

Developing test questions based on STACK plugin in ILIAS

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Introduction and Motivation:

ILIAS (Integriertes Lern-, Informations- und Arbeitskooperations-System (German for "Integrated Learning, Information and Work Cooperation System")) is a web-based open source Learning Management System (LMS). Learning management systems have become a standard in modern educational institutions as they offer content management, cooperation, assessment and evaluation [1]. GJU uses a different LMS called MOODLE. STACK (System for Teaching and Assessment using a Computer algebra Kernel) is a plugin that provides a type of mathematical test questions that are calculated by a Computer Algebra System (CAS) called MAXIMA. It has the many features and advantages such as [2]:

- Different question versions are randomly generated.
- There are many different kinds of inputs. Input could be, for example, a mathematical expression, or a simple true/false selection.
- Mathematical properties of students' answers are established using answer tests within the CAS Maxima.
- Feedback is assigned on the basis of these properties using a potential response tree.

- Generates outcomes which fulfill the purpose of formative, summative and evaluative assessment
- Stores data on all attempts at a certain question and/or by a certain student to be analyzed by the teacher.
- Multi-part mathematical questions are possible: each question may have any number of inputs and any number of potential response trees.
- Partial credit is possible when an expression only satisfies some of the required properties.
- Plots can be dynamically generated and included within any part of the question, including feedback in the form of a plot of the student's expression.

[1] <https://en.wikipedia.org/wiki/ILIAS>

[2] Chris Sangwin, 'Computer Aided Assessment of Mathematics', Oxford University Press, 2013.

Goals and timeline:

At the beginning of my visit to Hochschule Bremen(HSB), the collaborating partners listed the following goals to be achieved:

- Get familiar with ILIAS and its features and capabilities. **(First week)**
- Start authoring quizzes and exams and explore the possibility of having the math placement test at GJU done via ILIAS. **(First week)**
- Get familiar with MAXIMA, the computer algebra system in which STACK operates. **(First and Second week)**
- Get familiar with STACK and seek a platform where it could be installed and used. **(Second week)**
- Develop tests on ILIAS with STACK using different types of questions. **(Third and Fourth week)**
- Discuss the possibility of setting up the system on GJU servers. **(Second week)**
- Discuss the possibility of having questions for different courses at GJU in both English and German so that the students get familiar with the technical terms in both languages. **(Third and Fourth week)**

The vision is to have a weekly or bi-weekly homework assignments for all the first-year courses. These assignments will contain some questions fully in German. Students can seek help from their instructor who will be given an English translation of the question or they could ask their German instructors to translate some of the vocabulary in the question. This way the students will learn their technical vocabulary early on and gradually in contrast to taking it all at once in advanced German courses. This goal requires collaborations between GJU and HSB to author the questions in German and help GJU instructors to understand these questions. GJU instructors could author the questions and ask for a translation by HSB instructors or German language instructors here at GJU.

ILIAS has been used at HSB for quite some time. They are very familiar with the system and has been used to give exercises and sample exams. I would like to look into the opportunity of having the math placement tests at GJU done via ILIAS. Our technical IT team will need some training which could be provided by Mr. Ralf-Peter Balke of HSB who kindly agreed to help in any technical details needed.

Future work:

This project is to continue after my return to Jordan. Collaboration will continue between Dr. Thomas Risse and myself. We will discuss the progress during his visit to GJU in November.

Acknowledgements and Concluding remarks:

I would like to thank the DAAD for providing the financial support which made this collaboration possible through Train-the-Trainer program. I would like also to thank my host Dr. Risse at Hochschule Bremen for his generous hospitality and volunteering his precious time to work on this project under his guidance.

Examples:

I will show two examples of questions written in ILIAS using the STACK plugin:

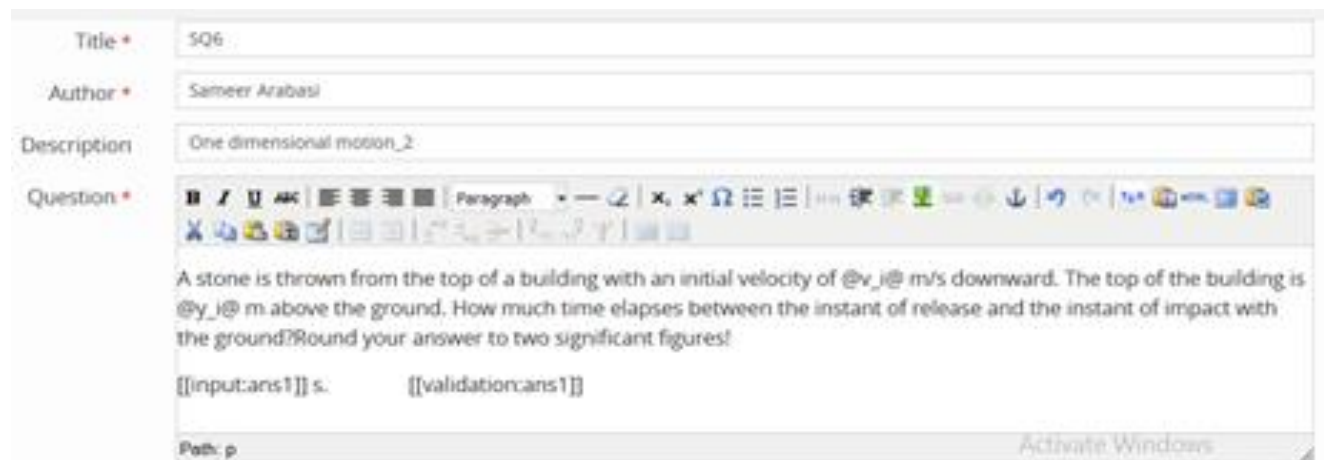
The first one is a Physics question in Mechanics and the second one is a Mathematics question in Differential Equations.

The first example shows the power of ILIAS and specifically when using STACK and its CAS MAXIAMA in generating multiple versions of the same question and solving the quadratic equation which represents the problem for each version.



The screenshot shows the ILIAS interface with the title "SQ6". The question text is: "A stone is thrown from the top of a building with an initial velocity of 40 m/s downward. The top of the building is 60 m above the ground. How much time elapses between the instant of release and the instant of impact with the ground? Round your answer to two significant figures!". Below the text is an input field containing "40", followed by "s.", a "Validate" button, and an "Evaluate Answer" button. A large blue question mark icon is visible on the right side of the question box.

Here is how the question is programmed in STACK:



The screenshot shows the STACK editor interface. The "Question" field contains the following text: "A stone is thrown from the top of a building with an initial velocity of @v_i@ m/s downward. The top of the building is @y_i@ m above the ground. How much time elapses between the instant of release and the instant of impact with the ground? Round your answer to two significant figures!". Below the text is the validation code: "[[input:ans1]] s. [[validation:ans1]]". The editor also shows a title field with "SQ6", an author field with "Sameer Arabasi", and a description field with "One dimensional motion_2".

Where the question text reads:

"A stone is thrown from the top of a building with an initial velocity of @v_i@ m/s downward. The top of the building is @y_i@ m above the ground. How much time elapses between the instant of release and the instant of impact with the ground?"

Round your answer to two significant figures!

[[input:ans1]] s. [[validation:ans1]]".

The student's answer will be saved in a variable called ans1 which will be compared to the correct answer calculated by the CAS.

ILIAS PERSONAL DESKTOP REPOSITORY

[[input:ans1]] s. [[validation:ans1]]

Path: p

Working Time Hours: 0 Minutes: 1 Seconds: 0

Point(s) 5
To set the total points of the question, go to label Scoring.

Hint To create new inputs just type on the question text the placeholder: "[[input:your_input_name]]" and "[[validation:your_input_name]]", to delete an input just delete the input placeholder from question text.

Question variables
v_i: rand([5,10,15,20, 30, 40, 50]);
y_i: rand([50, 60, 70, 80, 90, 100]);
eqn: -4.9*t^2-v_i*t+y_i=0;
tt: part(solve(eqn,t),2,2);

This field allows you to define and manipulate CAS variables, e.g. to create random versions. These are available to all other parts of the question.

Question note

Activate Windows
Go to PC settings to activate Windows.

The question variables are:

```
v_i: rand([5,10,15,20, 30, 40, 50]);  
y_i: rand([50, 60, 70, 80, 90, 100])  
eqn: -4.9*t^2-v_i*t+y_i=0;  
tt: part(solve(eqn,t),2,2);
```

Where eqn is the quadratic equation describing the problem. This will choose v_i and y_i randomly from the given values between the brackets.

Uncheck forbid floats in the inputs menu, to allow for non-integer answers:

The screenshot shows the 'Inputs' configuration menu in ILIAS. The 'Forbid float' option is unchecked, while 'Strict syntax', 'Student must verify', and 'Show the validation' are checked. The 'Input box size' is set to 15. The 'Syntax hint' and 'Forbidden words' fields are empty. The 'Allow words' field contains a single space character. The 'Require lowest terms' and 'Check the type of the response' options are also unchecked. The 'Extra options' field is empty. The interface includes the ILIAS logo, navigation tabs for 'PERSONAL DESKTOP' and 'REPOSITORY', and a Windows taskbar at the bottom showing the time as 12:41 PM on 9/8/2015.

In the answer test we will use the NumAbsolute which compares the student answer to the correct answer within the tolerance given in the test option box (here 0.1).

The screenshot shows the 'Nodes' configuration menu for a 'New Node'. The 'Answer test' is set to 'NumAbsolute'. The 'Student answer' field contains 'ans1' and the 'Teacher answer' field contains 'tt'. The 'Test options' field is set to '0.1'. The 'Quiet' option is set to 'No'. There is a 'Delete node' button. Below this, there are two columns of settings for 'Mod', 'Positive score', 'Penalty', 'Next node', 'Answernote', and 'Specific feedback'. The left column has a green background and the right column has a pink background. The 'Mod' is set to '=', 'Positive score' is 1, 'Penalty' is 0, 'Next node' is 'End', 'Answernote' is 'prt1-1-T', and 'Specific feedback' is 'Correct'. The right column has 'Mod' set to '=', 'Negative Score' is 0, 'Penalty' is 0, 'Next node' is 'End', 'Answernote' is 'prt1-1-F', and 'Specific feedback' is empty. The interface includes the ILIAS logo, navigation tabs for 'PERSONAL DESKTOP' and 'REPOSITORY', and a Windows taskbar at the bottom showing the time as 12:42 PM on 9/8/2015.

Here is a screenshot of a correct response.

The screenshot shows a web browser window displaying the ILIAS interface. The page title is "AULIS Hochschule Bremen". The main content area contains a question: "time elapses between the instant of release and the instant of impact with the ground? Round your answer to two significant figures!". Below the question is an input field with the value "1.3" and a "Validate" button. The "Evaluate Answer" button is also visible. The question text is: "A stone is thrown from the top of a building with an initial velocity of 40 m/s downward. The top of the building is 60 m above the ground. How much time elapses between the instant of release and the instant of impact with the ground? Round your answer to two significant figures!". Below the question, the system shows the evaluated answer: "Your answer was: 1.3". The feedback message is "Correct Correct answer, well done. Points reached: 5". The Windows taskbar is visible at the bottom, showing the time as 12:43 PM on 9/8/2015.

The second example is more elaborate and shows the STACK advantage in designing specific feedbacks for every student answer and its capability in understanding the student answers when the answer is a mathematical expression.

Solving a second order ODE:

We will solve a second-order ODE when the roots of the characteristic equation are complex numbers.

Here we will use the potential response tree to provide feedback for the student. The purpose of STACK is to assess students' answers to mathematical questions, and on the basis of the properties we establish to assign feedback.

- Formative assessment is to support and inform students' learning. Feedback here could be qualitative, e.g. written comments tailored to the student's answer and designed to help them improve their performance on the task.
- Summative assessment is to establish the achievement of the student. In mathematics, summative feedback is most often quantitative, either a mark or a percentage.
- Evaluative assessment is to measure the effectiveness of the teaching or the assessment of students. Such assessments could have quality enhancement or quality audit functions

Here is the question and the correct responses. The instructor could also insert a figure to show the student how the answer looks like when plotted.

The screenshot shows a web browser window with the following elements:

- Browser tabs: SquirrelMail 1.4.23 [SVN], Aulis-Hochschule Bremen..., STACK Documentation, HTML figure Tag.
- Address bar: 192.168.110.253:8084/ilias.php?ref_id=561896&q_id=79096&cmd=preview&cmdClass=ilassquestionpagegui&cmdNode=urp:pv7&base
- Page header: AULIS Hochschule Bremen
- Navigation: ILIAS, PERSONAL DESKTOP, REPOSITORY
- Section title: ODE_2nd_order_linear_4
- Question content:
 - For the given ODE
$$y'' + 4y' + 32y = 0$$
 - First, the charcteristic equation is: Use l for the variable. = 0
 - The real part of the roots of the characteristic equation. γ is:
 - The absolute value of the imaginary part of the roots ω is:
 - Finally, find the general solution:
- Buttons: Evaluate Answer
- Watermark: Activate Windows
- Taskbar: Windows 10 icons, system tray showing 1:44 PM 9/8/2015.

The screenshot shows the same web browser window as above, but with the following changes:

- Navigation: Question Pool Test, Edit Page, **Preview**, Edit Properties, Statistics
- Attention message: Attention: This question contains random variables, during this session this version will be shown. To change random variables restart the session.
- Section title: ODE_2nd_order_linear_4
- Question content:
 - For the given ODE
$$y'' + 4y' + 32y = 0$$
 - First, the charcteristic equation is: Use l for the variable. = 0
 - The real part of the roots of the characteristic equation. γ is:
 - The absolute value of the imaginary part of the roots ω is:
 - Finally, find the general solution:
- Buttons: Evaluate Answer
- Watermark: Activate Windows
- Taskbar: Windows 10 icons, system tray showing 1:46 PM 9/8/2015.

SquirrelMail 1.4.23 [SVN] | Aulis-Hochschule Bremen... | STACK Documentation | HTML figure Tag

192.168.110.253:8084/ilias.php?ref_id=561896&q_id=79096&cmd=preview&cmdClass=ilassquestionpagegui&cmdNode=ur:pv7&base

AULIS Hochschule Bremen

ILIAS PERSONAL DESKTOP REPOSITORY

$\exp(-2 \cdot t) \cdot (A \cdot \cos(\sqrt{28} \cdot t) + B \cdot \sin(\sqrt{28} \cdot t))$

Good job! Here is how y(t) vs. t looks like:

Correct answer, well done.
Points reached: 0,25

The following answers were evaluated:

Your answer was:

Activate Windows
Go to PC settings to activate Windows.

Windows taskbar: 1:47 PM 9/8/2015

SquirrelMail 1.4.23 [SVN] | Aulis-Hochschule Bremen... | STACK Documentation | HTML figure Tag

192.168.110.253:8084/ilias.php?ref_id=561896&q_id=79096&cmd=preview&cmdClass=ilassquestionpagegui&cmdNode=ur:pv7&base

AULIS Hochschule Bremen

ILIAS PERSONAL DESKTOP REPOSITORY

The following answers were evaluated:

Your answer was:
 $t^2 + 4 \cdot t + 32$

Correct answer, well done.
Points reached: 0,25

The following answers were evaluated:

Your answer was:
-2

Correct answer, well done.
Points reached: 0,25

The following answers were evaluated:

Your answer was:
 $\sqrt{28}$

Correct answer, well done.
Points reached: 0,25

Activate Windows
Go to PC settings to activate Windows.

Windows taskbar: 1:47 PM 9/8/2015

The screenshot shows the ILIAS interface for editing a STACK question. The question details are as follows:

- Title:** ODE_2nd_order_linear_4
- Author:** Sameer Arabasi
- Description:** (Empty)
- Question:**

For the given ODE $y'' + c_1 y' + c_2 y = 0$

First, the characteristic equation is: Use λ for the variable.

The real part of the roots of the characteristic equation. γ is:

The absolute value of the imaginary part of the roots ω is:
- Path:** p
- Working Time:** Hours: 0, Minutes: 1, Seconds: 0
- Point(s):** 1

Question variables:

```

l1:2+(-1)^rand(1)*rand(6);
l2:l1+(-1)^rand(1)*(1+rand(4));
c1:1*(-l1+l2);
c2: l1*l2;
q:'diff(y(t),t,2)+c1*'diff(y(t),t)+c2*y(t);
che: l^2+c1*l+c2;
lamdas: solve(che,l);
g:realpart(part(lamdas,1,2));
o:abs(imagpart(part(lamdas,1,2)));
ta:%e^(g*t)*(cos(o*t)+sin(o*t));

```

Potential Response Tree:

The potential response tree is the algorithm which establishes the mathematical properties of the student's answer and assigns outcomes.

Each potential response tree can set Maxima's level of simplification. Before the tree is traversed the feedback variables are evaluated. The feedback variables may depend on the values of the question variables and the inputs. The values of these variables are available to the answer tests and all CASText fields within the tree, for example the feedback could be built using these variables.

A potential response tree consists of one or more nodes that are linked together. In each node two expressions are compared using a specified answer tests, and the result is either true or false. A corresponding branch of the tree can do the following:

- Adjust the score, (positive or negative).
- Add written feedback specifically for the student
- Generate an "answer note", used by the teacher for evaluative assessment
- Nominate the next node, or end the process.

The outcomes are:

- The raw score
- The penalty for this attempt
- Feedback to the student
- An Answer Note

The potential response tree itself is expected to return a numerical raw score between 0 and 1. This number is multiplied by the question value before being returned to the student as feedback or recorded in the database [2].

In our last example, we have four parts and hence four potential response trees. Here is how they were programmed.

First Tree:

Feedback variables:

```
p:ev(q,y(t)=ans1,nouns,fullratsimp);
  l:setify(listofvars(ans1));
  l:setdifference(l,set(t));
  l:listify(l);
  lv:length(l);
  b1:ev(ans1,t=0,fullratsimp);
  b2:ev(ans1,t=1,fullratsimp);
  m:if not(b2=0) then fullratsimp(b1/b2) else 0;
  m:float(m);
lam1:diff(part(ans1,1),t)/part(ans1,1);
lam2: diff(part(ans1,2),t)/part(ans1,2);
ss: is (lam1 = lam2)
```

First node:

The screenshot shows the ILIAS interface for configuring a question node. The browser tabs include SquirrelMail, Aulis-Hochschule Bremen, STACK Documentation, and HTML figure Tag. The address bar shows the URL: `192.168.110.253:8084/ilias.php?ref_id=561896&q_id=79096&sel_question_types=assStackQuestion&cmd=editQuestion&cmdClass=ass`. The page header displays "AULIS Hochschule Bremen" and navigation options for "PERSONAL DESKTOP" and "REPOSITORY".

The main content area is titled "New Node" and contains the following configuration fields:

- Answer test: AlgEquiv
- Student answer: p
- Teacher answer: 0
- Test options: (empty)
- Quiet: No
- Delete node: Delete node

Below these fields are two columns of settings:

Mod	Value	Mod	Value
Positive score	1.000000	Negative Score	0.000000
Penalty	0	Penalty	0
Next node	1	Next node	End
Answernote	satisfies DE	Answernote	Fails to satisfy DE
Specific feedback	Here is how $y(t)$ vs. t looks like: $@plot(ta, [t, 0, 5])@$	Specific feedback	Your answer should satisfy the differential

The Windows taskbar at the bottom shows the time as 1:51 PM on 9/8/2015.

Second node:

The screenshot shows the ILIAS interface for configuring a question node. The browser tabs and address bar are identical to the first node. The page header displays "AULIS Hochschule Bremen" and navigation options for "PERSONAL DESKTOP" and "REPOSITORY".

The main content area is titled "New Node" and contains the following configuration fields:

- Answer test: AlgEquiv
- Student answer: lv
- Teacher answer: 2
- Test options: (empty)
- Quiet: No
- Delete node: Delete node

Below these fields are two columns of settings:

Mod	Value	Mod	Value
Positive score	1.000000	Negative Score	0.750000
Penalty	0	Penalty	0
Next node	2	Next node	End
Answernote	2 variables in answer	Answernote	Insufficient constants
Specific feedback	(empty)	Specific feedback	Your answer does not satisfy the solution, which

The Windows taskbar at the bottom shows the time as 1:53 PM on 9/8/2015.

Third node:

0 1 2 3 New Node

Answer test: AlgEquiv

Student answer: numberp(m)

Teacher answer: true

Test options:

Quiet: No

Delete node: Delete node

Mod: =

Positive score: 0.000000

Penalty: 0

Next node: 3

Answernote: Not two lin ind parts

Specific feedback: independent components, but is not.

Mod: =

Negative Score: 1.000000

Penalty: 0

Next node: End

Answernote: Correct

Specific feedback: Activate Windows
Go to PC settings to activate Windows.

Fourth node:

0 1 2 3 New Node

Answer test: AlgEquiv

Student answer: ss

Teacher answer: true

Test options:

Quiet: No

Delete node: Delete node

Mod: =

Positive score: 0

Penalty: 0

Next node: End

Answernote: Result-3-T

Specific feedback: You have given the same solution twice!

Mod: =

Negative Score: 0

Penalty: 0

Next node: End

Answernote: Result-3-F

Specific feedback: Activate Windows
Go to PC settings to activate Windows.

The second Tree:

Feedback variables:

che: $|^2+c1*|+c2;$

cc: is (ans2 = che)

The screenshot shows the ILIAS web interface for configuring a new test node. The browser address bar shows the URL: `192.168.110.253:8084/ilias.php?ref_id=561896&q_id=79096&sel_question_types=assStackQuestion&cmd=editQuestion&cmdClass=ass`. The page title is "AULIS Hochschule Bremen". The navigation menu includes "ILIAS", "PERSONAL DESKTOP", and "REPOSITORY". The main content area is titled "0 New Node" and contains the following configuration fields:

- Answer test: AlgEquiv (dropdown)
- Student answer: cc (text input)
- Teacher answer: true (text input)
- Test options: (empty text input)
- Quiet: No (dropdown)
- Delete node: Delete node (button)
- Mod: (dropdown)
- Positive score: 1 (text input)
- Penalty: 0 (text input)
- Next node: End (dropdown)
- Answernote: prt2-0-T (text input)
- Specific feedback: (empty text input)
- Mod: (dropdown)
- Negative Score: 0 (text input)
- Penalty: 0 (text input)
- Next node: End (dropdown)
- Answernote: prt2-0-F (text input)
- Specific feedback: (empty text input)

An "Activate Windows" watermark is visible in the bottom right corner of the interface.

The third and fourth trees are also a one-node tree to compare outputs.