11

Evaluating the impact on student activity and level of deep learning when implementing problem-oriented student activities in a lecture

Leise Riber

Department of Biology, SCIENCE, University of Copenhagen

Introduction

Several studies indicate that traditional models of learning based on memorizing and reproducing knowledge on demand do not develop reasoning skills, flexible knowledge or the ability to apply knowledge, to reflect and solve problems in new contexts. In order to do so, the students need to be actively engaged while learning, which leads to higher levels of performance, intrinsic motivation and productivity. Problem-based learning (PBL) is an example of an active teaching method in which the students develop self-directed learning, effective problem solving and decision making skills and thereby become progressively deeper in their approaches to learning compared with traditionally taught students (Newble & Clarke 1986, Hmelo-Silver 2004). Obtaining a deeper understanding of the subject as well as realizing how different threads of a subject are related to one another will also provide a better long-term recall of the knowledge the students acquire.

Particularly, the traditional lecture is an example of passive teaching in which the students typically remain inactive during a teacher-based monologue, thereby promoting a surface approach to learning. As lectures are often the dominant way of teaching at universities, reflections concerning how to activate students towards a deeper learning approach become essential (Gibbs 1981). Implementing a PBL-like approach using dialogue, asking questions, handing out small assignments for group work may promote an increased level of activity among the students, make them reflect and let them know of both the limitations and applications of the obtained

knowledge in specific case stories or problems thereby leading to a deeper learning approach.

However, several problems concerning both planning, executing and evaluating this type of deep learning approach may arise when introduced in one's own teaching. PBL is very sensitive to context and climate (Biggs & Tang 2007). First, the teacher is required to adopt a different philosophy of professional education; that education is more than acquisition of separate bodies of knowledge, and that both content and amount of teaching material for the lectures needs to be adjusted and restricted for this type of learning approach. Implementing either exercises for the students that reinforce and apply what has already been taught or designing problems set before the relevant knowledge has been acquired both represent a demanding and somewhat time-consuming task that may require severe adjustments of the current curriculum. Second, the teacher is required to be flexible, and planning the lecture should make room for both expected and unexpected dialogue and discussions in which the students are greatly involved. Finally, it takes some effort to create an appropriate atmosphere to motivate the students to be actively engaged which is a prerequisite for this type of learning approach.

Aim

The aim of this study is to change one's current teaching and develop quality enhancement processes and strategies focusing on what problem-based learning (PBL) ideas and techniques to implement in a lecture based teaching for improving the level of student activity and engagement as well as increasing the outcome of deeper learning.

Methods

The setup for implementing a PBL-like technique with increased focus on dialogue, discussions and actively solving problems was based on two specific lectures on bacterial whole-cell biosensors as well as on design and applications of microarrays, respectively. Both are part of the course "Emerging Techniques in Molecular Microbiology" at master level. The course usually hosts 20-25 students and teaching is a mixture of practical exercises, student presentations and lectures performed in English in the same

classroom. Previously, the lectures were focused on giving the students a basic introduction to the techniques and applications within the above mentioned research fields, and the students were expected only to reproduce and memorize these pieces of information promoting a passive, and according to theory, surface learning approach.

In order to increase the taxonomical level of the learning outcome towards a deeper understanding, pedagogical considerations have been made concerning what changes to make for employing a PBL-like method that adapts student activities ranging from engagement in classroom discussions to single or group based exercises. Enhancing the intrinsic motivation of students is a major advantage in PBL (Hmelo-Silver 2004). Consequently, designing a lecture that implements questions, assignments, discussions and variation for sustaining a high level of activity seems essential but will also require careful planning and selection of the content of material to be taught in order to make room for the intended activities.

In traditional PBL problems are usually set before the knowledge has been acquired, forcing students to acquire the knowledge they need before solving the task (Biggs & Tang 2007). For these lectures a slightly different format was used in which exercises and questions were designed to reinforce what has already been taught and demonstrate the relevance and use of knowledge already acquired. The following techniques were applied; specify the learning objectives as soon as possible, introduce an unsolved, but relevant case as an appetizer, use examples from real life to illustrate applications in order to make the students relate to the topic and during the lecture combine this knowledge with acquired blocks of factual information regarding design and techniques. The idea is to engage a motivation for the students to construct knowledge and enable them to solve assignments based on applying, analyzing and designing. Such assignments are handed out as group work (as part of the previously introduced case) and will be discussed in plenum in order to create dialogue and reflection. Additionally, questions, some having specific answers, others open for dialogue and discussion, will be given during the lecture to further actively engage the students. Finally, the lectures will be paused a couple of times in order to summarize the content on the blackboard, leaving time for the students to further reflect, structure and ask clarifying questions.

However, in order to develop and improve one's teaching further it is essential to produce an evaluation that provides information regarding impact level, level of activity as well as extent of learning outcome. Specifically, the following questions need answers:

- Are students motivated and activated to a higher degree when implementing class discussions, asking questions during the lecture, handing out small group exercises and structuring the lecture by summarizing on the blackboard for further reflection?
- Do the students appreciate this type of lecture and do they feel that they learn more efficiently and to a deeper extent?

For assessing the first lecture on biosensors, the students responded to a questionnaire (Appendix A) provided the same day. The questions raised were divided into sections, among them a general part addressing the alignment of learning objectives and the content of the lecture, whereas other sections of the questionnaire were focused on evaluating the impact on student activity and learning outcome of using either the black-board for summarizing and structuring, asking the class questions for obtaining dialogue or handing out small group exercises for plenary discussions. Specific academic questions directly testing the outcome of deeper learning could have been implemented but, to avoiding a too comprehensive questionnaire, the students were asked how they felt about their deeper learning as well as what concepts from the lecture they regard as the most important.

The second lecture regarding microarray design was assessed using the Delphi method best described as an anonymous group communication process in which a consensus of specific opinions is developed (Hsu & Sandford 2007). This type of feedback process is not as controlled as the questionnaire, but operates more openly, allowing the evaluators to express individual and qualitative observations that subsequently are quantified by others rating the statements as either agree or disagree. The Delphi evaluation was meant to supplement the questionnaire despite not assessing the same lecture. This might be a drawback, yet minimized by the fact that both lectures were planned and structured in the same way.

Results

For the evaluation of the biosensor lecture, eighteen students out of twenty answered the questionnaire, which indicates a good representation for statistical analysis. All data from this evaluation are listed in Appendix B, including the results from each individual evaluator.

Most students agreed on the fact that the learning objectives, presented in the beginning of the lecture, clearly stated what they were supposed to

learn and subsequently guided the teaching in a purposeful way (Fig. 11.1). For the outcome of each specific learning objective, the standard deviations become somewhat higher, but respondents tend to gain high outcomes for all objectives. There is a slight tendency indicating the lowest outcome on the objective that illustrates learning at a taxonomical deeper level of understanding (Construct, design and analyze your own whole-cell bacterial biosensor). Otherwise the scores do not seem to be significantly different (Fig. 11.1).

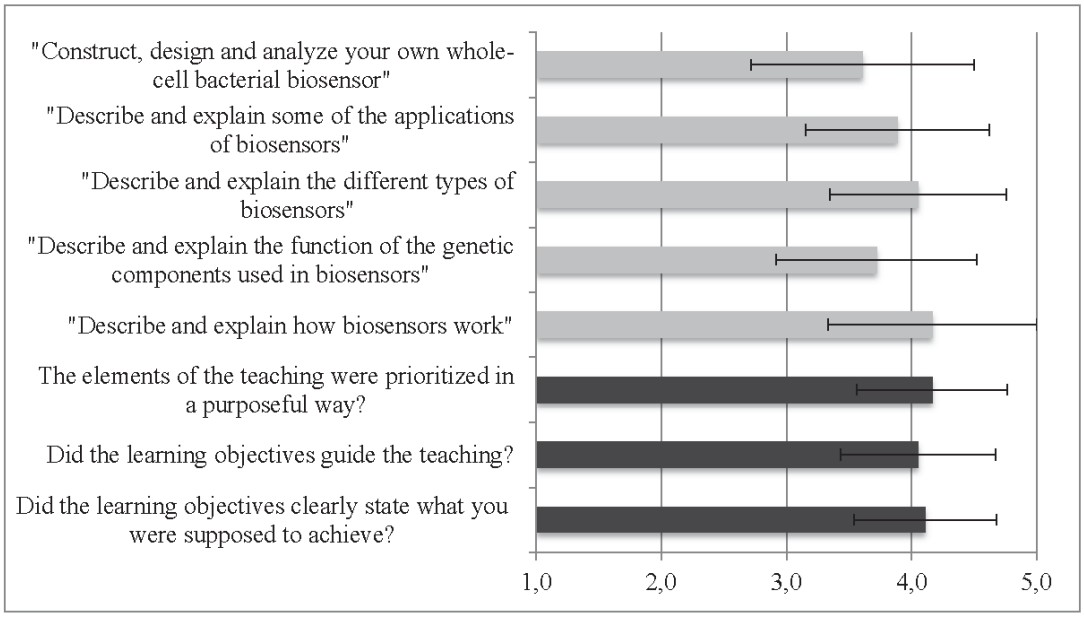

Fig. 11.1. Evaluation of the learning objectives of the biosensor lecture (dark grey) as well as the learning outcome from each individual learning objective (light grey). The outcome of each objective was evaluated on a scale from 1 to 5, 1 being the lowest and 5 the highest. The opinion of the learning objectives in general was rated 1: Fully disagree to 5: Fully agree. The black, horizontal bars indicate the standard deviations of the data.

When looking into statements on what people found particularly important during the lecture, categorizing these as either surface learning or deeper learning, indicates that the distribution is quite equal with almost the same amount of votes for both categories (Fig. 11.2). These findings more or less support the data in figure 11.1 and illustrates that the students have gained knowledge from all learning objectives (as listed in figure 11.1), leaning slightly more towards basic knowledge.

Statements	Number of "votes"
How biosensors work (S)	6
Different types of biosensors (S)	8
Reporter genes (S)	6
Applications of biosensors (S/D)	8
Many parameters (promoter, reporter, specificity, sensitivity, basal levels) to account for (D)	7
How to construct biosensors (D)	6

Fig. 11.2. An overview of statements written by the students to describe what they found most important during the lecture. The statements have been categorized with S: Surface learning or D: Deep learning, according to the taxonomical level of the statement.

In general, the students seem satisfied with this type and structure of teaching as the general learning outcome of the lecture has been rated quite high (good or very good) with a small standard deviation (Fig. 11.2). The general outcome of discussions, questions and the group exercise has also on average been rated as good, but the standard deviations tend to increase, indicating some outliers that obviously prefer a traditional lecture compared to the PBL activities (Fig. 11.3). This is supported by the fact that exactly the same people who dislike PBL activities tend to rate the lecture as the best method for obtaining a deeper understanding (data for individual evaluators are stated in Appendix B).

Concerning the impact of questions, discussions and group exercise on the level of activity and deeper learning, the respondents agree on some positive effect. However, the standard deviations are quite high, supporting the fact that some people prefer traditional lectures over PBL activities.

Interestingly, the impact of PBL activities on level of student activity and engagement is only slightly above average (Fig. 11.3), but studying the individual evaluations (Appendix B) reveals that those who do not show an increased level of activity still seem to obtain an increased level of understanding, which is also reflected in the level of knowledge gained by the specific people at learning objectives representing design and construction issues.

When looking into the specific evaluations on use of blackboard, asking the class questions, and having the group exercise, this tendency is repeated (Fig. 11.3). Neither the group exercise nor asking the class questions is found to increase the level of participation and activity much.

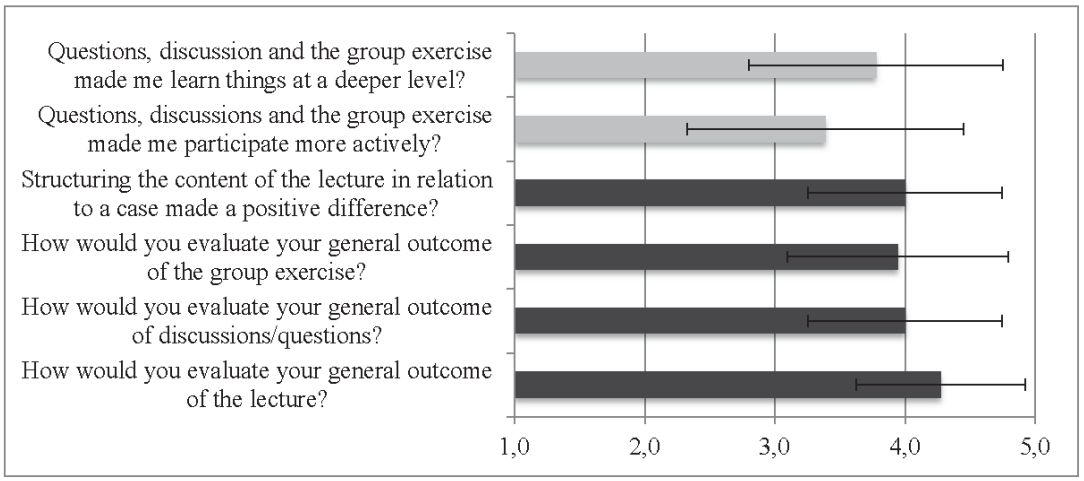

Fig. 11.3. General outcome from lecture, discussions, questions and group exercise; lower bars (dark grey) ranking from 1: very bad to 5: very good. Impact of discussions, questions and group exercise on activity level and level of deeper learning; upper bars (light grey) ranking from 1: fully disagree to 5: fully agree. The black, horizontal bars indicate the standard deviations of the data.

Despite huge standard deviations, the average of these statements is just a bit above neutral. However, students seem to agree that the group exercise helps to clarify important concepts and increases the level of higher understanding, whereas asking questions is relevant according to the learning objectives (Fig. 11.4). The huge standard deviations observed for statements regarding activity level illustrate that some people (around five in this investigation) tend to gain a high learning outcome without necessarily feeling actively engaged (individual data in Appendix B). Usually, one would expect these parameters to be more closely related; activity and engagement stimulating a deeper approach to learning. In general, this also goes for most respondents in this sample.

Using the blackboard for summarizing key points from the lecture seems on average to have a positive impact regarding giving the students time for reflection and asking questions to clarify unclear concepts. Even when taking the rather huge standard deviations into consideration the positive feeling about the blackboard never goes below neutral (Fig. 11.4). A few people seem to dislike the blackboard, but in general neither asking questions nor using the blackboard is stated as being disturbing to the lecture (Fig. 11.4).

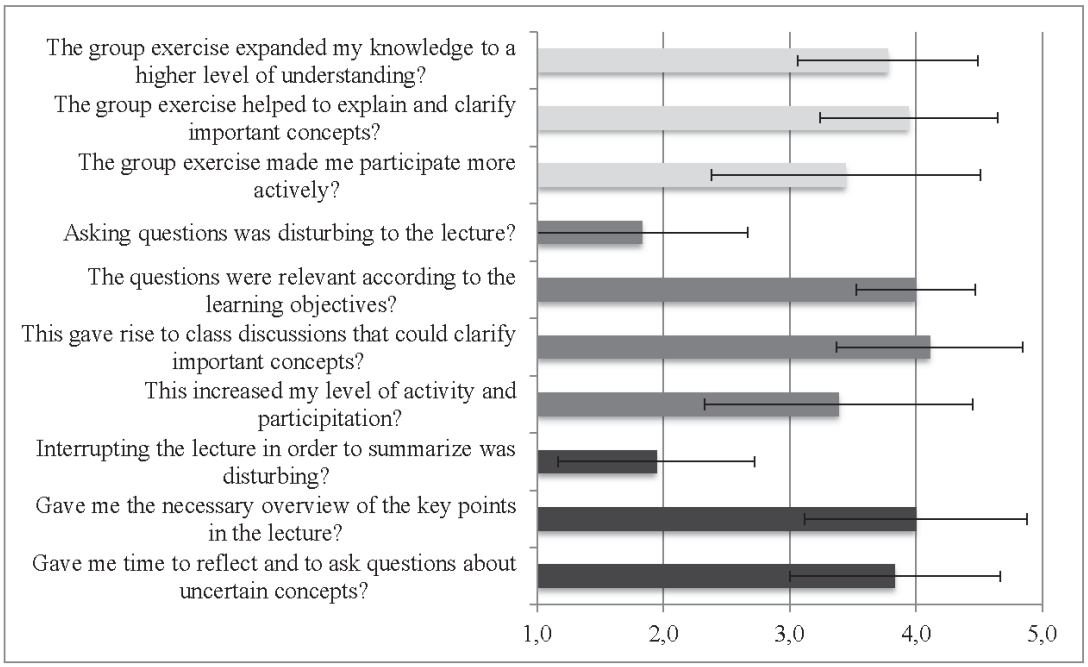

Fig. 11.4. Specific evaluations on: 1. Group exercise (light grey); 2. Asking questions (medium grey); 3. Using the blackboard for keynotes (dark grey). All statements are ranked from 1 (fully disagree) to 5 (fully agree). Some statements are left out, but data can be found in Appendix B. The black, horizontal bars indicate standard deviations.

When quantifying the contribution of lecture, blackboard, questions and group exercise, respectively, on outcome of surface learning, deeper learning or level of activity, using the blackboard does not get high scores but tends to account for around 10 % in all cases (Fig. 11.5). In general, the disagreement among the evaluators in finding some consensus is high, as indicated by huge standard deviations. In general, the lecture dominates in stimulating surface- and deeper learning, whereas the group exercise gets a slightly higher score for stimulating the level of activity. On the other hand, people agree that the group exercise does not contribute much in stimulating surface learning. Asking the class questions seems to account for 20-25 % in all categories.

Evaluating personal comments on issues that people particularly liked supports previous findings stating the group exercise and blackboard notes as positive elements (Fig. 11.6). Additionally, the structure and slides of the lecture as well as the engagement of the teacher was emphasized. Comparing these individual comments to the findings from the Delphi method

	Lecture	Blackboard	Questions	Group exercise
Outcome of surface learning	**51.5** ± 26.2	14.1 ± 22.6	21.1 ± 22	13.4 ± 10.3
Outcome of deeper learning	**42.9** ± 27.1	12.1 ± 23.6	22.1 ± 21.8	22.9 ± 18.6
Level of activity	29.5 ± 31.3	12.1 ± 23.6	23.1 ± 20.9	**35.4** ± 33.2

Fig. 11.5. Contribution of Lecture and PBL-like activities on the outcome of surface learning or deeper learning as well as on the level of activity and engagement. Numbers are given in percentage. Standard deviations are indicated.

(complete dataset in Appendix C) indicates that people have focused on the same issues in both lectures (Fig. 11.6).

Questionnaire		**Delphi**	
What people liked	**Vote**	**Statement**	**Agree/Disagree**
Slides	6	Too much repetition, could have used less explanation time	6/7
Structure of lecture	7	Very informative lecture	12/1
Engagement of teacher	6	Discussions and summaries of exercises were awesome	10/3
Questions asked to the students	3	Time for questions and discussion is a plus	12/1
Blackboard notes	6	Keynotes on blackboard are good	9/4
Group exercise	6	Good to have student exercises	12/1
		Blackboard notes did not add anything important	5/8

Fig. 11.6. Summary of individual statements of issues from the biosensor lecture that people liked (left column). These are quantified by the number of people agreeing on these (votes). Summary of individual statements from the Delphi method (right column). Delphi statements are quantified by the number of people agreeing or disagreeing with the given statement. For the Delphi method, 13 of 18 students did the evaluation.

The Delphi evaluation reveals that the students agreed on liking the lecture and found that student exercises and summaries of these as well as discussions and time for questions were a plus. Again, using the blackboard for summarizing keynotes is an issue that received favourable comments that some people tend to like very much, whereas others find this quite disturbing. Specifically, not using the blackboard was listed by three students as a

suggestion for improvement in the questionnaire (Appendix B). However, as seen previously, most people agree that using the blackboard is positive.

Other suggestions for improvement include putting the answers from the exercises on the blackboard, asking harder questions, using more examples of applications and making the slides available before the lecture.

Discussion

The student evaluations indicated that the applied PBL teaching activities such as summarizing keynotes on the blackboard, asking the students questions during the lecture and having small group exercises could to some extent motivate and activate most students to reflect on the course content and experience an increased- and somewhat deeper learning outcome. However, there was some disagreement concerning the impact of the implemented tools on the level of engagement, and clearly a few students did not experience an increased level of activity and motivation, despite indicating an improved learning outcome. The self-evaluation, based on perception of teaching experience, indicated that the changes implemented did sustain a higher level of student activity. In general, 50-60 % of the students were actively engaged and focused and clearly participated in the plenum discussions compared with traditional lectures in which I mostly do all the talking, while the students remain passively listening. Clearly, dialogue seemed to create an open atmosphere and helped to create an interactive classroom. These observations are in agreement with other studies showing that students gain a higher level of understanding when relevantly active and motivated with learning activities that require them to reflect and think about novel problems and apply the knowledge they have gained (Mazur 1998, Hmelo-Silver 2004).

In general, all PBL activities seemed to be successful in contributing to the observed improvements. Something to consider particularly successful, and which was also pointed out in the comments of several evaluators, was using the blackboard for summarizing keynotes. This may seem interrupting to the lecture, also from a teacher's point of view, and clearly some students dislike this activity, but to most students summarizing important concepts or answers from exercises was indeed a positive experience that gave them time to reflect and ask questions about unclear concepts. Usually, reflection helps students to relate their new knowledge to their prior understanding and to understand how their problem-solving strategies might

be reapplied. Reflection makes students tie general concepts and skills together, constructing a more coherent understanding (Chi et al. 1989). According to theory, using the blackboard should indeed be essential in making the students reflect on their knowledge and strategies relative to a problem, which is a prerequisite for deeper learning.

The group exercise was stated as another positive issue relevant for expanding student knowledge and for explaining unclear connections. For most students the exercises increased the level of activity, whereas a few students did not feel more engaged, but yet could gain a deeper approach to learning anyway. Self-evaluation also indicated that students were focused and concentrated on the exercises and many students took an active part in subsequent plenary discussions. Consequently, using small group exercises seems essential when implementing PBL activities. This is supported by the fact that problem solving is a way to achieve a self-defined learning goal and that the relationship between problem solving and learning is a critical component of PBL and is required to support the construction of extensive and flexible knowledge (Salomon & Perkins 1989).

However, various factors can influence the implementation of PBL activities: the extent of incorporation of PBL into the curriculum, group dynamics, nature of problems used and the motivation of the learners. Second, structuring and planning a lecture that contains a variable amount of learning activities is both time consuming and challenging. The number of PowerPoint slides must be kept to a minimum so that only the essential parts of the curriculum can be presented. This requires a certain focus and prioritizing of the teacher. From self-evaluation it became clear though, that despite thoroughly planning the lecture, the outcome might be different as control is hard to maintain when interaction and dialogue is expected.

Practising and further improving this type of teaching in future lectures seems essential for increasing the learning outcome. Based on this study, several points need to be taken into consideration; It was pointed out that people need a small break during the lecture which supports other findings stating that a short rest, or change in activity, every fifteen minutes restores performance to almost original level (Biggs & Tang 2007). Second, group exercises can be improved by introducing these properly and writing the proposed answers on the blackboard. Finally, when asking questions during the lecture, these should be thoroughly prepared and made relevant according to learning objectives. Some suggested that the questions could perhaps be harder, which would require more time for the students to think, perhaps accompanied by their neighbours.

Conclusion

In general, the employed changes and tools of PBL-like activities seemed to have improved teaching performance leading to an increased level of learning outcome. For most students learning activities such as using the blackboard for summarizing keynotes, asking the students questions and handing out exercises also seemed to increase the level of activity and engagement. Only a few students claimed not to have been engaged by these learning activities, but yet even they seem to have obtained an improved level of learning outcome. Self-evaluation also indicated an increased interaction with the students and most students seemed active and engaged compared with traditional lectures based on monologue and passive listening.

A Evaluation of Biosensor lecture 8 May 2012

General:

How would you evaluate your general outcome of the lecture?

Very good Good Neutral Bad Very bad

How would you evaluate your general outcome of the discussions/questions in the class during the lecture?

Very good Good Neutral Bad Very bad

How would you evaluate your general outcome of the group exercise?

Very good Good Neutral Bad Very bad

The "Learning objectives", which were first provided in the lecture, clearly stated what you were supposed to achieve?

Agree fully Agree Neutral Disagree Disagree fully

The "Learning objectives" guided the teaching?

Agree fully Agree Neutral Disagree Disagree fully

The elements of the teaching were prioritized in a purposeful way in the light of the "Learning objectives"?

Agree fully Agree Neutral Disagree Disagree fully

How well have you learned what the following "Learning objectives" of the day stated on a scale from 1 to 5 (1 lowest, 5 highest)?

1. Describe and explain how biosensors work
   1 2 3 4 5
2. Describe and explain the function of the genetic components used in the construction of biosensors
   1 2 3 4 5
3. Describe and explain the different types of biosensors
   1 2 3 4 5
4. Describe and explain some of the applications of biosensors
   1 2 3 4 5

5. Construct, design and analyze your own whole-cell bacterial biosensor
   1 2 3 4 5

Structuring the content of the lecture in relation to a case/problem has made a positive difference compared to an ordinary lecture?

Agree fully Agree Neutral Disagree Disagree fully

Introducing an actual case/problem in the beginning of the lecture had a positive effect on my motivation and level of engagement?

Agree fully Agree Neutral Disagree Disagree fully

The content of the lecture based on questions, discussions and the group exercise made me participate more actively than during an ordinary lecture?

Agree fully Agree Neutral Disagree Disagree fully

The content of the lecture based on questions, discussions and the group exercise made me learn things at a deeper level of understanding (design, construct, analyze)?

Agree fully Agree Neutral Disagree Disagree fully

Please state the distribution of your outcome of surface learning (ability to explain and describe concepts) between the different parts of the lecture (in percentage summing up to 100%):

Lecture Blackboard Questions/discussions Group exercise

Please state the distribution of your outcome of deeper learning (ability to analyze, design, construct, evaluate) between the different parts of the lecture (in percentage summing up to 100%):

Lecture Blackboard Questions/discussions Group exercise

Please state the distribution of your level of activity and participation between the different parts of the lecture (in percentage summing up to 100%):

Lecture Blackboard Questions/discussions Group exercise

Use of Blackboard to summarize/repeat important concepts:

This gave me time to reflect and to ask questions about unclear connections?

Agree fully Agree Neutral Disagree Disagree fully

This gave me the necessary overview of the key points of the lecture?

Agree fully Agree Neutral Disagree Disagree fully

Interrupting the lecture in order to summarize important points was quite disturbing?

Agree fully Agree Neutral Disagree Disagree fully

Asking students questions during the lecture:

Asking questions to the class helped me to keep concentrated and focused on the lecture?

Agree fully Agree Neutral Disagree Disagree fully

Asking questions to the class increased my level of activity and participation during the lecture?

Agree fully Agree Neutral Disagree Disagree fully

Asking questions gave rise to class discussions that could help clarify/understand important concepts?

Agree fully Agree Neutral Disagree Disagree fully

The amount of questions asked was too high?

Agree fully Agree Neutral Disagree Disagree fully

The questions asked were relevant according to the “Learning objectives”?

Agree fully Agree Neutral Disagree Disagree fully

The questions asked were well balanced and neither too hard nor too easy to answer?

Agree fully Agree Neutral Disagree Disagree fully

Asking questions to the class was disturbing to the lecture?

Agree fully Agree Neutral Disagree Disagree fully

Small group exercise:

The group exercise increased my motivation for the subject?

Agree fully Agree Neutral Disagree Disagree fully

The group exercise made me participate more actively in the final class discussion?

Agree fully Agree Neutral Disagree Disagree fully

The group exercise helped to explain and clarify important concepts?

Agree fully Agree Neutral Disagree Disagree fully

The group exercise expanded my basic knowledge obtained during the lecture to a higher level of understanding at which I could partly design, construct, evaluate and analyze biosensor related topics/problems?

Agree fully Agree Neutral Disagree Disagree fully

List the 3 most important things/concepts from today's lecture (that you find important):

1. _____

2. _____

3. _____

List 3 things that you like in particular about today's lecture:

_____

_____

_____

_____

_____

_____

List 3 suggestions for improvements:

_____

_____

B Results from student evaluation based on questionnaire

Statement	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	Mean	STD Dev
General (Very good: 5, Very bad: 1 or Agree fully: 5, Disagree fully: 1)																				
How would you evaluate your general outcome of the lecture?	5	5	4	5	4	4	4	4	5	5	5	5	4	3	4	4	4	3	4.3	0.65
How would you evaluate your general outcome of discussions/questions?	5	4	4	5	4	5	3	4	4	4	5	4	4	3	4	4	4	2	4.0	0.75
How would you evaluate your general outcome of the group exercise?	3	4	4	5	4	5	3	4	3	5	4	5	3	2	5	4	4	4	3.9	0.85
Structuring the content of the lecture in relation to a case/problem has made a positive difference?	5	4	4	4	4	4	3	4	4	5	4	5	4	3	5	4	4	2	4.0	0.75
Introducing an actual case/problem in the beginning has a positive effect on motivation and engagement?	3	3	4	4	2	3	4	5	4	4	4	5	3	1	3	5	3	3	3.5	1.01
Questions, discussions and the group exercise made me participate more actively?	4	3	4	4	2	5	2	2	3	3	5	4	2	2	4	5	4	3	3.4	1.06
Questions, discussion and the group exercise made me learn things at a deeper level?	5	4	4	4	3	4	4	3	3	5	4	5	3	1	4	5	4	3	3.8	0.97
Learning objectives (Agree fully: 5, Disagree fully: 1)																				
Did the learning objectives clearly state what you were supposed to achieve?	4	4	4	4	3	4	4	4	4	4	5	4	5	4	5	5	4	3	4.1	0.57
Did the learning objectives guide the teaching?	5	4	4	3	3	4	4	4	4	5	4	5	4	4	4	5	4	3	4.1	0.62
The elements of the teaching were prioritized in a purposeful way in the light of the learning objectives?	5	4	4	4	4	4	4	4	3	4	5	4	4	4	5	5	5	3	4.2	0.60
How well have you learned the following learning objectives? (1 lowest, 5 highest)																				
"Describe and explain how biosensors work"	4	5	5	4	4	4	3	4	4	5	5	5	5	3	5	4	4	2	4.2	0.83
"Describe and explain the function of the genetic components used in construction of biosensors"	4	4	5	5	3	4	3	4	2	3	4	5	4	3	4	4	3	3	3.7	0.80
"Describe and explain the different types of biosensors"	3	4	5	4	4	5	3	3	4	5	5	4	4	3	5	4	4	4	4.1	0.70
"Describe and explain some of the applications of biosensors"	4	3	4	3	5	4	3	4	4	5	5	4	4	4	4	4	4	2	3.9	0.74
"Construct, design and analyze your own whole-cell bacterial biosensor"	4	3	5	4	4	5	3	4	2	4	4	4	3	2	5	3	3	3	3.6	0.89
Use of blackboard (Agree fully: 5, Disagree fully: 1)																				
Gave me time to reflect and to ask questions about uncertain connections?	4	5	4	4	4	3	4	3	5	4	4	4	4	2	4	5	2	4	3.8	0.83
Gave me the necessary overview of the key points in the lecture?	4	5	4	3	4	3	5	3	5	5	4	5	4	2	4	5	3	4	4.0	0.88
Interrupting the lecture in order to summarize was disturbing?	1	2	2	3	1	3	2	3	2	1	3	1	2	1	2	1	2	3	1.9	0.78
Asking questions during the lecture (Agree fully: 5, Disagree fully: 1)																				
This helped me to keep concentrated and focused?	5	3	4	5	4	5	4	3	4	5	4	4	2	3	4	4	5	2	3.9	0.94
This increased my level of activity and participation?	5	3	4	4	3	5	4	2	4	4	3	3	2	2	4	4	4	1	3.4	1.06

This gave rise to class discussions that could clarify important concepts?	5	4	4	4	5	5	4	4	4	5	4	4	4	3	4	5	4	2	4.1	0.74
The amount of questions was too high?	1	3	2	3	2	2	1	2	3	3	3	3	2	4	2	1	2	5	2.4	1.01
The questions were relevant according to the learning objectives?	5	4	4	4	4	4	4	3	4	5	4	4	4	4	4	4	4	3	4.0	0.47
The questions were balanced and neither too hard nor too easy?	5	4	4	4	4	4	4	4	3	4	5	4	4	2	4	4	3	2	3.8	0.79
Asking questions was disturbing to the lecture?	1	2	2	3	1	2	1	3	2	2	2	1	2	1	2	1	1	4	1.8	0.83
Small group exercise (Agree fully: 5, Disagree fully: 1)																				
The group exercise increased my motivation for the subject?	4	3	4	4	4	4	4	4	3	3	3	5	2	2	4	5	3	3	3.6	0.83
The group exercise made me participate more actively?	4	3	4	4	2	4	2	2	2	5	5	3	2	4	4	5	4	3	3.4	1.07
The group exercise helped to explain and clarify important concepts?	4	4	4	5	5	4	4	4	3	4	4	5	4	2	4	4	4	3	3.9	0.70
The group exercise expanded my knowledge to a higher level of understanding at which I could design, construct and analyze biosensors?	4	3	4	4	4	3	4	4	3	4	4	5	4	2	5	4	4	3	3.8	0.71
Distribution of outcome of surface learning (%)																				
Lecture	40	60	25	30	50	0		60	0	60	60	55	75	90	70	50	50	100	**51.5**	26.16
Blackboard	20	15	25	5	10	0		5	100	5	5	10	5	5	10	20	0	0	14.1	22.64
Questions/discussions	30	20	25	30	20	100		5	0	20	20	15	10	3	10	20	30	0	21.1	22.02
Group exercise	10	5	25	35	20	0		30	0	15	15	20	10	2	10	10	20	0	13.4	10.28
Distribution of outcome of deeper learning (%)																				
Lecture	40	50	25	20	50	0		40	0	40	50	65	75	90	30	20	35	100	**42.9**	27.07
Blackboard	10	5	25	0	10	0		0	100	30	0	10	5	0	0	10	0	0	12.1	23.64
Questions/discussions	30	25	25	30	20	100		15	0	15	20	10	10	10	10	20	35	0	22.1	21.76
Group exercise	20	20	25	50	20	0		45	0	15	30	15	10	0	60	50	30	0	22.9	18.56
Distribution of outcome of level of activity (%)																				
Lecture	10	0	25	20	50	0		25	0	10	40	0	65	96	0	40	20	100	**29.5**	31.27
Blackboard	10	0	25	0	20	0		25	100	10	0	0	5	1	0	10	0	0	12.1	23.61
Questions/discussions	70	0	25	40	20	0		25	0	50	30	0	20	2	50	20	40	0	23.1	20.88
Group exercise	10	100	25	40	10	100		25	0	30	30	100	10	1	50	30	40	0	**35.4**	33.17
Typical what people find important (S: Surface learning, D: Deeper learning):																				
How biosensors work (S)		1	1	1					1			1	1						6	
Different types of biosensors (S)		1	1	1		1			1		1		1			1			8	
Reporter genes (S)		1	1		1		1								1	1			6	
Applications of biosensors (S/D)				1	1				1		1	1	1	1	1				8	
Many parameters (promoter, reporter, specificity, sensitivity, basal levels) in biosensing to account for (D)	1		1		1	1	1							1		1			7	
How to construct biosensors (D)									1		1	1		1	1	1			6	
Things people liked:																				
Blackboard notes	1	1			1					1			1			1			6	
Questions asked to the students	1			1													1		3	
Slides		1		1							1	1	1	1					6	
Motivation and engagement of the teacher			1		1						1	1	1				1		6	
Structure of the lecture			1							1		1	1	1		1	1		7	
Group exercise				1	1	1				1		1			1				6	
Suggestions for improvements:																				
Put answers for exercise on blackboard		1		1						1		1							4	
Ask harder questions			1																1	
Do not use the blackboard						1					1	1							3	
More examples on applications from real life									1										1	
Slides available before lecture													1						1	

C Results from student evaluation based on Delphi Method

Statements	Agree	Disagree	Blank
Slide pictures are too small	8	5	
Start the lecture introducing the applications	7	6	
Discussions and summaries of exercises were awesome	10	3	
The blackboard sessions didn't add anything important	5	8	
Good to have student exercises	12	1	
The lecture was too "pedagogical", could have used less explanation time	6	7	
Need 5 min break in the middle of the lecture	10	3	
Keynotes on blackboard are good	9	4	
Too much repetition compared to amount of information	6	7	
Good idea with keynotes on blackboard?	8	3	2
Time for questions and discussions is a plus	12	1	
Summarizing main points on blackboard is really good	9	3	1
Very informative lecture	12	0	1

All contributions to this volume can be found at:

http://www.ind.ku.dk/publikationer/up_projekter/2012-5/

The bibliography can be found at:

http://www.ind.ku.dk/publikationer/up_projekter/

kapitler/2012_vol5_bibliopgraphy.pdf/