To learn how to learn! Integrating a metacognitive approach in lectures

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***Abstract*—In this paper the use of a metacognitive approach in teaching to assist students to become aware of their learning process and improve their study techniques is explored in relation to a compulsory course in Microbiology given to second year students in the MSc engineering programme in Biotechnology at the Faculty of Engineering (LTH), Lund University. Lectures mostly focus on describing and explaining what to learn but more seldom on how to learn. This can have an impact on the learning outcome, students' motivation to read and influence whether they adopt a surface or deep approach towards acquiring new knowledge. A survey on metacognition and other modifications was introduced in the Microbiology course. Based on the outcome of these activities different ideas on how to implement metacognitive approaches in teaching and lecturing are proposed.**

***Index Terms*—Metacognition, teaching, processing information**

I. Introduction

MICROBIOLOGY (7.5 credits) is a compulsory course given to second year students in the MSc engineering programme in Biotechnology at the Faculty of Engineering (LTH), Lund University. It is in Swedish and consists of lectures, laboratory exercises including written lab reports, two exercises, one voluntary "dugga" (mid-term test) and finally a classical written examination at the end of the course. The accumulated points from the lab reports and the "dugga" contribute to the final total points. The course literature (Prescott's Microbiology, by Willey, Sherwood and Woolverton; McGraw-Hill) is an American book of about 1000 pages. Not all pages are to be read but still a major part is included in the course and page indications are given for each lecture/chapter in the book.

Both in the beginning and throughout the course we underline the importance of starting to work with the content right away. The aim is to learn basic microbiology with focus on cell physiology, genetics and industrial applications using an active and continuous approach. The goal is to connect all the different parts - not treating them as separate entities (fragmented knowledge) as they are presented in the lectures.

II. The Challenge

Despite our advice to the students, they continue to point out in the course experience questionnaire (CEQ) that (1) the book is overwhelming to read; (2) the overall context and relationships are blurred by detailed facts and (3) they started to study (process the information) too late for the exam. Obviously we have not succeeded to convey the aim of having a continuous approach when studying this course. Instead the students seem to not reach beyond the lower order of learning objectives (remember/memorizing; understanding) in the cognitive domain of Bloom's taxonomy presented in 1956 and do only infrequently reach the higher levels such as application, analysis and evaluation [1].

Why do not students start to read and process knowledge right away? Maybe the answer is that they simply have no idea of where and how to start…and if so - why do they not know that? Can we as lecturers help students to overcome this barrier to learning and succeed to implement that remembering facts, although crucial, is not the end – it is the beginning towards creating understanding? How can we modify our lectures and our way of teaching to stimulate this?

III. Metacognition

Metacognition (MC) was introduced to us by a paper from Tanner (2012) [2]. Besides describing MC, many strategies for how to use this in teaching are presented. MC - "to know how to learn and strategize the studying" - includes planning for learning, monitoring progression and evaluating what has/what has not been learned and analyze how/why not. Different types of questions and strategies that can promote students to start applying a metacognitive approach are exemplified in the paper by Tanner (Table 1). The aim is to assist and inspire students to not only reflect on what they learn but also on how they learn/ understand; to assist them to plan and formulate successful study strategies that will put them in the position where they "orchestrate their own learning" and become expert learners [3].

IV. What did we try & how did it go?

A. Introduction lecture and exercises

The introduction lecture was changed from pure practical information to a lecture having microbiology in focus. A mix of microbiological applications, historical milestones, discussions and our interest in improving the teaching/lecturing was presented. Two teachers (the authors), instead of one, gave the intro lecture. Exercises were introduced in the middle and in the end of the course aiming to tie the lectures together. The students were divided in groups that discussed questions covering topics from several lectures. Each group presented their conclusions to the entire

TABLE I
EXAMPLES OF MC QUESTIONS FOR STUDENTS TO DEVELOP THEIR AWARENESS OF THEMSELVES AS LEARNERS (ADAPTED FROM TANNER, 2012 [2])

MC action:	Questions:
Planning	• How could/have I prepare/d/ for the lecture today? • What do I already know? • What strategies will I use to study this topic? • What resources/how much time will I need? • How will I monitor my learning in this course?
Monitor progress	• Which questions/confusion do I have and why? • How did I clarify questions and confusions? • Do the study strategies I am using work well to help me learn?
Evaluate/ Analyze	• Did my exam preparation work well? • Why did I miss those questions in the exam? • When I take a similar course – what do I want to remember to do differently? • What have I learned about how I learn in this course that I can use in the future biology courses and career?

group and a continuation of the discussion was promoted by us (the authors) asking more questions to the entire group.

During both the intro lecture and the exercises we observed a high level of engagement and more questions were asked compared to previous years. During both exercises the students started to abandon linear thinking and initiated to apply knowledge from different lectures to solve questions. After both exercises students demonstrated a deeper understanding of several aspects of the topic by for example more complex questions and reflections in line with the higher levels (especially relational) of the SOLO taxonomy [4].

B. Metacognitive survey

A 4-part survey on MC was performed to gain insight into whether this is something students employ - if and/or how the students reflect on their own learning (Table II). Do they actively analyze their learning process and their progress? Do they have any strategies for how to study and do they ever evaluate the final outcome in relation to how they worked during the course in order to improve their study technique for the courses to come?

The answers we obtained signaled that (1) metacognitive approaches were not generally used and (2) this could be a strategy to improve learning outcomes in Microbiology and reach beyond memorization. For example, many students found the subject interesting but anyhow they arrived to lectures unprepared and found the book too challenging to read. The most common advice to next year's students was to "start reading – keep up the tempo and plan your studies" along with attending the lectures since they appeared to be a valuable source of guidance for studying.

C. Lecturing

To promote student metacognition and teach how to approach learning can either be accomplished in a direct way or indirectly by building a classroom culture where metacognitive strategies are embedded in our language and teaching/lecturing. A direct way of promoting MC could look like this in the Microbiology course:

We teach the topics "Central Dogma", "Antibiotics", "Mutation and Recombinations" and "Viruses". The central dogma describes the flow of genetic information within a biological system and is often illustrated by the simple expression "DNA→RNA→Protein". Behind these three words, however, there is a myriad of terms, components and mechanisms – just impossible to remember and interlink or…? To go about this we advise the students to 1) NOT read but instead LOOK at animations (provided through the book publisher's web-based interactive learning platform) of the mechanisms; 2) formulate explanations of the mechanisms with their own words based on previous knowledge and experiences; 3) then start to use/read the book and focus primarily on parts that are not understood to fill in knowledge/understanding gaps, and finally 4) look at the animations again to now identify separate components/terms and their functions within the overall mechanism.

If starting the other way around by reading the book from page 1 all the terms and components are presented one after the other - but no picture exists of how and where they fit into the context. No wonder you stop reading – we would probably too – since nothing makes any sense at all and the frustration of being bombarded with all these facts gets overwhelming.

We also advise them to wait with Antibiotics, Mutations and Viruses until the Central Dogma is in place. Many antibiotic substances for example target different mechanisms/components in the Central Dogma and it will thus be much easier to understand the action of antibiotics once the overall picture of Central Dogma is constructed and processed! The other way around would be much more challenging…

…so we help them *how* to study and learn in parallel to *what* to study!

To summarize: the efforts described above did produce some improvements regarding the levels of understanding however based on the latest CEQ the challenges still prevail and more can be done in the future to address these issues.

V. HOW TO CONTINUE IN THE FUTURE?

To know how to learn is a skill. Including metacognitive strategies when teaching may be one way of promoting students to develop their abilities in planning, monitoring and evaluating their learning process that in turn will give positive effects on student learning and understanding – or? What could be successful strategies in supporting student learning in relation to MC?

TABLE II
QUESTIONS IN METACOGNITIVE SURVEY

Survey no:	Questions
#1 **(intro lecture)**	• Why did you come today? • Do you have any idea of how to study in this course?
#2 **(lecture 3 out of 13)**	• Why did you come today? • Did you know what the lecture would cover when you came today?
#3 **(lecture 6 out of 13)**	• Why did you come today? • Have you started to read the book/the ppt-handouts/look at the figures? • How have you solved questions and confusions that have appeared during the course?
#4 **(last lecture)**	• In what way has this course influenced you? • During the course, did you ever reflect on how much you had learned? • How did you feel about reading the book/attending the lectures? • What type of good advice would you give a student that will take this course next year?

Topics for round-table discussion:

A. The use of direct metacognitive approaches?

…such as 1) giving guidance on how to study; 2) ask "How did you prepare for the lecture today?" to promote preparation; 3) ask them to identify confusions (muddiest point) to emphasize the importance of processing - in contrast to just memorizing and 4) perform retrospective post assessment by asking the students to reflect on how their ideas are/are not changing to monitor progress in their learning [2].

B. To build a metacognitive classroom culture?

…such as 1) increased number of regular pair discussions ("bikupor") during classical lectures; 2) introduction of more active learning sessions and 3) "homework" assignments/exercises/study questions including metacognitive questions to start reading the book and processing information [2].

C. "Learning how to learn cannot be left to the students. It must be taught." [5].

…yes indeed – but how much time should be devoted to this? Or – no, not at all: this is something students have to take care of themselves?

D. To promote processing of information?

…such as 1) reflect together with the students both in terms of knowledge but also metacognitive; 2) share experiences in thinking as a researcher with the students; 3) use different type of exams: "mid-term tests, open-book exams etc to promote a continuous and integrative approach towards studying.

E. Other suggestions?

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