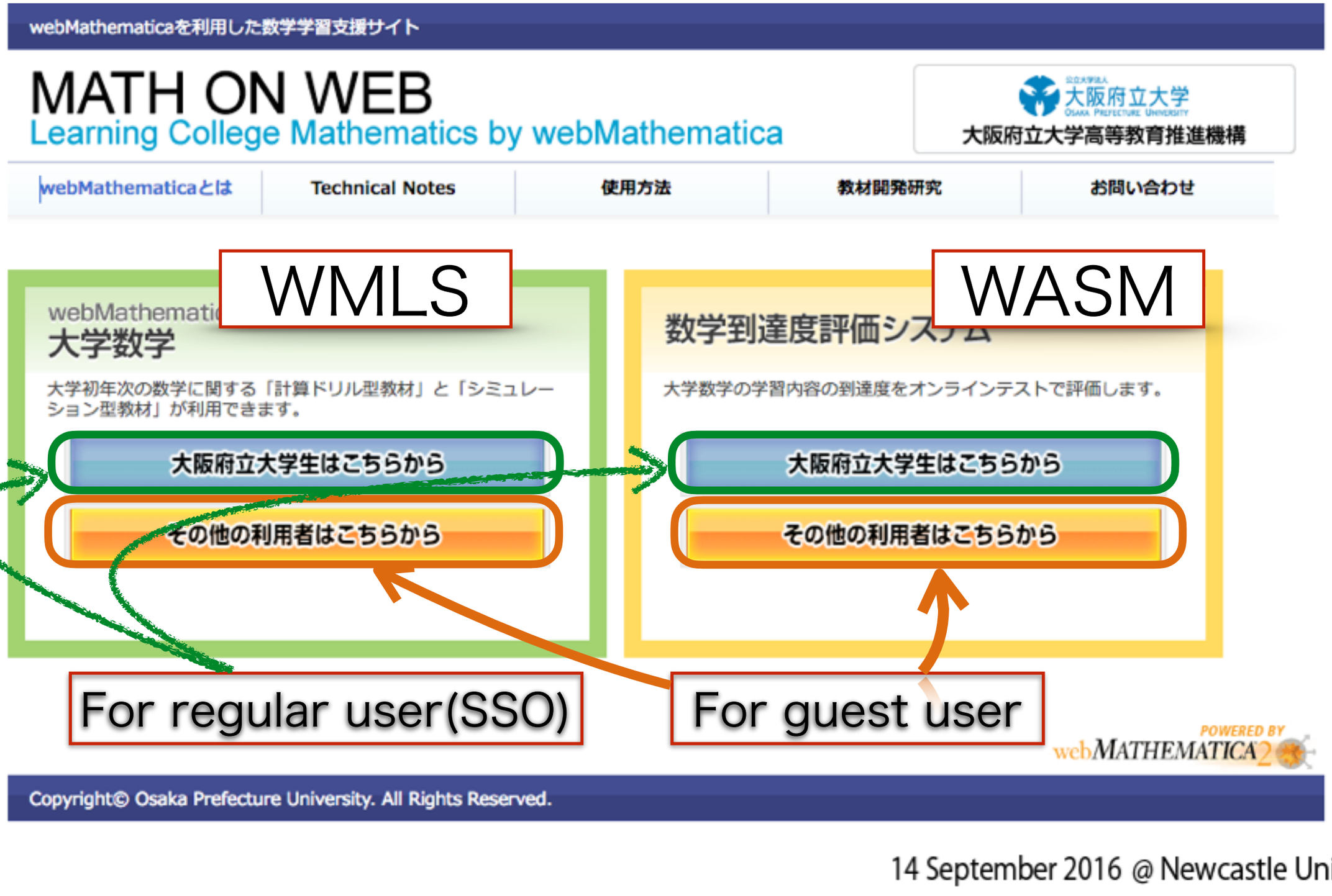
- Background CAS = web*Mathematica and Mathematica* (Wolfram)
- Used for after-class learning
- More than 1200 questions implemented

Search “MATH ON WEB”…

http://www.las.osakafu-u.ac.jp/lecture/math/MathOnWeb/

Screenshots

http://www.las.osakafu-u.ac.jp/lecture/math/MathOnWeb/



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Screenshots (WMLS)

webMathematicaで学ぶ大学数学
Learning College Mathematics by webMathematica

大阪府立大学 Osaka Prefecture University
大阪府立大学高等教育推進機構

webMathematica を利用した大学初年次の数学学習支援用教材集です。講義を補完する自習支援環境の提供をめざし、「計算ドリル型問題」と「シミュレーション型学習教材」の作成・公開を行っています。「シミュレーション型学習教材」は、数学的概念や現象の背後にある法則を、具体例を通じて試行錯誤しながら学習者自らが考え理解していくための教材です。

システムの使い方

前回実施した問題

2013/02/25 16:34　部分空間の和(2)

最新のお知らせ　過去の一覧

2012/02/01
二重積分の問題の入力エラーについて

2011/12/19
[お詫び] システムの障害について

2011/06/05
方向微分の問題の不具合について

2010/06/25
リーマン和と極限　(2) の正解判定

2010/04/22
[重要] 夜間定期メンテナンスのための一時サービス停止について

教材一覧

Calculus

微積分学
- 計算ドリル型問題　0件完了/全110件　ランク:511位/636人

Linear Algebra

線形代数
- 計算ドリル型問題　10件完了/全100件　ランク:257位/621人
- シミュレーション型学習教材　0件完了/全3件

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List of Learning Contents (WMLS)

■ Vector space

単元	問題	
Subspace	Def. of Subspaces(1)	部分空間の定義(2)
Linearly independency	Lin. ind'cy of num vectors (1)	数ベクトルの1次独立性(2)
	Lin. ind'cy of polynomials	
Dimension and Basis	空間内の平面の基底	生成される部分空間の次元と基
	生成される部分空間の次元と基底(3)	生成される部分空間の次元と基
	解空間の次元と基底(2)	部分空間の和(1)
	部分空間の共通部分(1)	部分空間の共通部分(2)

Dim of and basis for the solution space

3 元斉次連立 1 次方程式の解空間

問1.

$A = \begin{pmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{pmatrix}$ に対し，Vを連立一次方程式Ax= 0 の解全体のなす R^3の部分ベクトル空間

Vの次元と基底を求めよ。

解答欄： 次元は [ ] ，基底は{ $\begin{pmatrix} \square \\ \square \\ \square \end{pmatrix}$, $\begin{pmatrix} \square \\ \square \\ \square \end{pmatrix}$, $\begin{pmatrix} \square \\ \square \\ \square \end{pmatrix}$ }

基底を構成するベクトルが3個より少ないときは、余ったベクトルの欄は空欄に すること。
次元が0のときは，基底の欄は空欄にすること。

チェック

大学 高等教育推進機構

lis

解空間の次元と基底(1) Problems list

次の行列Aに対し，Vを連立一次方程式Ax= 0 の解全体のな

問1. $A = \begin{pmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{pmatrix}$

問2. $A = \begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 2 \\ 1 & 1 & 3 \end{pmatrix}$

問3. $A = \begin{pmatrix} 1 & 1 & -1 \\ 2 & 2 & -2 \\ -1 & -1 & 1 \end{pmatrix}$

問4. $A = \begin{pmatrix} 1 & 1 & 3 \\ 1 & -1 & -1 \\ 2 & -1 & 2 \end{pmatrix}$

問5. $A = \begin{pmatrix} 1 & 0 & 1 \\ 0 & 1 & 1 \\ 2 & -1 & 1 \end{pmatrix}$

Feedback of learning status (WMLS)

The number of all students who completed the problem.

Completed!

Suspended

Given-up

■ ベクトル空間

:完了 :中断 :[illegible] マークなし:未実施

単元	問題　※()内の数字は完了者人数		
Subspace	Def. of subspaces (1) (169人)	Def. of subspaces (2) (124人)	
Linearly independence	Lin. indep. of num vectors (1) (123人)	Lin. indep. of num vectors (2) (98人)	Lin. indep. of num vectors (3) (79人)
	多項式空間での1次独立性 (90人)		
Dimension and basis	Basis of a plane in the space (133人)	Dim and basis of a generated subspace (1) (125人)	Dim and basis of a generated subspace (2) (108人)
	Dim and basis of a generated subspace (3) (64人)	Dim and basis of a generated subspace (4) (79人)	解空間の次元と基底(1) (91人)
	Dim and basis of a null space (48人)	Sum of subspaces (1) (70人)	Sum of subspaces (2) (53人)
	部分空間の共通部分(1) (62人)	部分空間の共通部分(2) (42人)	部分空間の共通部分(3) (16人)

Completed!

Suspended

Given-up

The system summary

Find a basis and the dimension for the solution space of the following system of linear equations.

$$\begin{pmatrix} 1 & 2 & 3 \\ 2 & 4 & 6 \\ 3 & 6 & 9 \end{pmatrix} \begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}$$

Check List

1) #Basis=Dim?
2) Appropriate Vectors in Basis?
   - No zero vector?
   - Inside the space?
   - Linearly independent?
3) Correct Dim?

$\mathbf{Basis} = \left\{ \begin{pmatrix} \mathbf{1} \\ \mathbf{-2} \\ \mathbf{1} \end{pmatrix} \right\}, \ \mathbf{Dim} = \mathbf{1}$

Student

Basis? $\begin{pmatrix} 1 \\ -2 \\ 1 \end{pmatrix}$? ?

Dimension=1?

"Dim is incorrect."
Try again?
or Give up?

$\mathbf{Basis} = \left\{ \begin{pmatrix} \mathbf{1} \\ \mathbf{-2} \\ \mathbf{1} \end{pmatrix} \right\}, \ \mathbf{Dim} = \mathbf{1}$

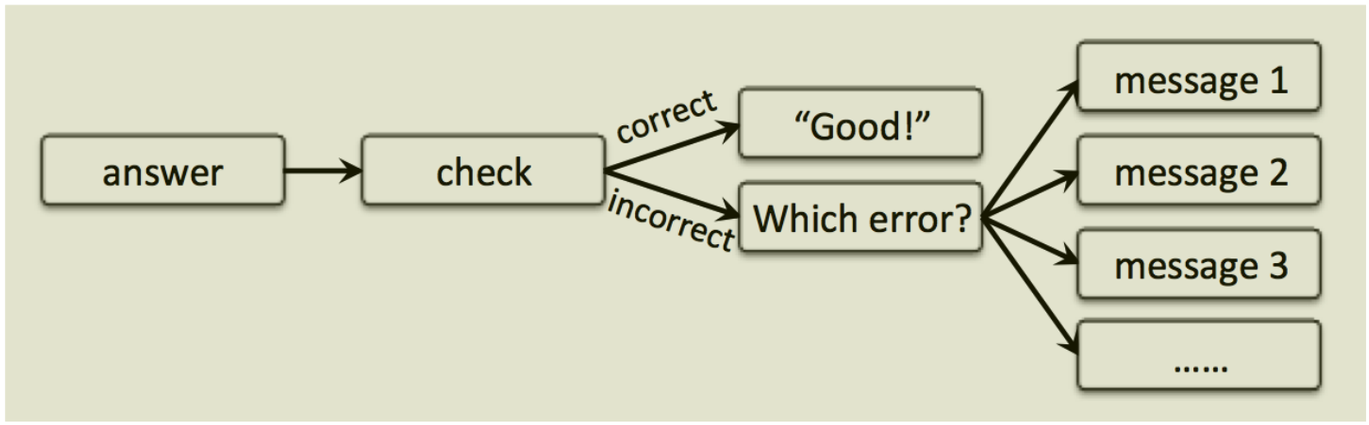
TOMCAT
+
webMathematica

Mathematica

Web-based Learning System

Log line: ID, name, problems parameters, time, answers, correct/incorrect, etc...

Database



Features of WMLS and WASM

WMLS Key feature:

- WMLS is a self-learning system.
- WMLS consists of the drill section and the simulation section.
- The system has over 200 learning units and each unit consists of 5 problems. (Over 1000 problems!)
- Each learning unit is equipped with a problem example and its model answer in PDF format.
- There is no assessment mode, no time limit.
- Students can retry the same problems repeatedly until they get correct answers.
- The correct answer is never shown.

WASM Key feature:

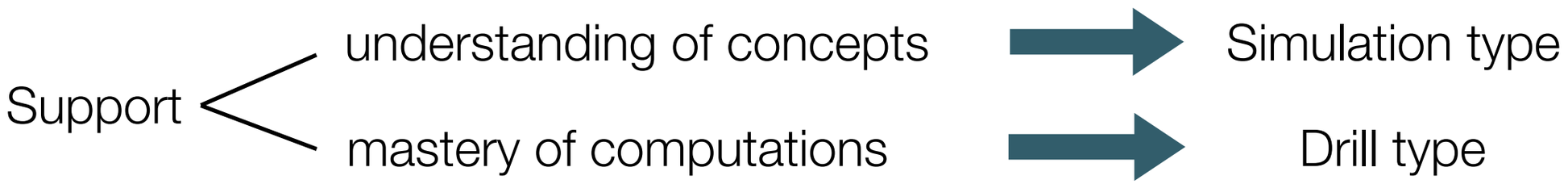
- WASM is an online assessment system.
- Assessment mode and drill mode have been implemented.
- Assessment materials are associated to the learning units.
- Problems are randomly generated.
- Answer time limits are set in all problems in an assessment mode.
- The correct answer is never shown.
- No simulation section.

Motivation

To develop the students' understanding of the students,
we want to support and promote after-class learning.

To support after-class learning,
we thought web-based system might be appropriate.

We wondered how to develop a web-based simulation system,
web*Mathematica* 1.0 was launched timely (2002).



The merits of the drill system

- Paper-based exercise … students want to know the answer.
- There are some questions which have non-unique answer … CAS can handle such cases with appropriate program.
- The program not only can judge the correctness, but also can respond appropriate feedback message to the students.

Feedback samples

Find a basis and the dimension for the solution space of the following system of linear equations.

$$\begin{pmatrix} 1 & 2 & 3 \\ 2 & 4 & 6 \\ 3 & 6 & 9 \end{pmatrix} \begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}$$

Check List

1) #Basis = Dim ?
2) Appropriate Vectors in Basis ?
   - · No zero vector ?
   - · Inside the space ?
   - · Linearly independent ?
3) Correct Dim ?

$\text{Basis} = \left\{ \begin{pmatrix} 1 \\ -2 \\ 1 \end{pmatrix} \right\}, \text{Dim} = 2$ → **Number of vectors in Basis does not equal Dim. See the definition of Basis and Dim.**

$\text{Basis} = \left\{ \begin{pmatrix} 1 \\ -2 \\ 1 \end{pmatrix}, \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix} \right\}, \text{Dim} = 2$ → **Basis contains the zero vector. See the definition of Basis.**

$\text{Basis} = \left\{ \begin{pmatrix} 1 \\ -2 \\ 1 \end{pmatrix}, \begin{pmatrix} -2 \\ 4 \\ -2 \end{pmatrix} \right\}, \text{Dim} = 2$ → **Vectors in Basis are linear dependent. See the definition of Basis.**

$\text{Basis} = \left\{ \begin{pmatrix} 1 \\ -2 \\ 1 \end{pmatrix}, \begin{pmatrix} 2 \\ -1 \\ 0 \end{pmatrix} \right\}, \text{Dim} = 2$ → **Good!**

$\text{Basis} = \left\{ \begin{pmatrix} 3 \\ 0 \\ -1 \end{pmatrix}, \begin{pmatrix} 0 \\ 3 \\ -2 \end{pmatrix} \right\}, \text{Dim} = 2$ → **Good!**

Project and related history

- 2002 pre-WMLS(Simulation) was developed with web*Mathematica* 1.0
- 2003 pre-WMLS(Drill type) was developed with web*Mathematica* 1.0
- 2005 STACK 1.0 was launched.
- 2005 Practical use of pre-WMLS for all students started.
- 2009 WMLS was developed with support by MEXT(2009-2011).
- 2012 WASM was developed with support by MEXT(2012-2013).
- 2013 Tentative use of WASM started.
- 2014 Practical use of WASM started.
- Oct 2014 STACK 3.x became available in our university!!

MEXT : Ministry of Eduction, Culture, Sports, Science and Technology, Japan

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Practical use of the systems

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Learning environment with WMLS

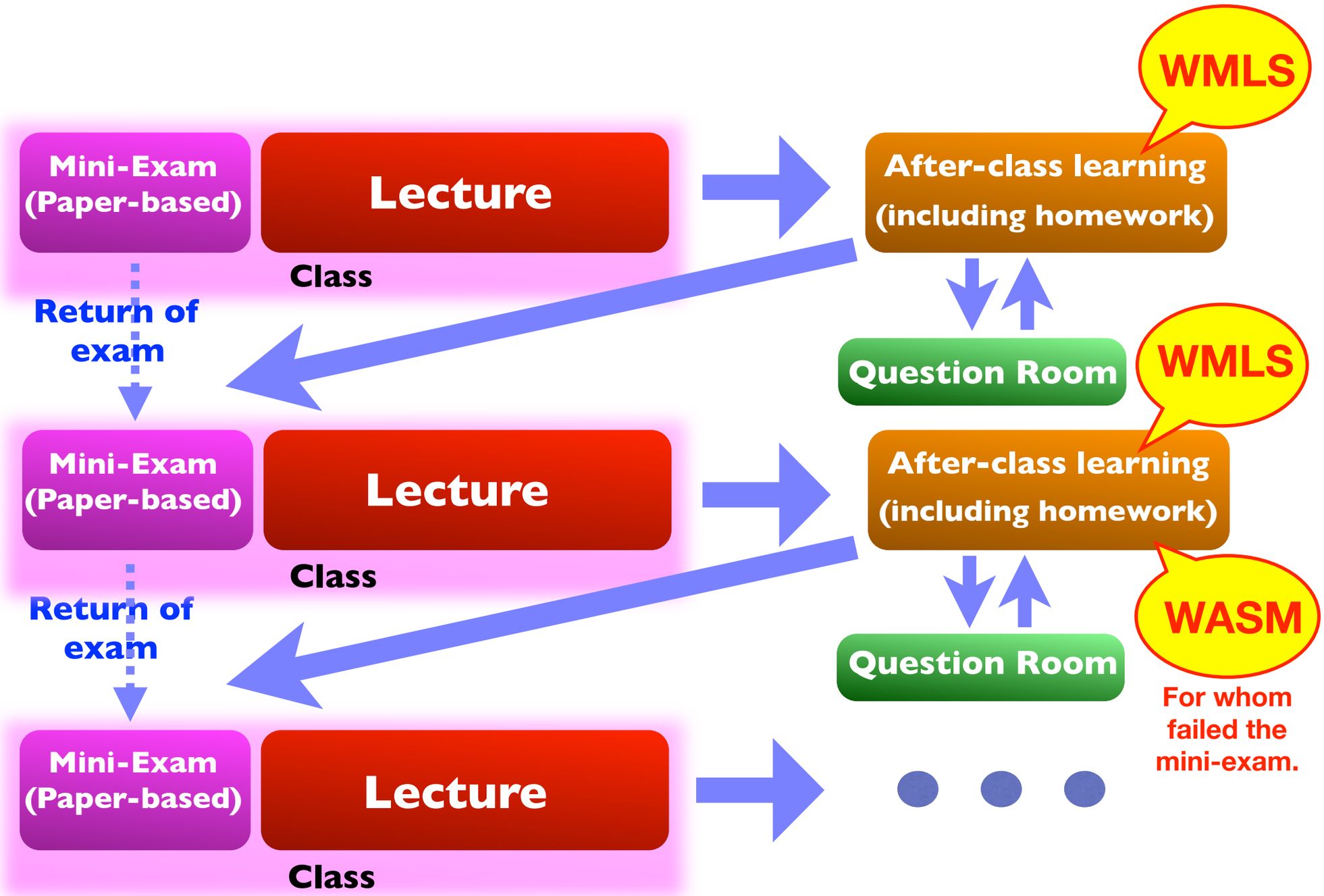
We use WMLS :

1. In all the classes of linear algebra and calculus.
2. As a tool for after-class learning.
3. To complement the regular class activities.
4. Combined with public office hour (in a designated room(*))

Teachers not compel but recommend the students to use the system.

(*) We call this room *"Question Room"*, opened regularly in the semesters afternoon.

Example class with ‘MATH ON WEB’



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Effectiveness
- Log analysis -

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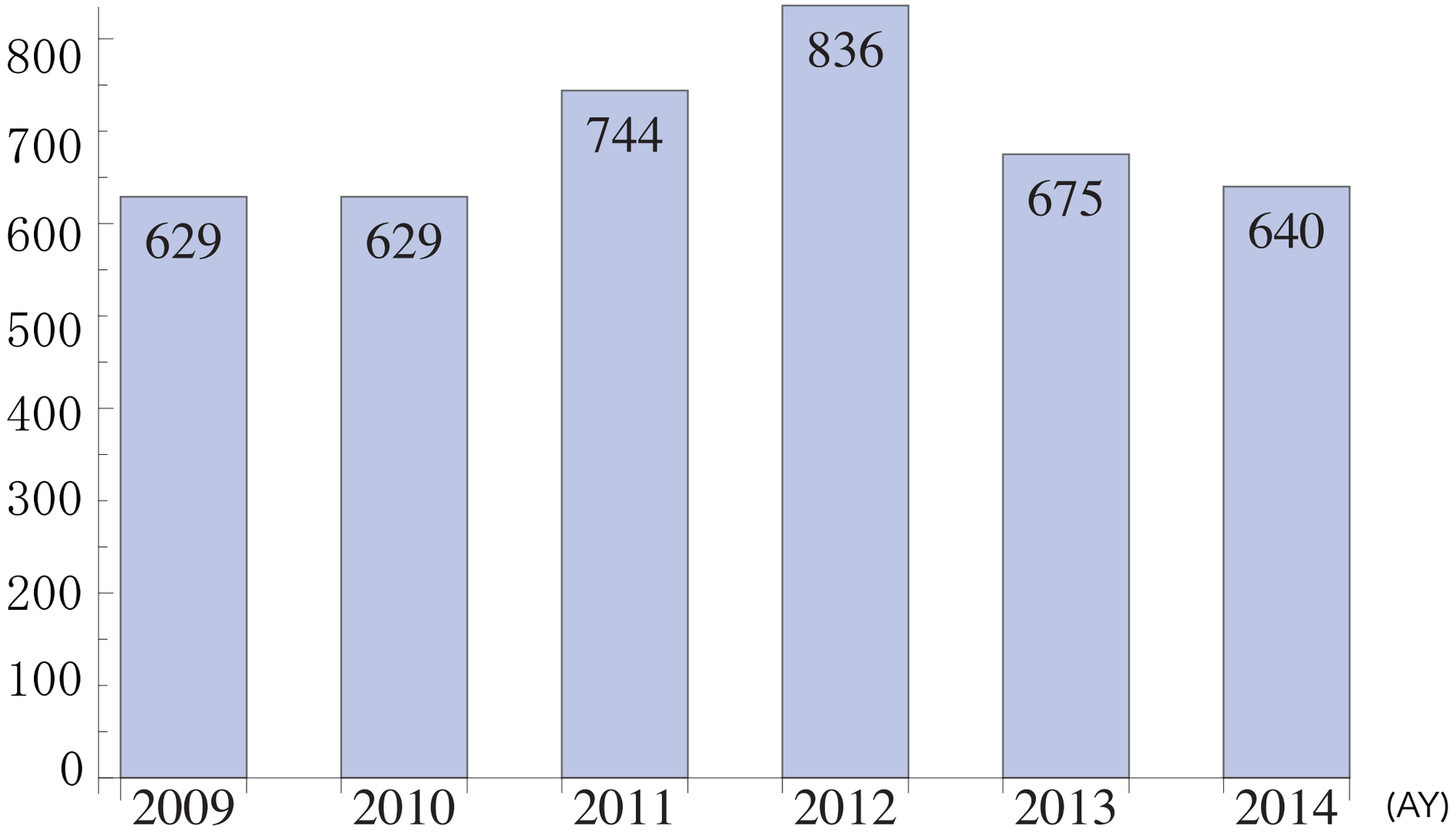
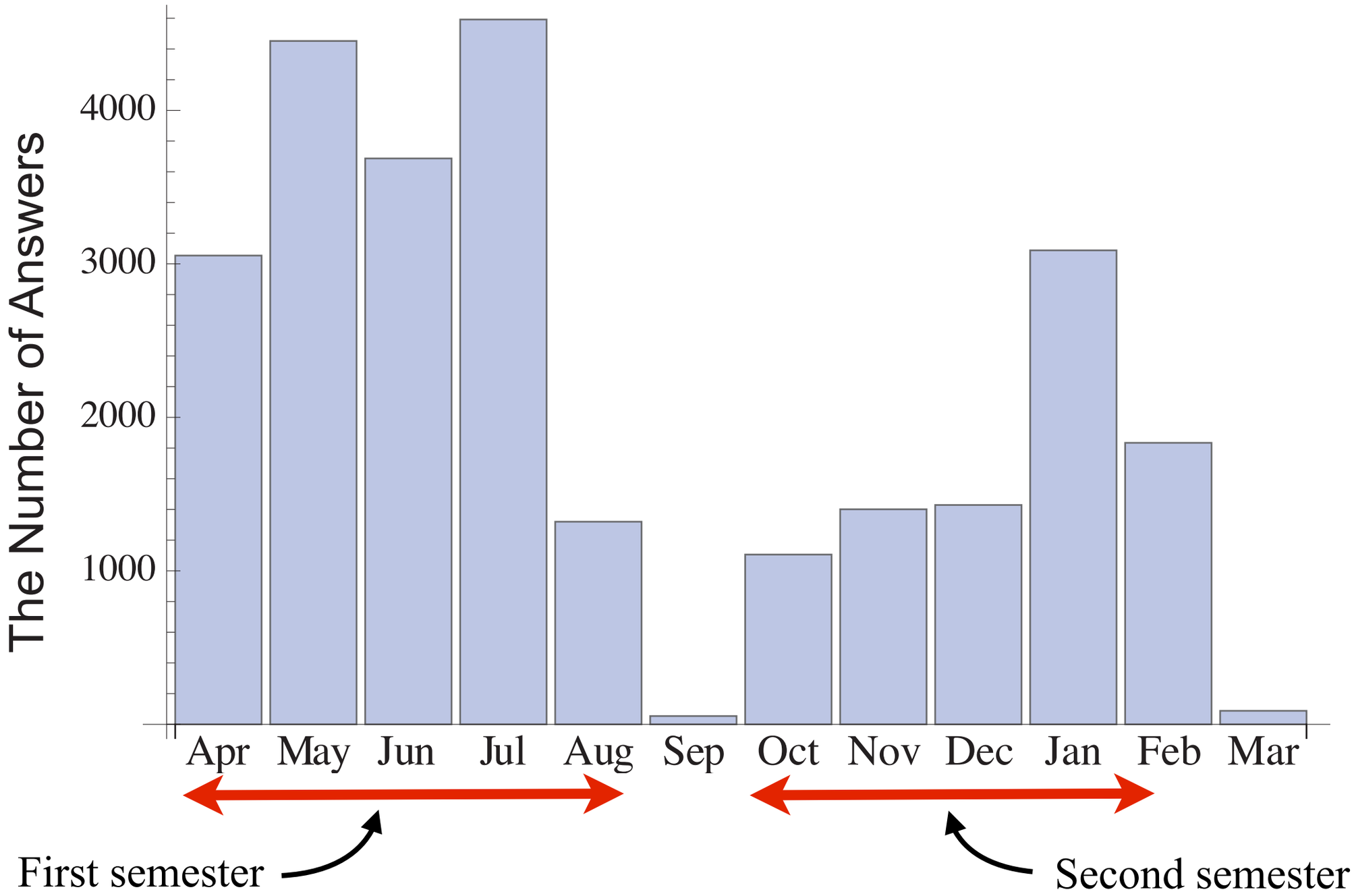
The number of users (WMLS and WASM)

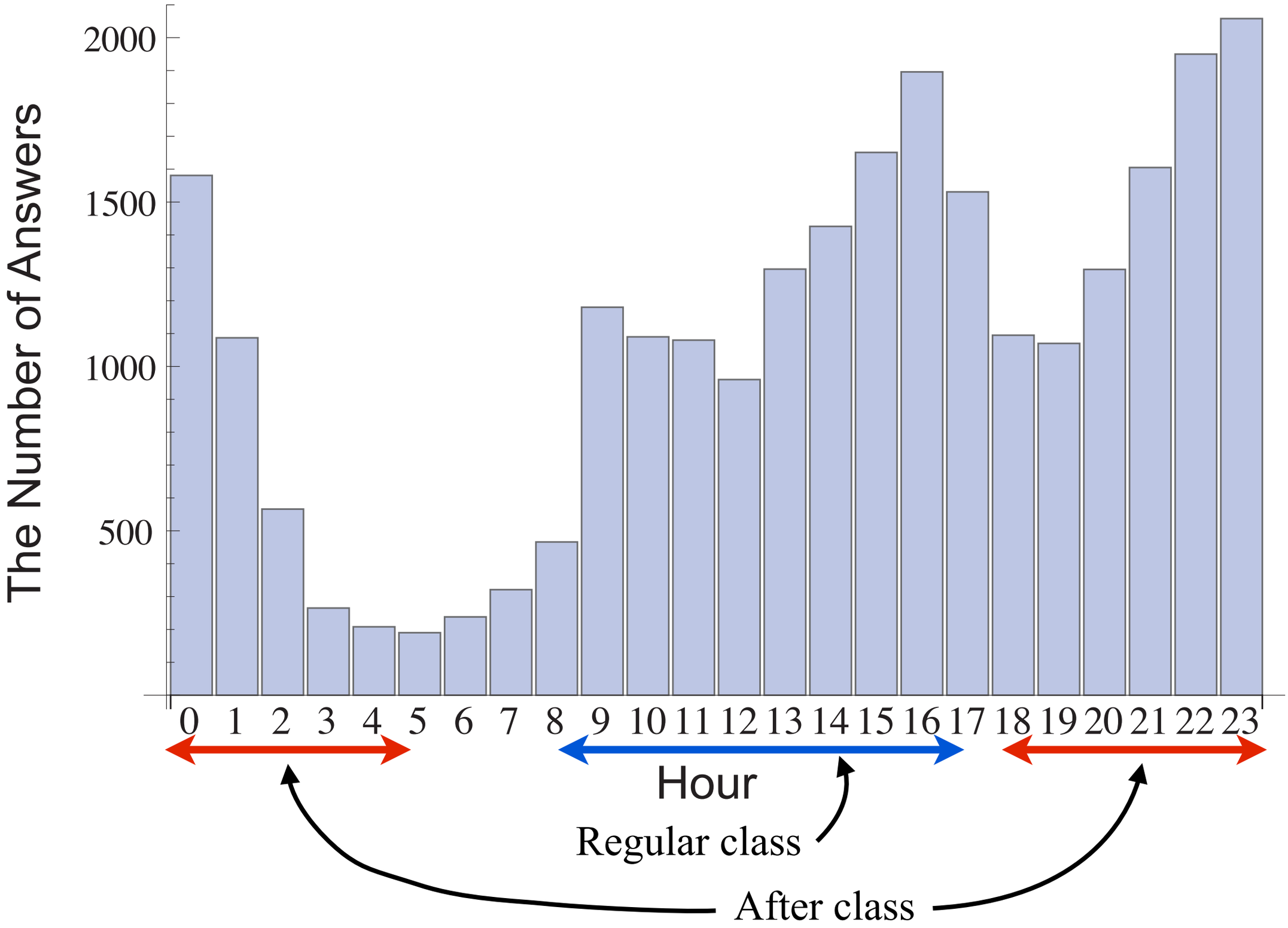


✳ WMLS is since 2009
✳ Up to AY2012, WMLS only.
✳ Data of AY2014 is at 1/19/2014

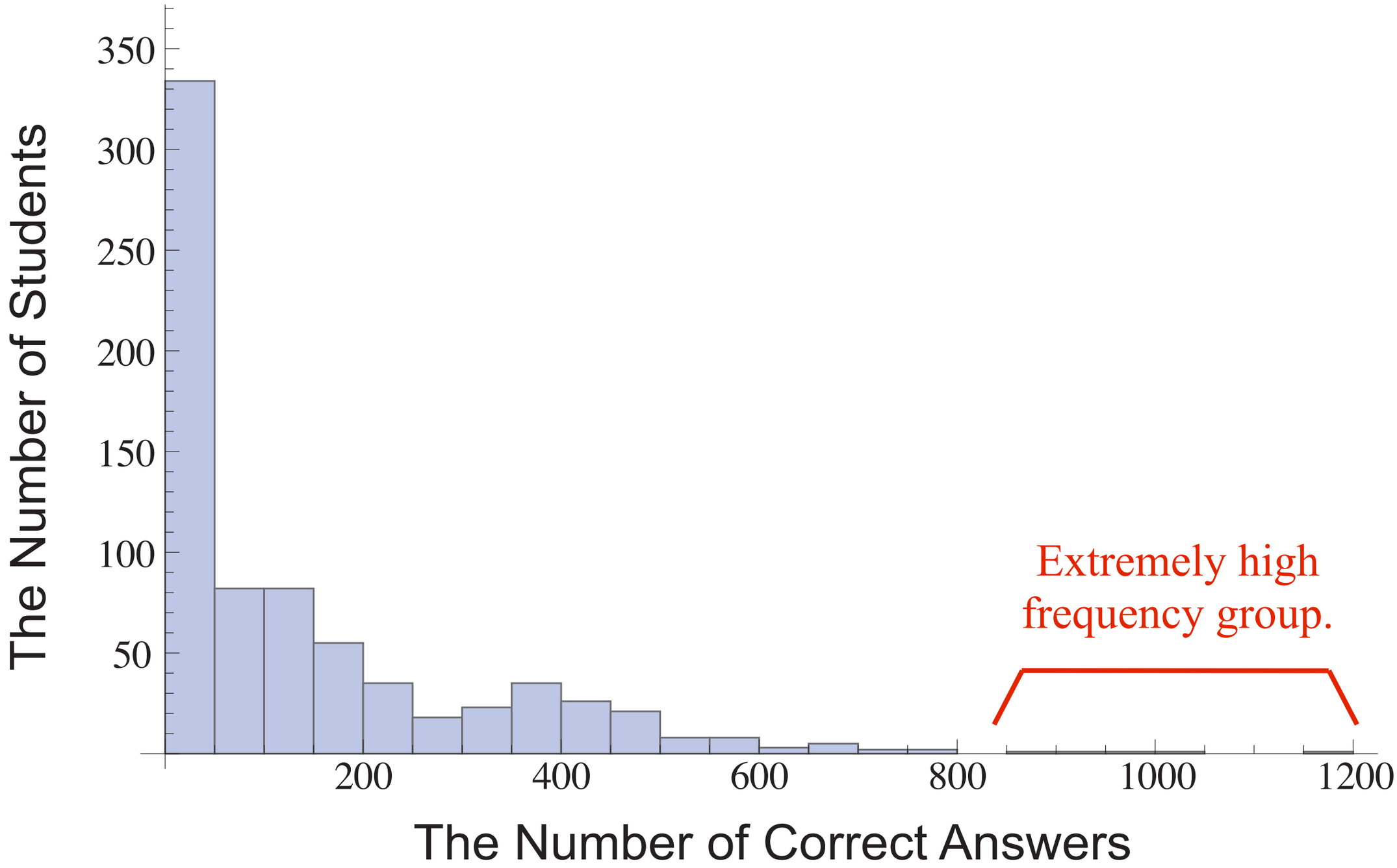
Frequency of use split by month (WMLS)



Frequency of use split by hour(WMLS)



The number of students and correct answers (WMLS)



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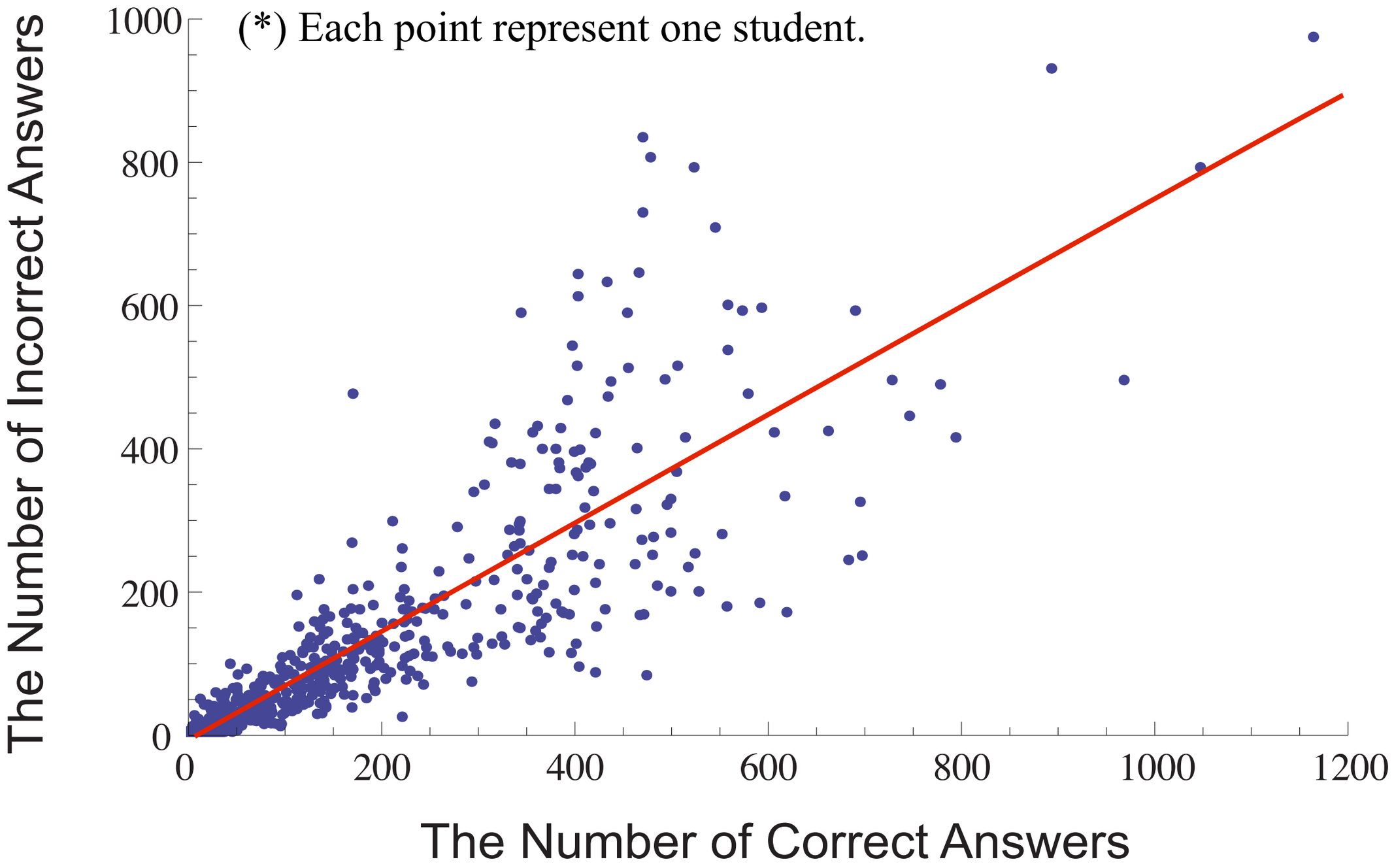
The number of correct and incorrect answers (WMLS)

(*) Each point represent one student.



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Effectiveness
- Questionnaire Survey on WASM -
(AY 2014, Fall)

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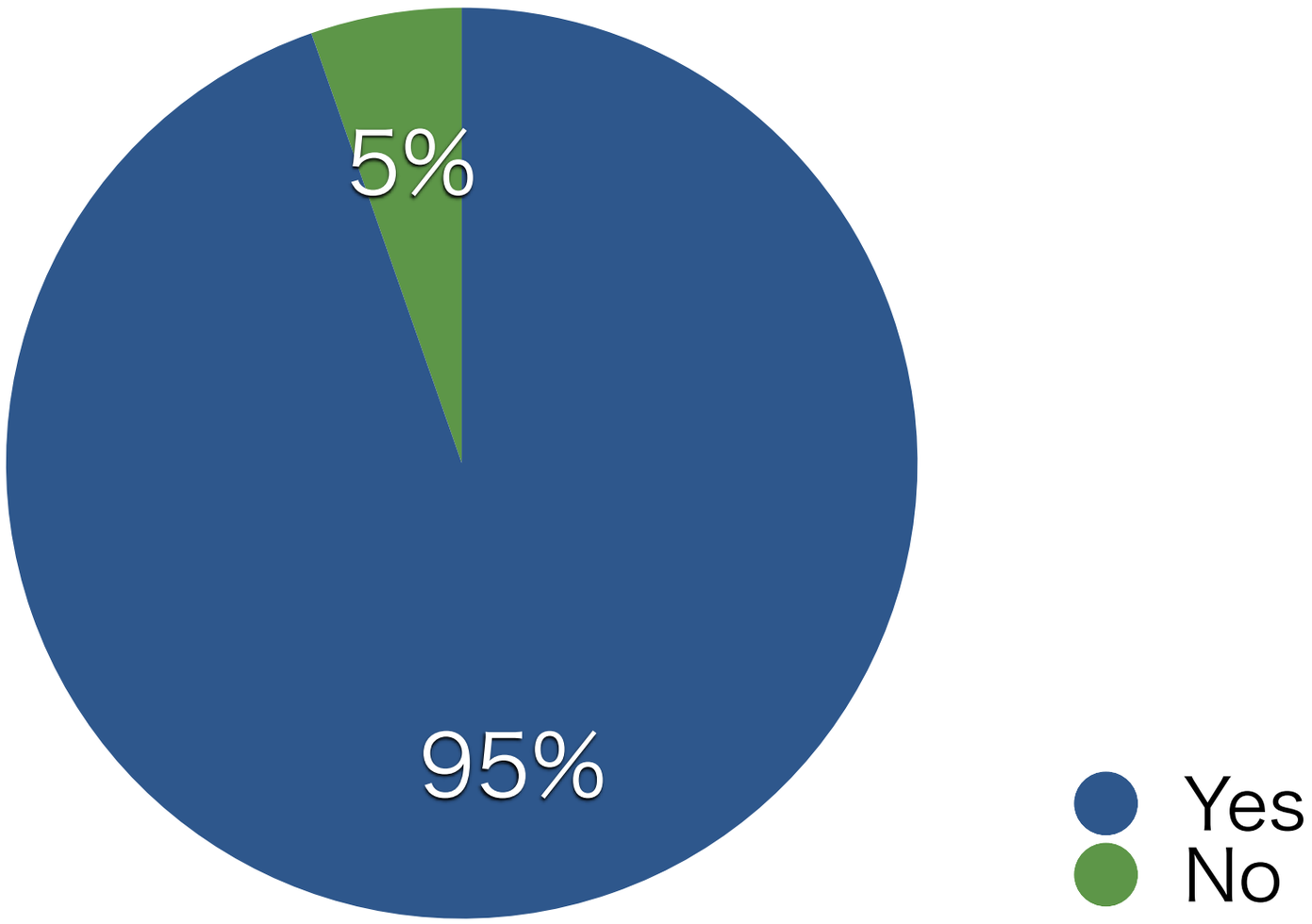
Questionnaire survey on WASM (1)

- Linear Algebra course / AY2014 Fall -

Have you ever used MASM?



n=56

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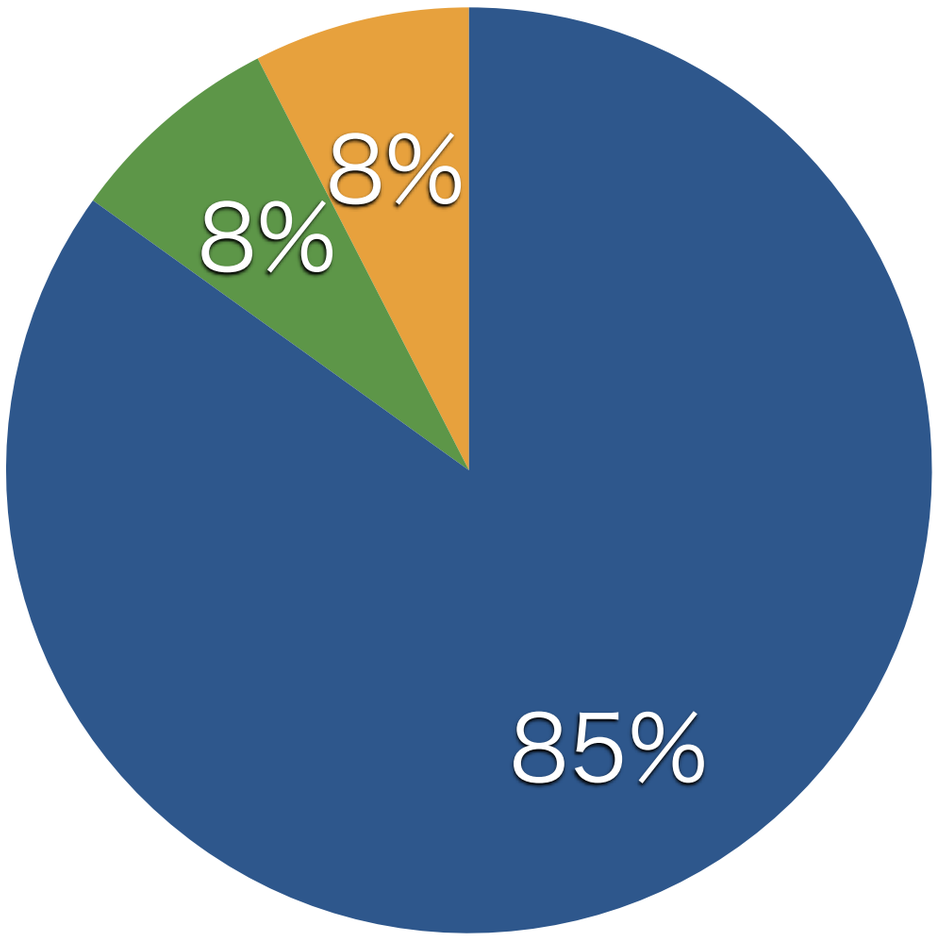
Questionnaire survey on WASM (2)

- Linear Algebra course / AY2014 Fall -

For whom replied YES in the question (1)

Why did you use the WASM?



n=53

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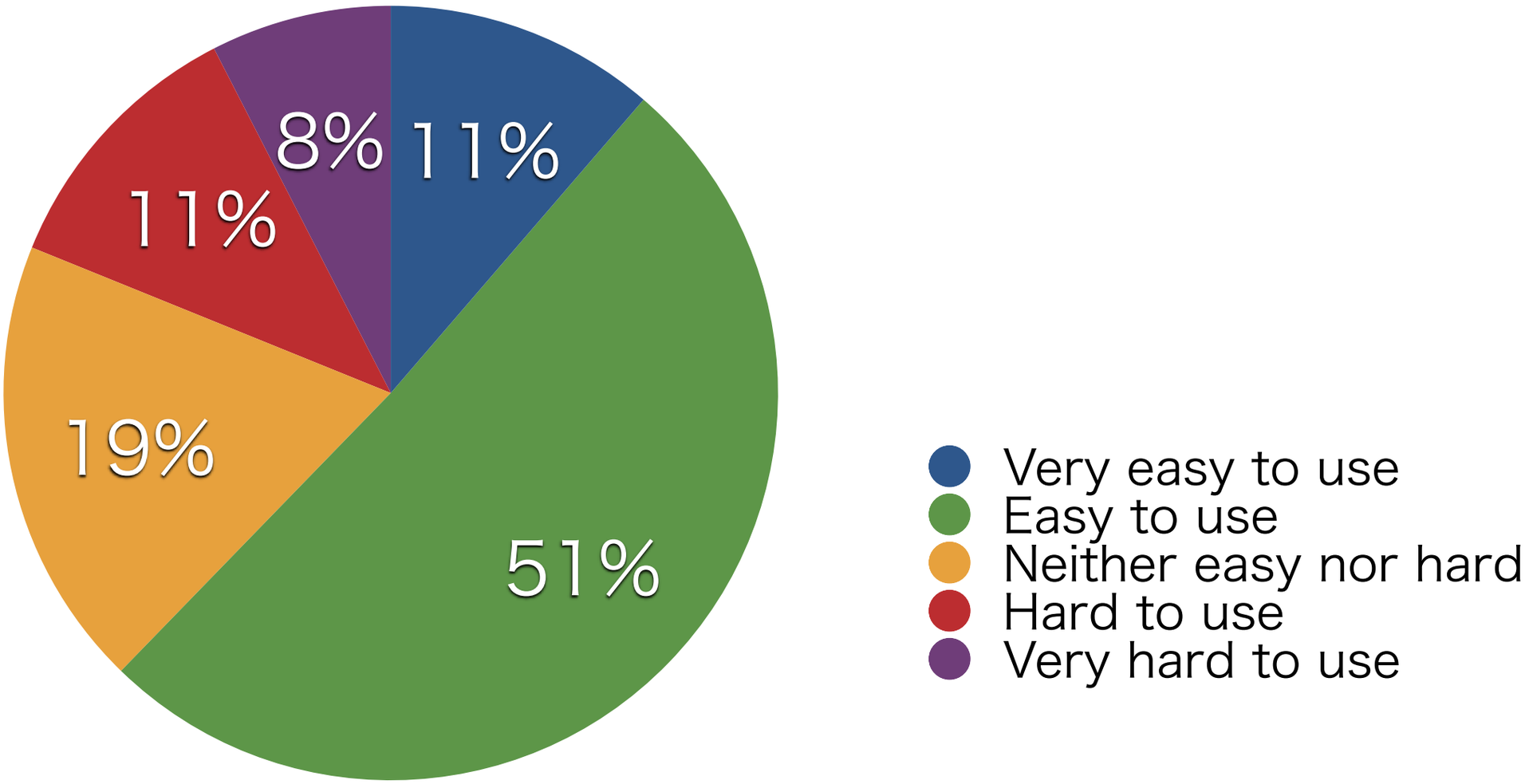
Questionnaire survey on WASM (3)

- Linear Algebra course / AY2014 Fall -

For whom replied YES in the question (1)

What do you think about the usability of the system?



n=53

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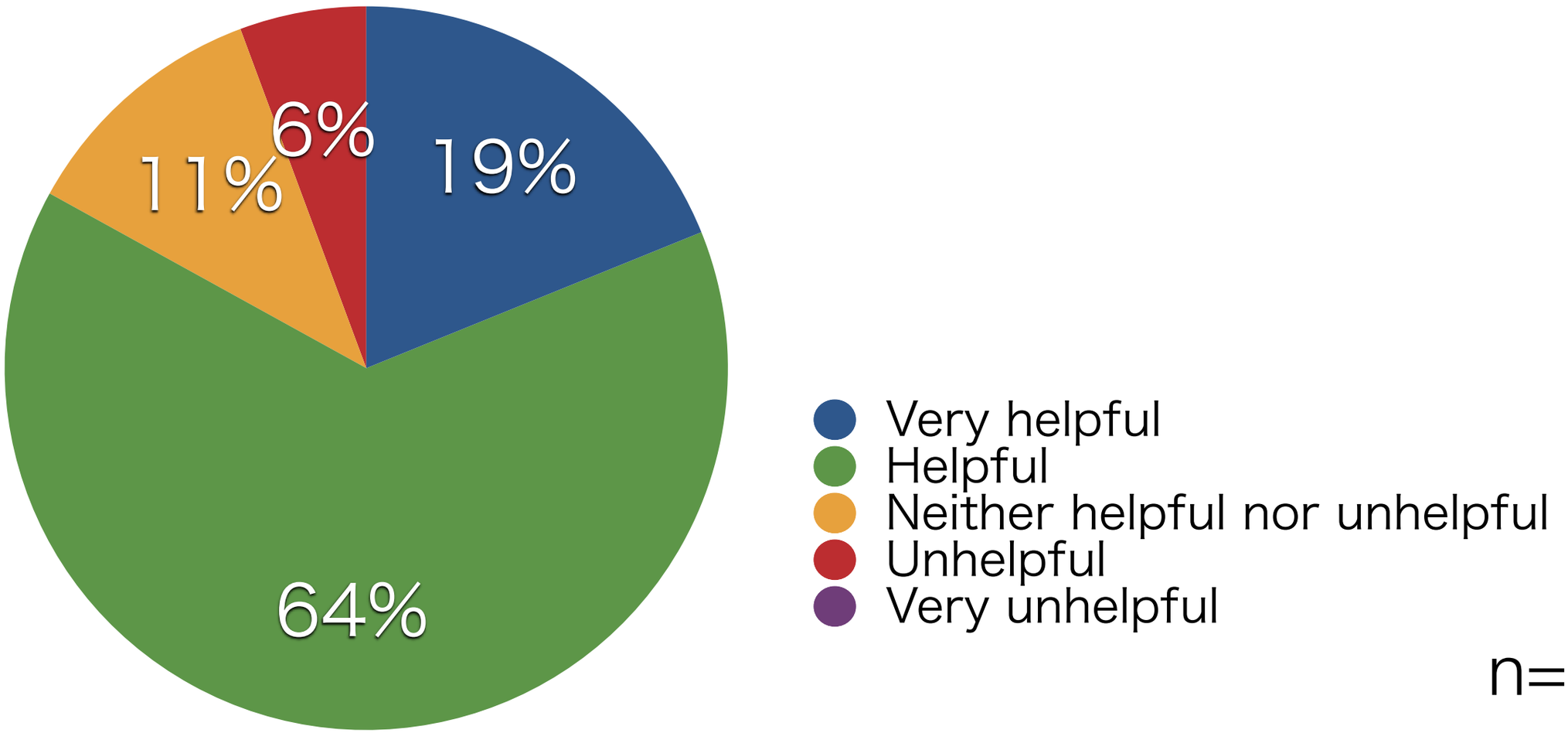
Questionnaire survey on WASM (4)

- Linear Algebra course / AY2014 Fall -

For whom replied YES in the question (1)

Do you think the system is helpful for mastering computational procedures and checking your understanding of mathematical concepts?



n=53

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Data structure

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Contents structures

- Parameters … List of fixed or programmed (random) parameters.
  The system decides randomly which parameter is used.

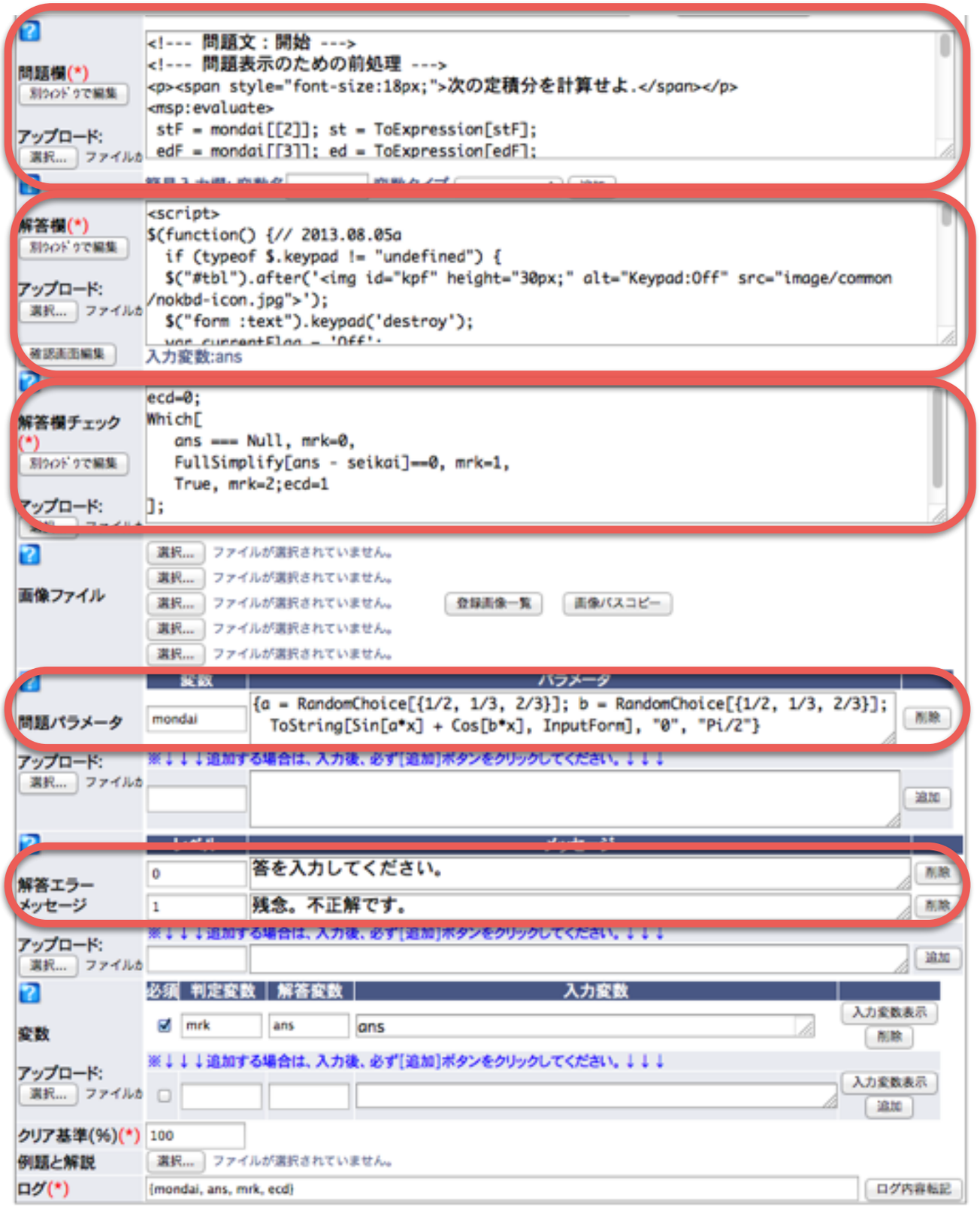
- Question text and answer form … Html based text (JSP).
  Parameters formatted by MSPFormat command (Image or MathJax)

- Judgement program … Mathematica program using parameters and inputs.
  Any style is available and return a code.
  Typically Which[ ] is used. (first match semantic)

- Feedback message … Consist of CSV of the codes and messages.
  Codes are the return value above.

- Example question and how to solve it … PDF files are linked.
  To explain how to solve the problem.

Contents structures (overview via screenshot)



← Question sentence

← Answer form

← Judgement program

← Parameters

← Feedback messages

Contents samples (question text)

```
<msp:evaluate>
 mon=mondai[[1]]; MCT=Length[mon];
 seikai=Array[0,MCT]; hf=Array["",MCT];exp=Array["",MCT];
 For[i=1,i<=MCT,i=i+1,seikai[[i]] = ToExpression[mon[[i]]];hf[[i]]="HoldForm[" <> mon[[i]] <> "]";
   exp[[i]] = StyleForm[ToExpression[ hf[[i]] ], FontSize->18]];
 pi = StyleForm[Pi, FontSize->18];
</msp:evaluate>
<p>Find the next values.</p>
<table><tbody>
<tr>
<th width=20px;>(1)</th><td width=120px;>
\(\displaystyle\large<msp:evaluate>ToString[TeXForm[exp[[1]]]]</msp:evaluate>\)</div></td>
<th width=20px;>(2)</th><td width=120px;>
\(\displaystyle\large<msp:evaluate>ToString[TeXForm[exp[[2]]]]</msp:evaluate>\)</div></td>
<th width=20px;>(3)</th><td width=120px;>
\(\displaystyle\large<msp:evaluate>ToString[TeXForm[exp[[3]]]]</msp:evaluate>\)</div></td>
<th width=20px;>(4)</th><td width=120px;>
\(\displaystyle\large<msp:evaluate>ToString[TeXForm[exp[[4]]]]</msp:evaluate>\)</div></td>
</tr><tr>
<th width=20px;>(5)</th><td width=120px;>
\(\displaystyle\large<msp:evaluate>ToString[TeXForm[exp[[5]]]]</msp:evaluate>\)</div></td>
<th width=20px;>(6)</th><td width=120px;>
\(\displaystyle\large<msp:evaluate>ToString[TeXForm[exp[[6]]]]</msp:evaluate>\)</div></td>
<th width=20px;>(7)</th><td width=120px;>
\(\displaystyle\large<msp:evaluate>ToString[TeXForm[exp[[7]]]]</msp:evaluate>\)</div></td>
<th width=20px;>(8)</th><td width=120px;>
\(\displaystyle\large<msp:evaluate>ToString[TeXForm[exp[[8]]]]</msp:evaluate>\)</div></td>
</tr>
</tbody></table>
```

Contents samples (answer form)

```
 <table>
  <tr>
  <td>Answer form</td>
  <td><input type="text" name="cx" value="<msp:evaluate> MSPValue[ $$cx , ""] </msp:evaluate>" size="3"
autocomplete="off" onkeyup="javascript:checkInput(this.form.cx);"></td>
  <td>x+</td>
  <td><input type="text" name="cy" value="<msp:evaluate> MSPValue[ $$cy, ""] </msp:evaluate>" size="3"
autocomplete="off" onkeyup="javascript:checkInput(this.form.cy);"></td>
  <td>y+</td>
  <td><input type="text" name="cz" value="<msp:evaluate> MSPValue[ $$cz, ""] </msp:evaluate>" size="3"
autocomplete="off" onkeyup="javascript:checkInput(this.form.cz);"></td>
  <td>z+</td>
  <td><input type="text" name="cc" value="<msp:evaluate> MSPValue[ $$cc, ""] </msp:evaluate>" size="3"
autocomplete="off" onkeyup="javascript:checkInput(this.form.cc);"></td>
  <td>=0</td>
  </tr>
 </table>
<p>
<font color=red>
In the case that coefficients are 0 or 1, enter 0 or 1, and in the case that answer is negative one, enter like as (-2) or -2.
</font>
```

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Contents samples (parameters)

Simple Case

```
mondai,{"ArcTan[Sqrt[3]/2]+ArcTan[Sqrt[3]/5]", Pi/3}
mondai,{"ArcSin[11/14]+ArcSin[13/14]", 2Pi/3}
mondai,{"ArcSin[1/3]+2ArcSin[1/Sqrt[3]]", Pi/2}
mondai,{"ArcTan[3/4]+ArcSin[4/5]", Pi/2}
```

Random Case

```
mondai,{p=RandomInteger[3]+2;1/(n(n+p))}
mondai,{p=RandomInteger[3]+2;q=RandomInteger[2]+1;1/Expand[(p*n+q)*(p*(n+1)+q)]}
mondai,{a=RandomInteger[3]+1;b=(RandomInteger[5]+1)/(RandomInteger[]+1);(a*n+2*b)/(n(n+1)(n+2))}
mondai,{a=RandomInteger[3]+1;b=(RandomInteger[5]+1)/(RandomInteger[]+1);(a*n+2*b)/((n+1)(n+2)(n+3))}
```

Complex case (programmed)

```
mondai,{a=RandomInteger[3]+2;"(-1/" <> ToString[a] <>
")^n",p=RandomInteger[3]+1;q=RandomInteger[3]+1;r=RandomInteger[3]+2;"(" <> If[p>1,ToString[p],""] <> "n+" <>
ToString[q] <> ")/" <> ToString[r] <> "^n"}
mondai,{a1=RandomInteger[4]+4;b1=RandomInteger[a1-2]+1;b=Numerator[b1/a1];a=Denominator[b1/a1];"(" <>
ToString[b] <> "/" <> ToString[a]
<> )^n",p=RandomInteger[3]+1;q=RandomInteger[3]+1;r=RandomInteger[3]+2;"(-1)^(n-1)(" <> If[p>1,ToString[p],""]
<> "n+" <> ToString[q] <> ")/" <> ToString[r] <> "^n"}
```

※ “mondai” means problem in English.

Contents samples [judgement] (1)

```
ecd=0;sel=ToExpression[sel];
BadPat=RegularExpression[".*Limit.*|.*->.*"];
Which[
  !MemberQ[{0,1,2,9},sel], mrk=0;ecd=1,
  sel===0 && val===Null, mrk=0;ecd=2,
  sel===0 && StringMatchQ[ansstr,BadPat]===True,mrk=2;ecd=5,
  sel===0 && NumericQ[val]===False, mrk=2;ecd=5,
  asel=!=sel,mrk=2;ecd=3,
  asel===sel && asel===0 && aval=!=val,mrk=2;ecd=4,
  asel===sel && asel===0 && aval===val,mrk=1,
  asel===sel && asel=!=0,mrk=1,
  True, mrk=2;ecd=99
];
```

Contents samples [judgement] (2)

```
ecd=0;
Which[
  matq===Table[Null, {i,1,4},{j,1,4}] && matd===Table[Null, {i,1,4},{j,1,4}], mrk=0;ecd=1,
  MemberQ[Flatten[{matq,matd}],Null], mrk=0;ecd=2,
  Simplify[matq.Transpose[matq]]=!=IdentityMatrix[4], mrk=2;ecd=3,
  Simplify[mondai.matq-matq.matd]===Table[0,{i,1,4},{j,1,4}], mrk=1,
  True, mrk=2;ecd=4
]
```

Contents samples [judgement] (3)

```
ecd=0;ans={ans1,ans2,ans3,ans4};
PolynomialQx[fx_] := Module[{v}, v = fx /. x -> 1;
  If[! NumericQ[v], Return[False]];
  If[! PolynomialQ[fx, x], Return[False]];  Return[True]];
TmpDeg[fx_]:=Exponent[fx,x]; AnsDegs=Map[TmpDeg,ans];
ChkDegs={};For[i=1,i<=MCT,++i,
  If[Exponent[ans[[i]],x] <=
n[[i]],ChkDegs=Append[ChkDegs,True],ChkDegs=Append[ChkDegs,False]]];
ChkPX=0;For[i=1,i<=MCT,++i,
  If[Limit[(FX[[i]]-ans[[i]])/x^n[[i]],x->0]!=0,++ChkPX]]
Which[
  MemberQ[ans,Null], mrk=0;ecd=1,
  MemberQ[Map[PolynomialQx,ans],False], mrk=2;ecd=2,
  MemberQ[ChkDegs,False], mrk=2;ecd=3,
  MemberQ[ChkPX,False], mrk=2;ecd=4,
  ChkPX > 0, mrk=2;ecd=5+ChkPX,
  ChkPX == 0, mrk=1,
  True, mrk=2;ecd=99
];
```

etc…

E·A·M·S
2016

Moodle plugin

14 September 2016 @ Newcastle University

Problems of the system

- Usability for the teachers : difficult to handle the learning status.
- An problem caused by upgrade of OS occurred at early in 2015.

Fortunately our university provides the LMS (Moodle).

Moodle plugin

(assisted by Nakahara)

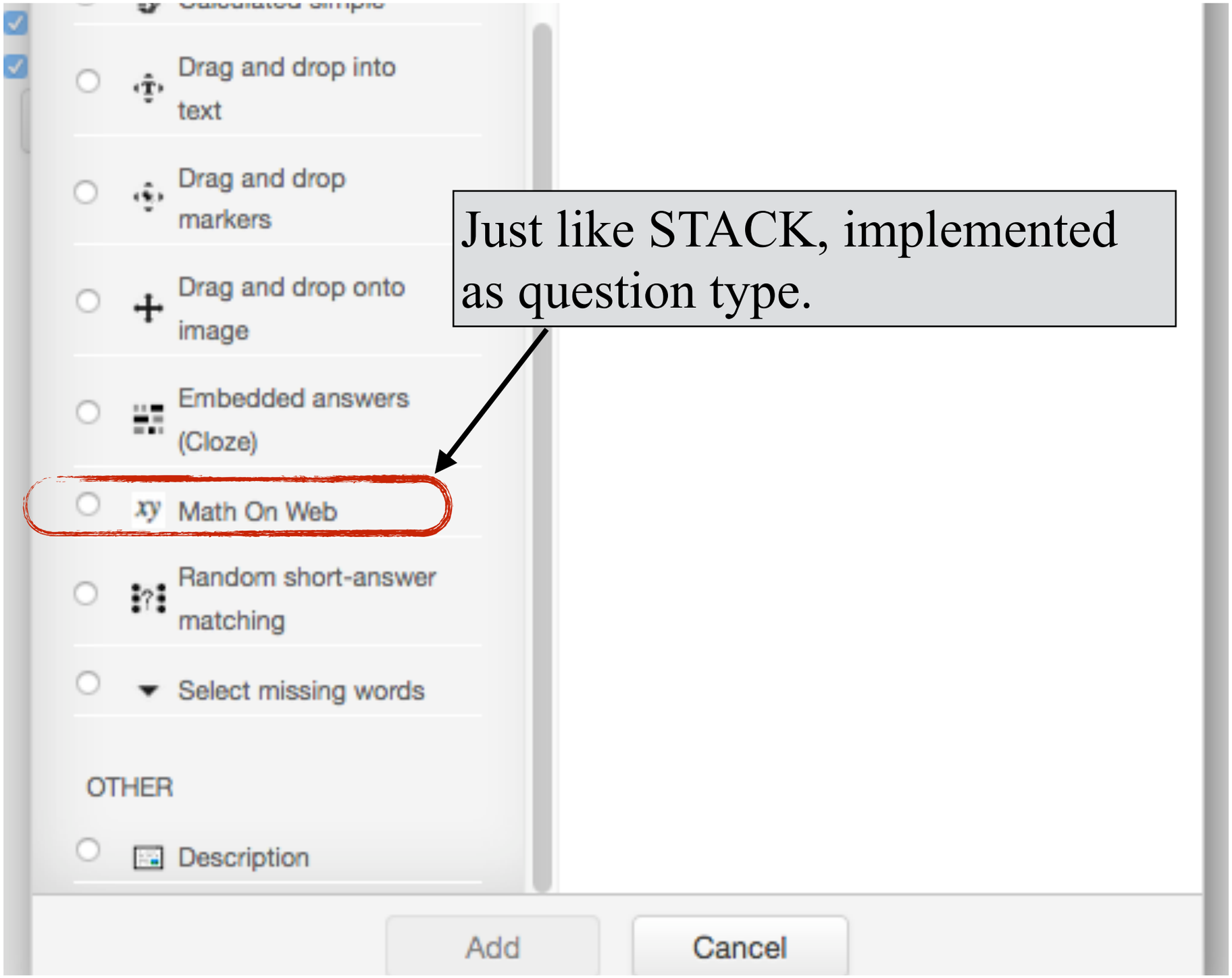
Spec :

- Full compatible with WASM w.r.t. question data.
- Network license of Mathematica required.

History and Plan :

- 2015 : Developed prototype (which can handle simple questions)
- 2016 : Bug fix.
  Addition of function to import from WASM data archives.
  Other improvements(‘LTI’ may be included?).
- 2017 : Starting test use.
- 2018 : Starting practical use.

Screenshots



Just like STACK, implemented as question type.

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System of the plugin

Input

Find the next limit of a sequence.

$\lim_{n\to\infty} 0.57^n n^6$

Input the answer:

(To enter ∞, use 'Infinity', −∞, use '-Infinity', e, use E).

Save | Fill in correct responses | Submit and finish | Close pre

Find the next limit of a sequence.

$\lim_{n\to\infty} 0.57^n n^6$

Input the answer: 0

(To enter ∞, use 'Infinity', −∞, use '-Infinity', e, use E).

Correct!!

Result

Moodle

Question data

Problem sentence,
input form
Parameters
Judgement program
Feedback message.

proc()
Express by MathJax
Transform webMathematica formula
Correspond distinctive HTML
input expression

Mathematica

Evaluation

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‘MeLQS’

the project for sharing materials
among heterogeneous systems

14 September 2016 @ Newcastle University

What we want to do

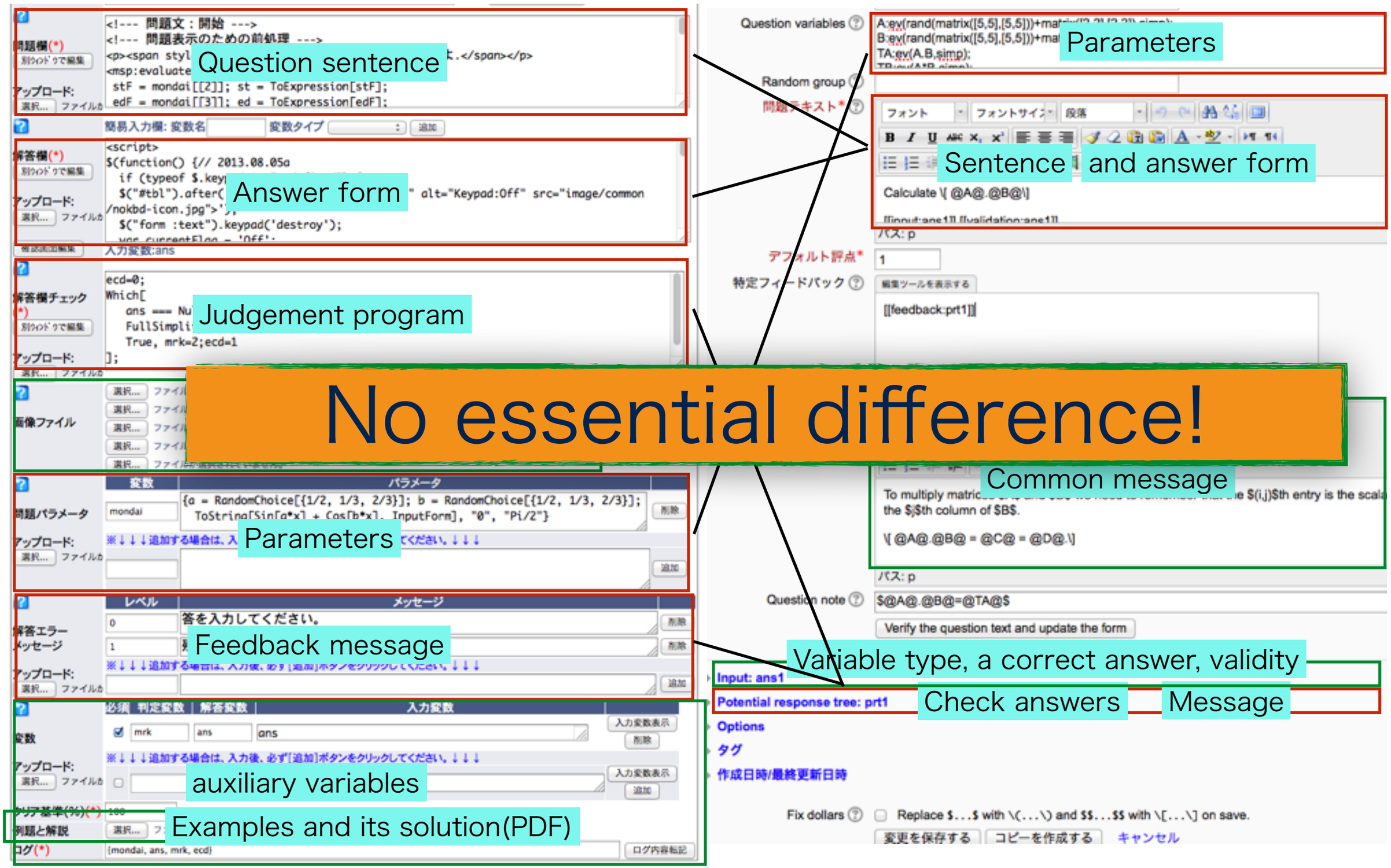
- We can use STACK 3.x in our university.
- We have already more than 1200 question data.
- BTW, there are so many drill or assessment systems.
  e.g. Maple T.A. Numbas, DEWIS,…
- The question data is the key of such systems and should be shared.
- But how? Converter ?

E·A·M·S 2016

Structures of the systems

	WASM	STACK	Notes for mutual use of contents data
CAS	Mathematica	Maxima	Number and kind of functions are different
Contents Structure	Question sentence Parameters Answer form Judgement program Feedback message	Question sentence including answer form Quest. variable PRT Sample answer	A little different, but almost the same, correspondence is clear
Language	JSP(HTML)/MathJax Mathematica formula	HTML/MathJax CAS Text (maxima)	Basically same as difference of CAS, outputs are different
Misc	Judgement only, no correct answer required	display a correct answer.	STACK is assumed to be prepared a correct answer.
	Code is full compatible with CAS(subset).	Supported command not fully compatible with CAS	Feedback variables fit for PRT should be computed.

Compare the contents data



MeLQS

- Question data formats may be quite analogous even if the systems are different.
- We want to share question data among heterogeneous systems.
- Rather than a converter, it will be more useful to store the question data in accordance with more generic format.

‘Specification’ is the key of question data.

We call this
“Mathematics e-Learning Question Specification”
or ‘MeLQS’ for short.

Conclusion

- We have developed a *Mathematica*-based drill and assessment systems WMLS and WASM to create a blended learning environment.
- We have more than 1200 questions. We think the question data is the most important element of such systems and will be glad to disclose the data to the public, in a compatible format, like as XML.
- Aiming to share the contents data among heterogeneous systems, we suggested "Mathematics e-Learning Question Specification", which we call 'MeLQS' for short ([2014Y]).
- We are starting to survey how the 'Specification' should be, cooperating with Japanese STACK contributors, Y. Nakamura and T. Nakahara, and an Application Engineer for Maple T.A., K. Kato.

[2014Y] K.Yoshitomi, On a formulation of "Mathematics e-Learning Contents Specification" and it's applications to some systems, The 39th Annual Conference of JSiSE (Japanese Society for Information and Systems in Education) at Wakayama Pref.

Finally…

- By sharing the question data, all of teachers will be so happy.
- Even if they use any other system, they can concentrate to improve their class using questions shared and imported from MeLQS db.

If you are interested in the question data or MeLQS,
please feel free to contact us below :

yositomi@las.osakafu-u.ac.jp