notes

Developing CITE, a Concept Inventory Tool for Electrical Engineering

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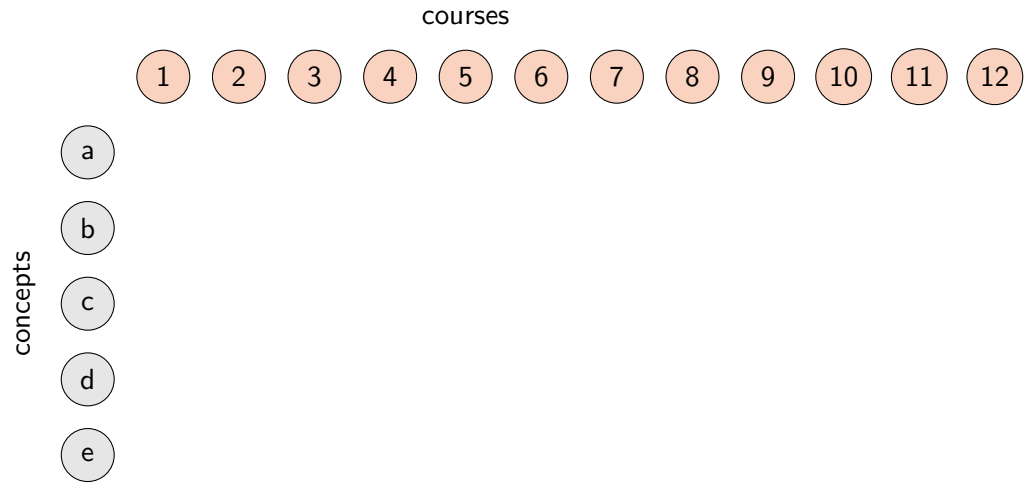
notes

A whole program can be thought as a series of courses, each introducing, extending or building on top of specific concepts

A schematic representation of a generic university program



notes

For example the first course may introduce two concepts, in this case a and c

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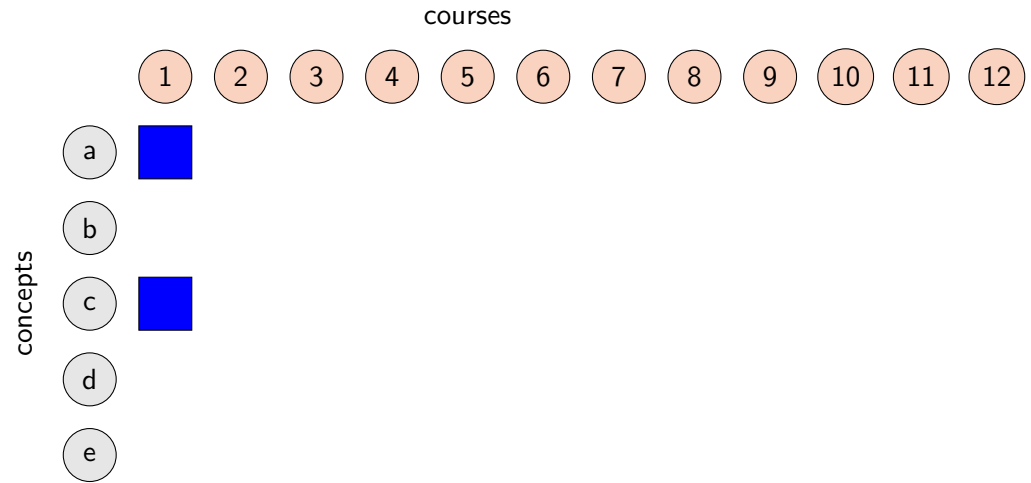

notes

The second course may introduce concept b but ladder or extend a

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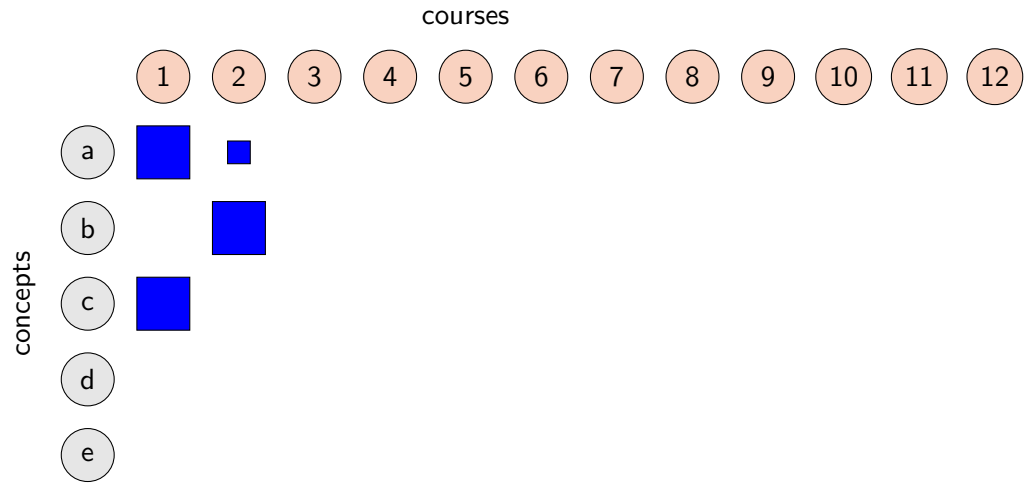
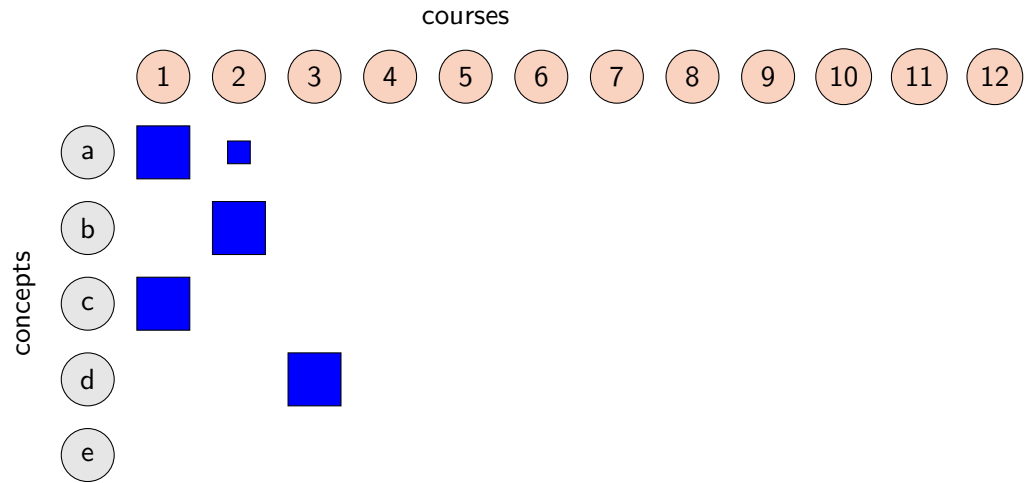


notes

. . . and so on . . .

A schematic representation of a generic university program



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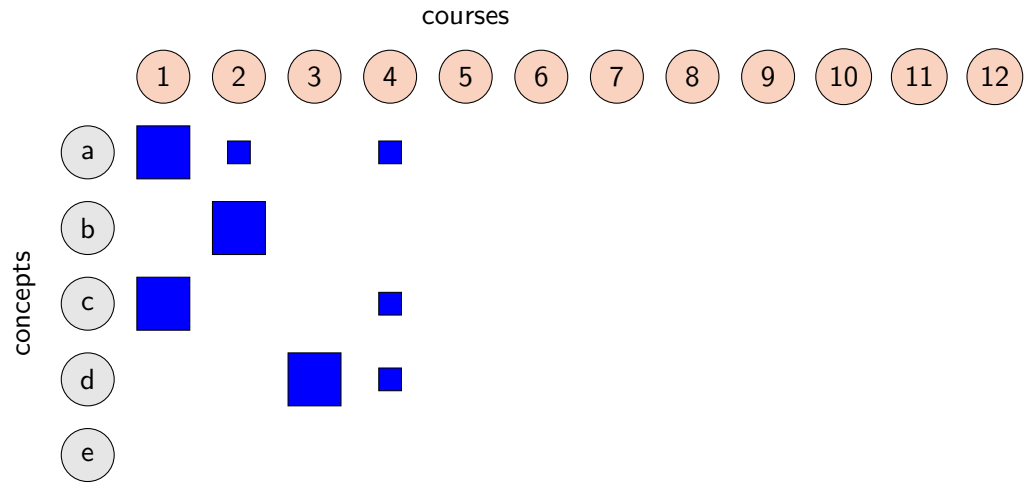

notes

. . . and on. Examinations, though, are typically:

- performed at the end of each course
- referring only to that set of concepts that have been introduced or extended in that specific course. E.g., here the examination of course 5 will be based on concepts b, c and e, and thus ignore if students have been forgetting a and d or not.

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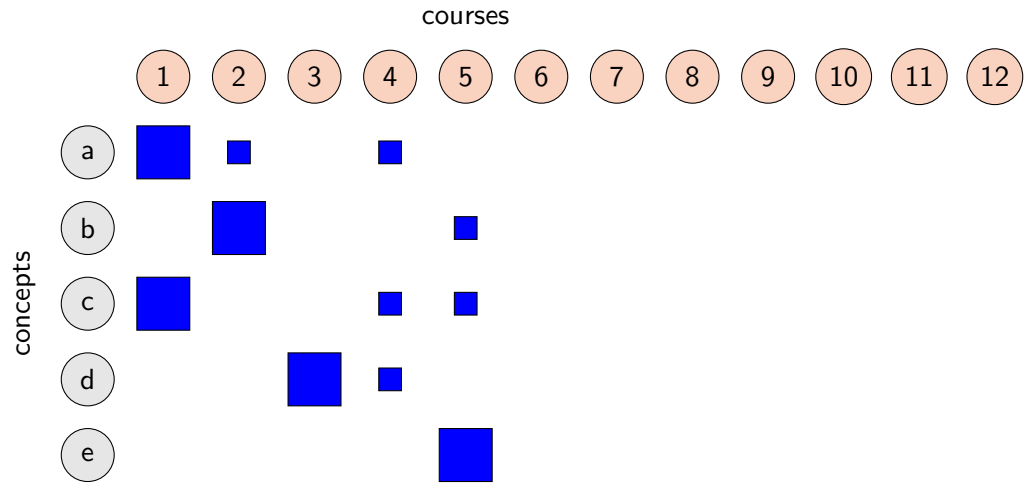
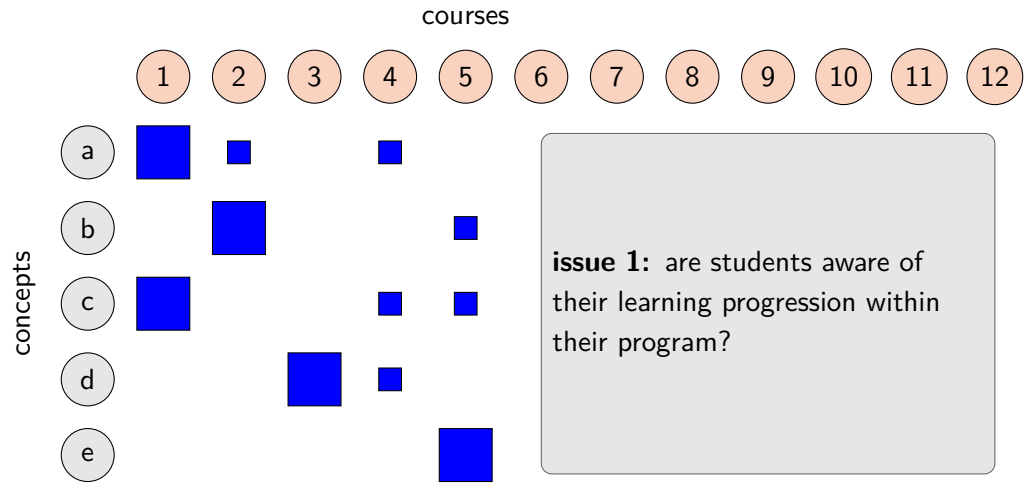


notes

This implies a series of issues. . .

A schematic representation of a generic university program

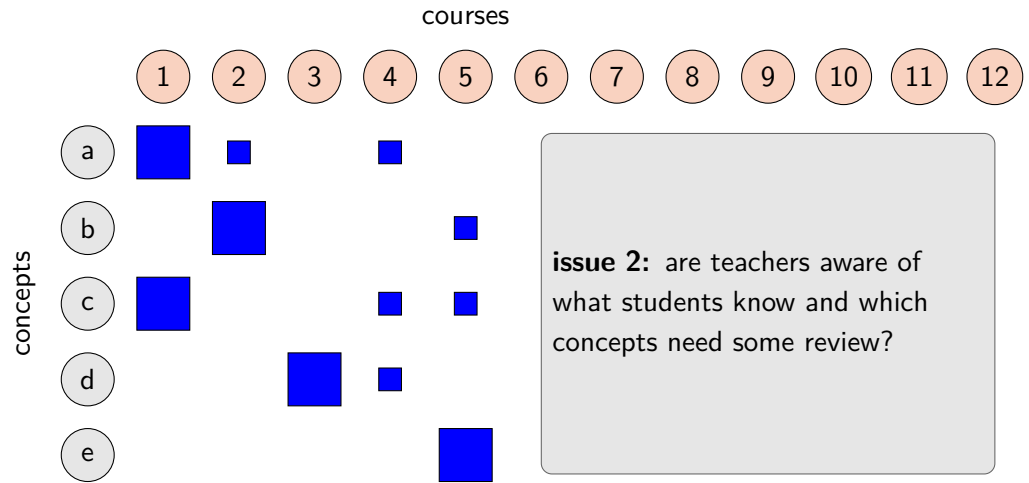


issue 1: are students aware of their learning progression within their program?

notes

This implies a series of issues. . .

A schematic representation of a generic university program

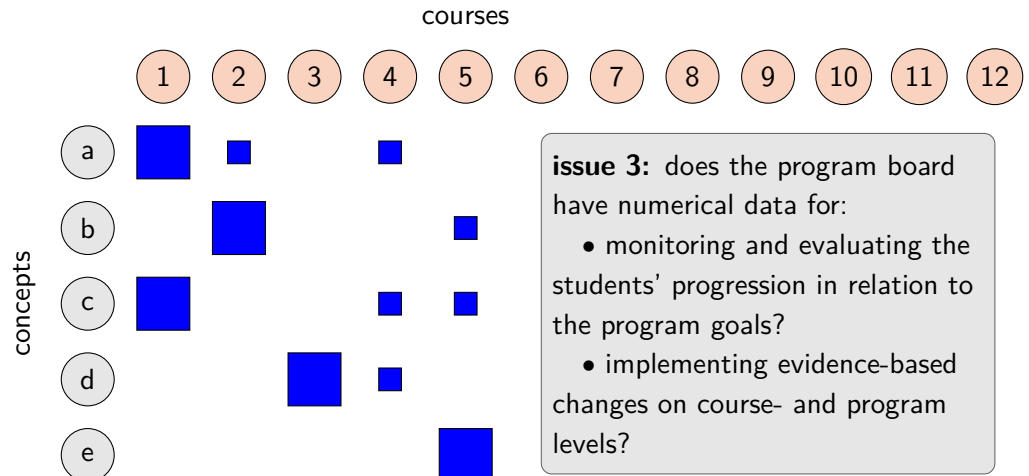


issue 2: are teachers aware of what students know and which concepts need some review?

notes

This implies a series of issues. . .

A schematic representation of a generic university program



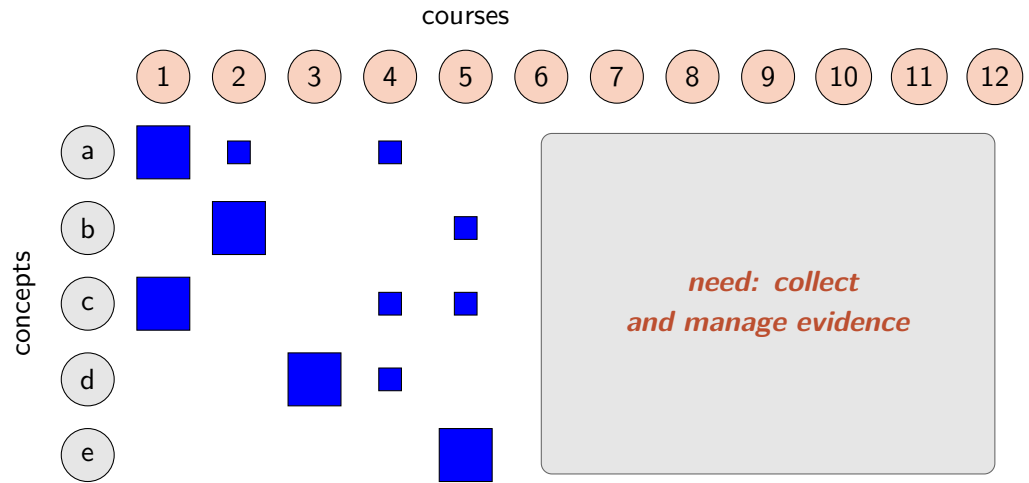
issue 3: does the program board have numerical data for:

- monitoring and evaluating the students' progression in relation to the program goals?
- implementing evidence-based changes on course- and program levels?

notes

Even more importantly, there is no systematic strategy at the program level for collecting evidence on how much and how fast students forget each individual concept. And without numerical evidence the problem-correction actions risk to be opinion-based instead of being facts-based.

A schematic representation of a generic university program

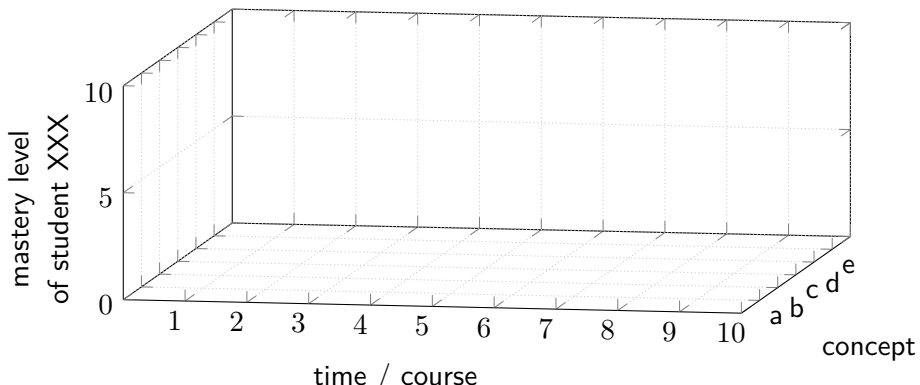


notes

From mathematical perspectives the best thing possible would be to have a situation like the one assumed here

Best situation possible in terms of amount of information

Assumptions: we can measure the knowledge level of each individual student continuously and perfectly *(these assumptions will be removed later on)*



notes

Graphically speaking, we may think that at time 1 we measure this specific knowledge level for a specific student for all the various concepts of the program board

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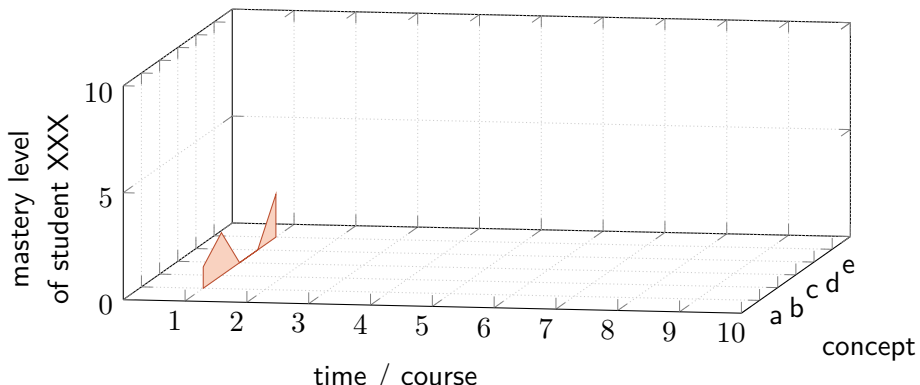

notes

Then after one week we measure this. . .

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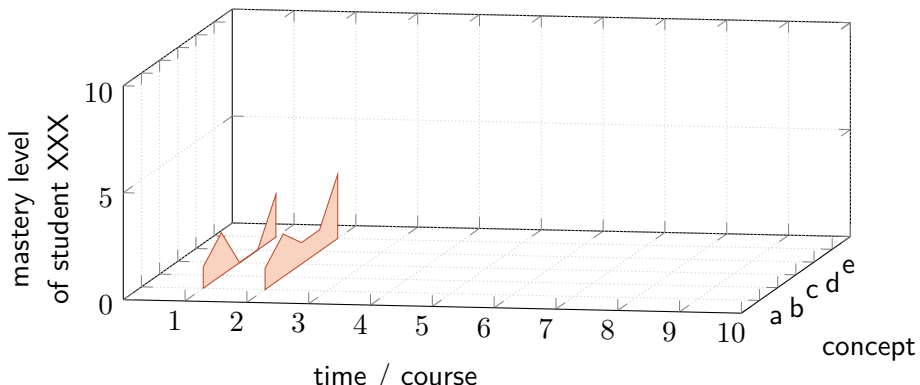

notes

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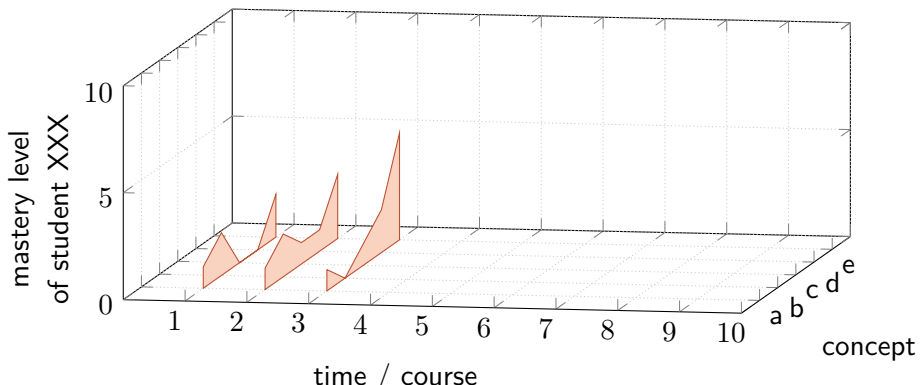

notes

Continuing like this we would get the whole "surface" of how the knowledge is evolving in time for that specific student

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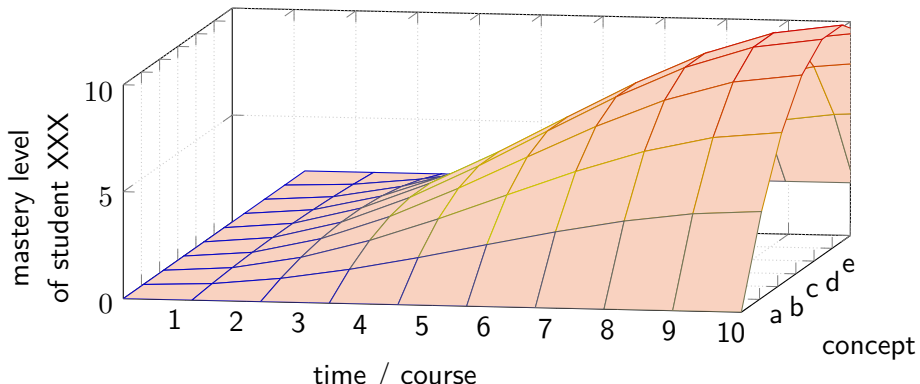

notes

But having this information for all the students, one would also have the average behavior, the standard deviations, etc., and have a lot of information that could be used in a lot of different ways.

Best situation possible in terms of amount of information

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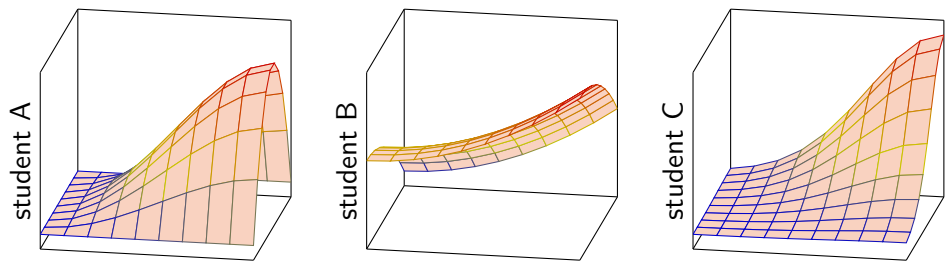


notes

Of course measuring the knowledge level of every student every month seems infeasible. Nonetheless testing strategies that are not as detailed as the one above may still provide information useful for everybody

How do we collect data to meet those needs?

notes

Thus we want to develop a test that can be implemented, and that –even if it is an approximation of the ideal test– gives information useful to everybody. And which kind of purpose would we like to serve?

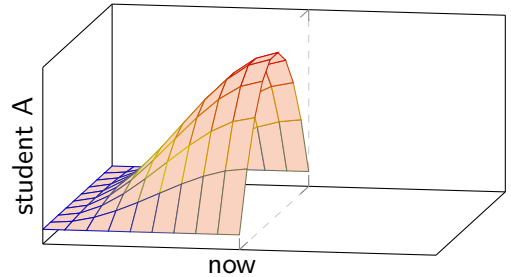
How do we collect data to meet those needs?

CITE, a Concept Inventory Tool for Electrical Engineering

notes

The test that we want to develop should help students answering these questions . . .

Desired extractable information - students side



- do I know enough to take the next courses?
- how am I currently doing with respect to the program goals?
- what do I tend to forget, and how fast?
- where should I focus?
- what should I eventually know at the end of the program?

notes

. . . and help teachers answering these questions . . .

Desired extractable information - teachers side

- what can I expect my students to know (and thus understand)?
- which variety exists in the prior knowledge (both among students and across the various years)?
- where do I have to start, and how can I adapt my teaching to the current situation?
- which material (and how much / how fast) do my students forget?
- *(if having comparative data)* how do changes in the class / teaching strategy transform into long term effects in the performances?
- *(if having comparative data)* what are the best changes to do?

notes

. . . and program boards answering these questions

Desired extractable information - boards side

notes

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Desired extractable information - boards side

- how does the average performance of a single concept evolve in time?

notes

. . . and program boards answering these questions

Desired extractable information - boards side

- how does the average performance of a single concept evolve in time?
- how does the performance vary among students (both among students and across the various years)?

notes

. . . and program boards answering these questions

Desired extractable information - boards side

- how does the average performance of a single concept evolve in time?
- how does the performance vary among students (both among students and across the various years)?
- how do performances of different courses correlate / causate?

notes

. . . and program boards answering these questions

Desired extractable information - boards side

- how does the average performance of a single concept evolve in time?
- how does the performance vary among students (both among students and across the various years)?
- how do performances of different courses correlate / causate?
- where and when students drop?

notes

. . . and program boards answering these questions

Desired extractable information - boards side

- how does the average performance of a single concept evolve in time?
- how does the performance vary among students (both among students and across the various years)?
- how do performances of different courses correlate / causate?
- where and when students drop?
- *(if having historical / comparative data)* how do changes in the program / teaching strategies transform into long term effects in the performances?

notes

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Desired extractable information - boards side

- how does the average performance of a single concept evolve in time?
- how does the performance vary among students (both among students and across the various years)?
- how do performances of different courses correlate / causate?
- where and when students drop?
- *(if having historical / comparative data)* how do changes in the program / teaching strategies transform into long term effects in the performances?
- *(if having comparative data)* what are the best changes to do?

notes

The problem is: how do we actually make a test that can give the various stakeholders the information that we listed above?

and how can we get this information?

notes

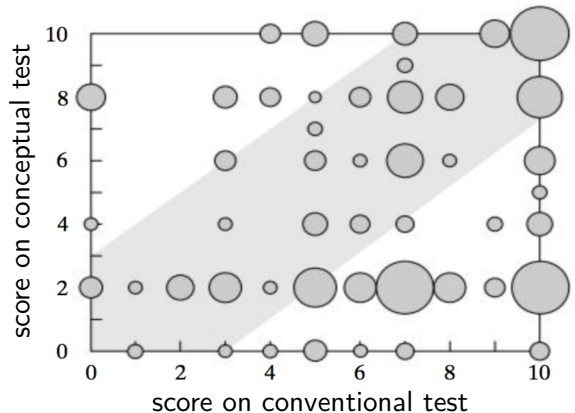
One of the most important points is understanding how these implementable tests should look like?

Very important point: which knowledge shall CITE assess?

notes

Scholars have been making students of math-related classes take two types of tests: classic ones, and "conceptual" ones, where the "conceptual" ones are as we will show later on. Evidence shows that statistically if a student gets a good grade in the conceptual tests then she/he is very likely to get a good grade also on the classic ones, but not the viceversa. This suggests the potential (and intuitive) interpretation that if one has understood a concept then that person is more likely to solve classical procedural exercises. At the same time if one has understood how to solve a procedural exercise, that person may not have understood the concept. This suggests us to make tests that assess conceptual knowledge, and not procedural one.

Very important point: which knowledge shall CITE assess?



[From Mazur, E. (1997). Peer Instruction: A User's Manual. Prentice Hall, Upper Saddle River]

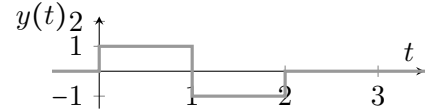
(radius of the circles = number of students represented by that circle)

notes

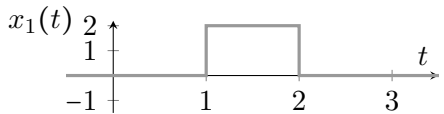
The currently foreseen approach is to use *concept inventory tests*, i.e., multiple-choice tests that should specifically assess if a person has understood a specific concept. If the person has misunderstood something then that person is likely to choose a wrong answer, since the alternative answers are designed to trick the person

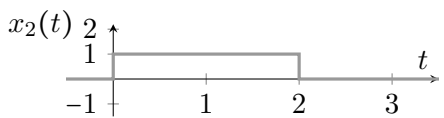
Example of conceptual question (1)

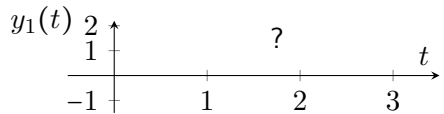
Consider an LTI system for which to this input signal $x(t)$ corresponds the following output signal $y(t)$:

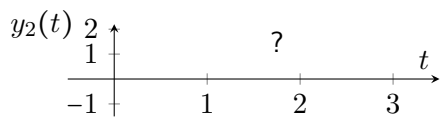


Sketch the output signals $y_1(t)$ and $y_2(t)$ corresponding respectively to the following input signals $x_1(t)$ and $x_2(t)$, which would be fed into the same system as above:







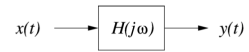


notes

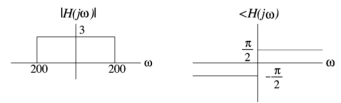
In this second concept inventory test example if one has understood what a Bode plot is then that person will answer correctly immediately.

Example of conceptual question (2)

Question 6
Consider the LTI system with input $x(t)$ and output $y(t)$ shown in Fig. 3(a). The magnitude response $|H(j\omega)|$ and phase response $\angle H(j\omega)$ (in radians) of the system are shown in Fig. 3(b).



(a) System for Question 6.



(b) Magnitude and phase response of the system in Question 6.

Suppose that the input $x(t) = \cos(50t)$ for all time. What is the output $y(t)$?

(a) $3\cos(50t + \frac{\pi}{2})$
(b) $\cos(50t + \frac{\pi}{2})$
(c) $3\cos(50t)$
(d) $3\cos(200t)$

notes

Specifically, our project focuses on doing the following actions

Objectives of CITE

1. develop the test items
2. develop plans for the format and implementation of the tests
3. develop tools to provide relevant results to all stakeholders
4. do full scale test pilots

notes

And up to now we did this . . .

Status of the project @ June 2018

- developed a CITE prototype focusing on basic math concepts
- performed several tests in Uppsala and Luleå on volunteering students
- interviewed students about their preferences on the implementation strategies
- developed a methodology (see the next slide)
- identified (main) concepts for the courses in year 1-3 at LTU and UU
- assigned weights to the concepts for each course at LTU and UU (see the "CCM" tool in the next slide)
- compared the assigned weights from the students' perception vs. the teachers'
- developed questions for some of the most important concepts

notes

. . . following this methodology

Our methodology

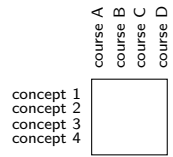
notes

First, create the CCM (i.e., the courses-concepts matrix), that can be in practice an excel sheet where the rows are labeled with the names of the concepts, the columns labeled with the various courses of the program, and every element of this matrix being either:

- 0, to indicate that that specific course does neither make use nor introduce that specific concept;
- 1, to indicate that that specific course makes explicit use of that specific concept;
- 2, to indicate that that specific course teaches or heavily rely on that specific concept.

Actually, the very same process of compiling the CCM generates a lot of potentially useful information – think, for example, at the fact that if two teachers have different opinions on how the CCM should be compiled this means that they have some misaligned interpretation of the program. However in CITE we focus more on the test, and thus for now neglect potential spin-off research issues related to the CCM.

Our methodology

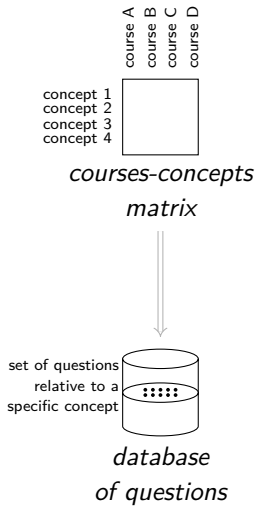


courses-concepts matrix

notes

Once the CCM is compiled, one can understand the relative importance of the various concepts within the program by integrating the CCM values by column, and taking the resulting number as an indication of how much that concept "weights" in the program. This means that one can then focus on creating a database of conceptual questions where for each concep there exist a number of questions that is proportional to the importance of that concept (since more important concepts will be assessed more often and more extensively)

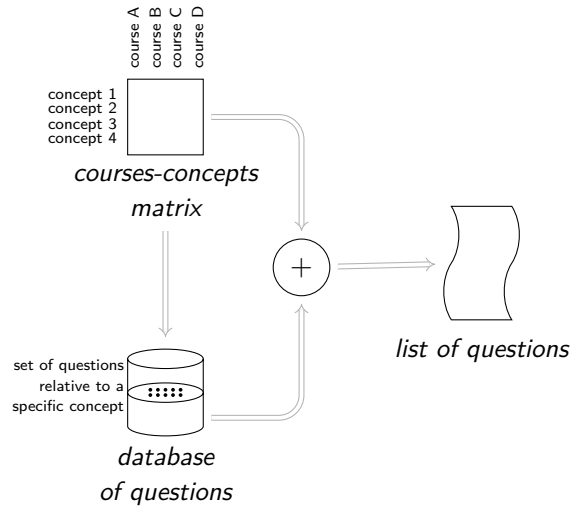
Our methodology



notes

From the CCM and the database one can then extract an actual test. As hinted before, the test should comprise questions extracted through a probability density that accounts for how much important a concept is, how often that concept has been assessed, and how well the students in average score on that concept. Note that we still have no clear picture of how the mathematics should look like, but we currently feel that there should be some "adaptive questions extraction" mechanism

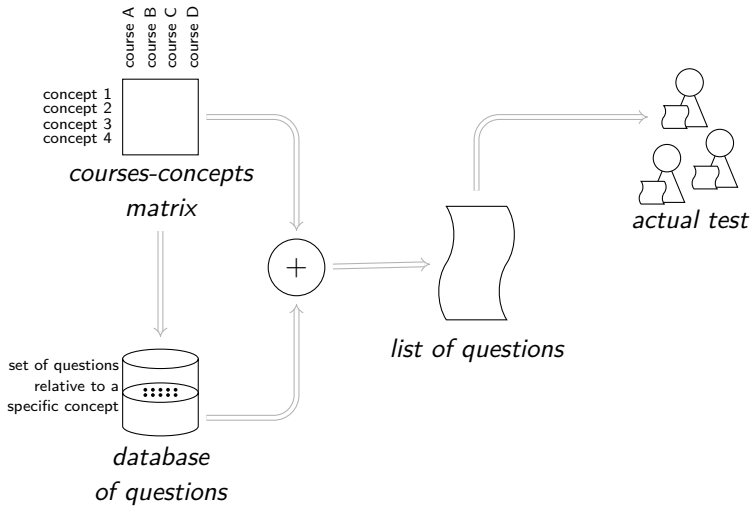
Our methodology



notes

Students can then take the test – how, we still have to understand (for now we are using web-based tests)

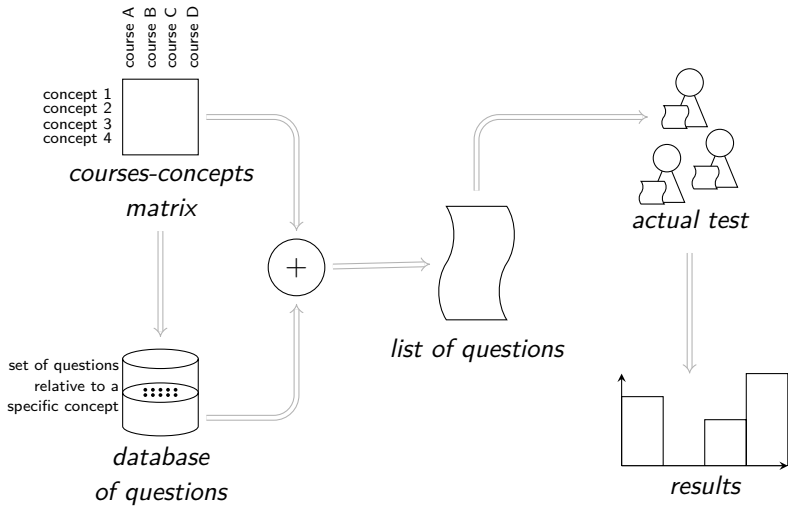
Our methodology



notes

We can then compute the results, . . .

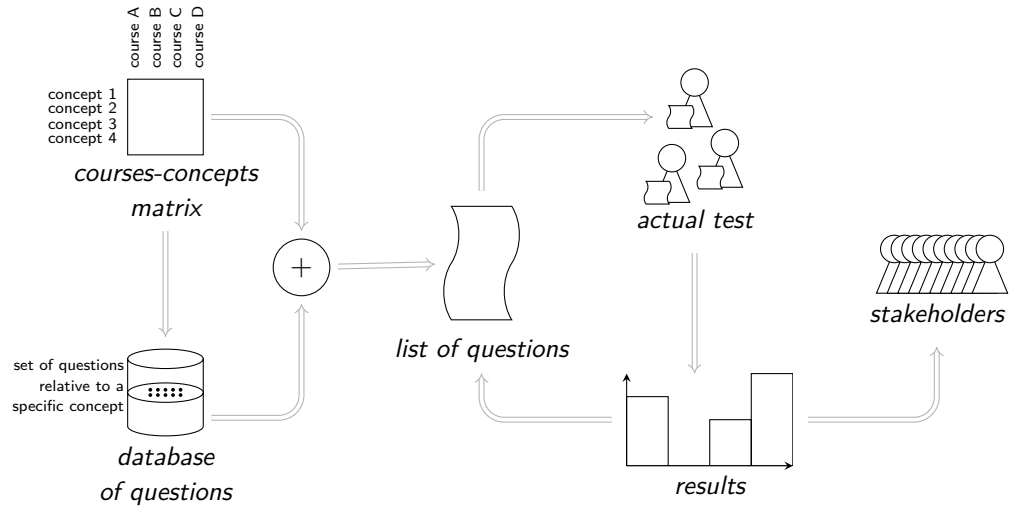
Our methodology



notes

. . . and use them to both inform the stakeholders and influence how the next test should look like

Our methodology



notes

Our next steps are the following ones

Next steps

- complete the CCMs for LTU and UU and investigate a wider range of its applications
- extend the current set of questions
- involve more teachers and other organizations
- organise large-scale tests
- develop the data-visualisation and data-analysis tools

notes

And this is how people has been perceiving our project. The mentioned paper is available at the following link: `http://staff.www.ltu.se/~damvar/Publications/Fjallstrom%20et%20al.%20-%202018%20-%20Developing%20Concept%20Inventory%20Tests%20for%20Electrical%20Engineering%20(CITE)%20extractable%20information,%20early%20results,%20and%20learned%20lessons.pdf`

Bonus slide: summary of the opinions from the stakeholders

(see our UKACC paper for more details)

- perceived as useful for everybody (students, teachers and boards)
- preferred online, at the beginning or before a learning period, 1 or 2 hours per test, 2 or 4 times per year
- very important for students is to see their progressions (much less to compare themselves with others)
- students slightly appreciate using reports for future job applications
- students do not like at all having the test count as an academic record