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New teaching and learning activities in Biomedicine

Peter Karlskov-Mortensen

Department of Basic Animal and Veternary Sciences, LIFE, University of Copenhagen

Introduction

We have over the last four years taught a course in biomedicine (module 1) which is a course in advanced molecular genetics for veterinary master students. Biomedicine, module 1 is part of the differentiation in biomedicine which is one of the four branches in which veterinary students can specialize during the last two and a half year of their studies. Approximately 25 students normally attend this course.

The course is designed to provide the student with an understanding of the general theoretical and practical possibilities in working with pro- and eukaryote genomes and it also concerns principles related to molecular pathology and diagnostics (Appendix A).

The course consists of three weeks with lectures and theoretical exercises followed by one and a half week with laboratory exercises (Appendix B). The lectures have until now generally been of a classical form. That is, students have prepared for the lectures by reading and a teacher expounds the subject in the class room. Lectures have of course been open for questions and discussions but in general there has not been done any extra effort to encourage this in practice.

The laboratory exercises have been made up as four different cases reflecting normal tasks and challenges in our laboratory. Every case runs over several days and gives the students opportunity to work with a number of different standard laboratory techniques for molecular genetics. Every day during the period with laboratory work begins with a briefing about the days work and the techniques to be used. The students are divided in two

groups for the work in the laboratory and the teacher is assisted by a laboratory technician. The small group size makes a good opportunity for the teacher to asses for each student the theoretical knowledge and the practical application of this knowledge in the laboratory work. Hence, these exercises enable us to evaluate the quantitative outcome of lectures through dialogue and discussion with the students, and the qualitative outcome of their learning can be estimated by observing their ways to deal with cases and specific problems in the laboratory. Their written reports on the laboratory exercises should reflect both the quantitative and qualitative outcome of the combined theoretical and practical teaching.

Description of the problem

One of our experiences from the laboratory exercises has been that the students have a quite limited understanding of different basic techniques. One such technique is the polymerase chain reaction (PCR) which is a fundamental part of many analyses in molecular biology. The theoretical background for this technique is covered in the lectures and is thoroughly described in the textbook for the course. Still, we have found that many students find it hard to explain the PCR technique and its use when they get to laboratory. When they use the technique in the laboratory they often just follow the protocol without reflecting on the rationale. Troubleshooting forms a special problem, for example when the students don't get the expected outcome of the reaction. Then the student has to analyze, argue and conclude and almost no student has been able to do that properly in the previous years.

Aim

In the following I will try to analyse why the learning outcome has been limited and how we can improve the teaching and increase learning outcome of the theoretical teaching of the PCR technique. I will describe an alternative plan for the lecture on PCR and I will evaluate the actual execution of this plan as the course was running in March 2009. Finally, I will evaluate the effect of the new teaching and learning activities based on discussions with students in the laboratory and on their written laboratory reports.

Analysis of the existing problem

The course is generally burdened by a large curriculum, where the students have to read up to three chapters for one day and in two weeks they get through 500 pages of a text book at an advanced level. The large curriculum is a huge challenge for both the students and the teacher. For the student the many pages leave them with insufficient time to go in depth with the material. Teaching in the block structure, where the students focus on one course over four weeks may even intensify this problem. The students do not just have three long chapters for one day they have two big chapters again tomorrow and again the day after. New information is coming in such a pace that it can be almost impossible for the student to keep up with it. This is of course frustrating for the student and it strongly discourages a deep approach to learning.

For the teacher the great challenge is to enable the student to cope with the curriculum in a constructive way. There is an overhanging danger that coverage will be emphasized at the expense of depth. The teaching can easily end up in transmitting information by quickly going through a number of bullet lists. This will further encourage surface learning by the student. In the worst case this may even destroy interest in the topic even for the student who from the beginning was motivated and interested.

I think this is a fundamental problem for the entire course which also concerns the teaching and learning about the PCR technique. But it is also a problem which has all along been recognized by the teachers and they have dealt with it. However, I think it is fair to say that the teachers' ways of dealing with this problem have largely been focused on what the teacher should do in order to give the students the knowledge they should have. Focus has been on what the teacher should do to make the teaching as effective as possible. Different teachers have done great efforts to clarify the topics, to make power point slides illustrative, precise, concise and interesting. They have done everything they could to keep the attention from the students and to keep the lectures from getting boring. However, in all this, focus has been on what the teacher should do and the student has been left as a passive listener. Any active participation of the student has been on the students' initiative, in the way that questions and dialogue has been welcome in the class. But only very few students take such an initiative and it quickly dies out when it is not encouraged and nourished by the teacher. The result has been a one-way communication of a very good quality but at a high speed and with the student as a passive receiver of information.

This has not supported a deep approach to learning by the students. This is a serious problem in the teaching of PCR technology and a likely cause of the limited learning outcome in this topic in previous years.

Key-points for improvement

The question is now: What sort of teaching would best help the students engage the learning activities that could lead to the intended learning outcome? In the following I will focus on three factors which I think are key-issues in a solution to this problem. These are 1) motivation, 2) a good and positive teaching and learning climate and 3) student activities which can support deep learning. I will focus exclusively on the teaching covering the PCR technique. I will describe the intended learning outcome of this lecture and I will give my suggestion for how teaching should be performed and at the same time describe arguments for and the rationale behind the chosen teaching and learning activities.

This year's course in Biomedicine Module 1 is attended by 24 students. All of them have had a course in basic genetics where PCR has also been touched upon. It is two years since they had this course. They normally have no practical experience with laboratory work.

Intended learning outcome and criteria for evaluation

My definition of the intended learning outcome from the lecture on PCR techniques is that:

- The students should understand how PCR is a method to explore DNA.
- The students should be able to describe all central elements of the technique and be able to design a set of primers for a specific PCR given a DNA sequence.
- They should comprehend the logic of the polymerase chain reaction and be able to explain each step in the reaction and its outcome.
- When presented for different cases where the PCR went wrong they should be able to apply their knowledge in troubleshooting and give suggestions to correct the reaction. In doing this they should relate to the principles and reflect on the knowledge they have obtained during the lecture.

I will not use the final exam of the course to evaluate the learning outcome of this lecture. Instead I will use questions and dialogue during the laboratory exercises and the written reports on the exercises. In the laboratory the students will perform PCR a number of times and almost all of them will at least once end up with a PCR that does not work correct – experience tells us. In this way the task to be assessed is aligned with the intended learning outcome.

Proposal for an alternative teaching plan

I will begin the lecture with an institutionalization by giving examples of usage of PCR in various "real-life" situations from our own laboratory. By this I aim to give the students an idea about why the technique is used and how widely it is used in solving very different problems. Setting the stage of the lecture and motivating the students for learning are the central points here. My goal is to motivate the students by illustrating the value and usefulness of the knowledge they are about to receive. By connecting to everyday situations from the laboratory I also want to bring the topic "down-to-earth", thereby give the students the feeling that this knowledge is achievable. I want to give the students the expectation that they can have a successful learning outcome of the days lecture.

After this I will start with the broad picture mentioning different methods to explore DNA. I will then focus on the PCR technique by briefly telling about the invention of the technique. I will try to asses how much the students remember about PCR from previous courses / basic genetics. I will do this by simply asking the class to tell me anything they remember. I will emphasize that independent facts are ok. This is a very important step in the lecture. The students' answers will tell me at what level I shall continue.

After this I will give a quick overview of the reaction. This should work as a map with milestones, a map the students can relate to when we afterwards go through each step in details. This overview should give the student an idea about where we come from, where we are and where we are going as we go through the details. I think keeping a clear line in the lecture and a clear goal is very important in order not to discourage students from participating in their own learning.

Next I will describe details about each component and each step in the reaction. I use the same figure for illustration for both the overview and the explanations for details, and as I go along I mark the current point on

the figure with a red frame. During my exposition I will try to involve the students with questions and make clear that there is room for their questions to me.

After this theoretical exposition of the technique I will encourage the students to engage more actively in their learning of the subject. I will do this by presenting two cases, one where the students get a DNA sequence with a target region indicated and another where they get two gel pictures with the result of a PCR reaction.

For both exercises they are to work in groups of three to four students. The groups will give each student a possibility to contribute with different fragments of knowledge of which the group hopefully can make a good combined solution to the problem. In doing this the students will reflect on the theoretical knowledge they just learned and through discussions they will have a chance to catch misunderstandings and help each other to a more correct and deeper understanding of the subject. In applying the theoretical knowledge on the case the students will explore the potential usefulness of what they learned. This will hopefully help the students to let the knowledge settle in their mind in a well ordered way.

In the first case the students should select a pair of primers designed to amplify the indicated region. The main challenge here is to get the orientation of both primers right.

In the other case pictures of gels are handed out on prints. On one of the pictures there is a size ladder but no PCR product, on the other there is smears of DNA coursed by unspecific amplification. I ask the students to select one of the pictures and discuss what they see, and what possibly went wrong. A picture of a gel with the product of a successful PCR is shown on a power point slide.

While the students are working on the cases I will go and ask different groups to come to the blackboard later and give their suggestion for a solution for a specific part of one of the cases. In this way they can prepare themselves and I won't have to wait for volunteers.

Specific improvements

What I will generally aim at in this lecture compared to previous years' lectures is to supply the students with activities that can support a deeper approach to learning. These activities are:

- I will encourage the students to ask questions and engage in discussions whenever they need.
- I will try to involve the students in describing and discussing each step of the PCR in order to help them memorize and understand key events in the reaction.
- Most importantly we will work on cases where the students will have to apply their knowledge, integrate, analyze, argue and conclude in order to plan a hypothetical repetition of a PCR experiment.

Additionally, I will make an effort to motivate the students by illustrating how the day's topic is of importance in solving many different problems in our own lab, i.e. in a world where they may see themselves in a few years time. By referring to our everyday life I will also try do de-mystify the subject to make the students see that understanding of this subject is achievable and obtainable with just a little effort from them.

A few reflections after giving the lecture

The lecture was given in March 2009. Seventeen students meet for the lecture.

When I ask to their background knowledge about PCR, before I start my own exposition of the subject, I get a good response from three students. One student makes a minor mistake by referring to a primer as a probe. I correct this nice and easily. We already have a good atmosphere where students can make mistakes and learn from them without feeling embarrassed. Responses from the three students indicate that I have a good foundation to build on in today's lecture. However, I don't know if the rest of the class has the same understanding. A better way might be to ask all students to write down at least one fact about PCR and when all had done that they could read it up.

Even though I try to involve the students in the detailed description of PCR, this part easily becomes the long and tiresome part of the lecture.

I involve the students in discussing the steps of the temperature cycle of PCR. There is again good response and a fruitful atmosphere. Input from the students gives good points to elaborate on.

The first case about primer design is working well. There are good discussions in all groups. I can see that almost all groups have problems with the orientation of the forward primer. Because it seems to be a general problem I leave this to be discussed in plenum when a solution is presented by a

group. The presenting group does well but they have got the orientation of the forward primer wrong. I show them how their primers will anneal and let themselves identify the problem. Within a few moments they correct their mistake and make a primer with the right orientation.

There are a lot of good suggestions about what went wrong in the cases with unsuccessful PCR, from both the presenting group and from the class. The students only miss one point namely low annealing temperature as a cause of unspecific amplification.

Assessment of learning outcome

The learning outcome from the lecture on PCR technique was assessed through questions and dialogue with students during the practical laboratory exercises two to four weeks after the theoretical part of the course and via the students' written reports.

The students are divided in two groups for the laboratory exercises. During the exercises the students are taught by a teacher assisted by a laboratory technician. I taught one of the groups while a colleague taught the other. Hence, I follow one group closely. For the other group I try to mingle as much as possible in the lab, listening to their discussion, observing their approach to the work, and occasionally asking questions. The same technician participated in teaching both groups.

As expected almost all students encounter problems with a PCR at least once during the laboratory exercises. Their problems are equivalent to the case with different pictures of gels with unsuccessful PCR products. By evaluating how the students deal with these problems it appears that the obtained learning varies quite a lot between them.

A few students clearly just want to get the exercises done as quickly as possible. They are clearly not motivated for learning and they have a surface approach to learning during the practical teaching of the exercises. These students do not want to put much of an effort into finding the cause of their missing success. In dialogue and in the reports these students demonstrate a lack of understanding and some basic elements and key events are misunderstood. Interestingly some of the students who perform worst are two of the students who initially gave good response during lecture, when I asked to the students' background knowledge on PCR before my teaching.

Other students do an effort when they are asked for it and a few students engage the task with great enthusiasm. They all demonstrate that they re-

member facts about the different components and steps of the reaction and they are to different degrees able to integrate their knowledge with their actual results and identify possible problems. It is clear that it is a bit hard to recall right away what they learned two to four weeks ago but still, they know they have the tools to solve their problem, they just have to find them again when they suddenly need them.

Discussion and conclusion

Two to four weeks passed between the lecture and the laboratory exercises. This clearly made it difficult for many students to make the same troubleshooting on their own unsuccessful PCR as they had made in the case during the lecture. Given the large curriculum and the volume of information they had met since the lecture this was indeed expectable. That the majority of students could actually deal appropriately with the task during the laboratory exercise indicates that the learning outcome of the lecture was good. According to the laboratory technician, who has followed the course over several years, this was also improved compared to previous years.

During the laboratory exercises the class was divided in two. One group was taught by me and the other by a colleague. My colleague repeatedly complained that her group lacked motivation. This was not the experience with my group. Why it was so, is hard for me to account for but the lack of motivation on one team certainly affects the engagement in troubleshooting and hence gives a bad impression of the students learning outcome from the lecture. Hence, it is to some degree a question if the learning outcome from the lecture was poor or if the conditions for evaluating the learning outcome were not optimal for one of the groups.

Some of the students who in the lecture demonstrated good background knowledge about PCR actually performed worst during the exercises. These were two foreigners who had their bachelor degree from other universities. Their good response regarding previous knowledge indicates that they probably learned more about PCR on their basic courses than our own bachelors. I am afraid that this might have given them the impression that they already knew enough about the day's subject so that there would be nothing to gain from engaging actively in learning during the lecture. This might have been prevented if I had stated the intended learning outcome more clearly in the beginning of the lecture; thereby making them aware what they now had a chance to build on a new layer in their knowledge about

PCR. Their good background could be used in a positive way to point out that they actually were in a first class position to learn more.

The majority of students were able to deal with PCR problems in a way that demonstrated a good level of understanding of general principles and ability to apply this knowledge into a practical solution of a specific and real problem. This level of understanding was an improvement compared to what we have seen in previous years. Hence, it seems that the teaching and learning activities in the theoretical exposition of the PCR technique have had a positive effect on learning outcome.

Now, what could still be improved? As stated above, going through the details of the PCR easily becomes a tedious part of the lecture. Still, this is an important part of the learning objectives. Hence, this part should receive more attention. It is important that the students engage actively in learning this part, and we need to stimulate new activities to facilitate this.

In conclusion the new teaching and learning activities in this year's teaching in PCR techniques had a positive effect on the obtained learning for a majority of students. However, improvements are still possible for example in motivating students by making clear that there is a potential for advancement in knowledge even though you may have good background knowledge. Also, there is still room for many more activities which could support learning with a deep approach. The large curriculum to be covered in a short period is a great challenge not only for teaching of the PCR technique but for the entire course. Therefore, the problem that we have been dealing with here is probably a general problem for the entire course and the total learning outcome from the course might be improved if changes similar to those described here for the teaching of one specific technique were considered for all topics in the course.

A Appendix: Part of the Course description

Part of the course description

Source: http://www.kursusinfo.life.ku.dk/Kurser/300056.aspx

Biomedicine, module 1 - 300056

Course Description 2009/2010

Please note: Course Description 2008/2009 is also available.

Overview:

Course Contents
The course provides the basis for understanding the general theoretical and practical possibilities for working with pro- and eukaryot genomes and products from these. Furthermore, the course provides a basis for understanding the general principles related to molecular pathology and diagnostics. The course is based on "state-of-the-art" molecular biological techniques and it provides an introduction to Bioimaging and sophisticated use of microscopy.

Teaching And Learning Methods
Lectures, cases, theoretical and practical exercises.

Learning Outcome
Learning Outcome
- Describe the structure and function of the mammalian genome
- Describe the structure and function of the prokaryote genome
- Summarize the main issues in relation to genetic mapping of qualitative and quantitative traits in mammals
- Summarize the main issues in relation to identification of mutations that are responsible for diseases in mammals
- Describe the main molecular biological methods that are used in relation to research

within the area of pro- and eukaryote genomics
- Perform the basic molecular biological techniques used in relation to research within the area of pro- and eukaryote genomics
- Understand and provide a critical evaluation of literature describing basic molecular pathological problems

Skills
- Evaluate which molecular genetic techniques are relevant for the study of a given genetic problem
- Evaluate the result of a sequencing analysis
- Perform basic annotation of sequence information
- Analyse and evaluate results from simple diagnostic tests in mammals
- Analyse and evaluate results of parentage tests
- Analyse and evaluate results of expression studies
- Be able to discuss professional and scientific problems in relation to molecular pathology both with colleagues and non-specialists

Competences
- Be able to find new information/literature on topics within the area of genomics
- Be able to take responsibility for own professional development and specialization within the area of molecular biology

Mark 12: A student that has passed the exam of the course with mark 12 must have answered all sub-questions within each of the 5 questions satisfactorily .

B Appendix: Teaching plan – theoretical and practical parts

Teaching plan, theoretical part

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Dato	Ca. tid	Emne	Form	Literatur*	Lære
Mandag d. 2/2	9-10	Intro to course and brush up			-
	10:15-11 11:15-12	Intro to Exercise 1 Genes in pedigrees	Results in report Lecture	 Chapter 4	-
Tuesday 3/2	9-11 11:15-12	Analyzing DNA	Lecture	Chapter 5, 6 & 7	-
Wednesday 4/2	11:15-12 13-14	Genome projects and organization of the mammalian genome Paper for group work (Exercise 3)**	Lecture Results in report	Chapter 8 & 9	-
Thursday 5/2	9-11	Gen expression	Lecture	Chapter 10	-
Friday 6/2	9-11	Comparative genomics	Lecture	Chapter 11 & 12	-
Monday 9/2	9-12 12:30-15	Identification of disease genes: simple and complex traits Exercise 2	Lecture Results in report	Chapter 13, 14 &15	-
Wednesday 11/2	9-11	Molecular pathology/cancer genetics	Lecture	Chapter 16 & 17	-
Friday 13/2	9-10 10:15-11	Genetic testing Beyond the genome projects	Lecture Lecture	Chapter 18 Chapter 19	-
Monday 18/2	9-15	The microbiology genome; phylogenetics; transcriptomics	Lecture		-
Tuesday 19/2	9-9:45 10-12:30	Bioimaging: overview and techniques Immunocytokemi and fluorescensmikroskopi	Lecture Lecture		-
Wednesday 20/2	9-11 12:30	Transmisson electron microscopy Manipulation of cells and animals	Lecture Lecture	 Chapter 20 &21	-
Thursday 21/2	13-14 (H1) 14-15 (H2)	Confocal laser scanning microscopy	Demonstration§		-

Teaching plan, practical part

Week 1

	Monday 16/3	Tuesday 17/3	Wednesday 18/3	Thursday 19/3	Friday 20/3
9:00-12:00	**Introduction to the practicals** (MF) **Briefing** (PKM/SCS) **Personal presentation** **Safety** (TNM) **Labtour** (TNM, MMJ) Extraction of DNA (A.1)	**Briefing** (PKM/SCS) Extraction of DNA(A.1) OD (A.1) PCR(A.2) cDNA synthesis (D)	**Briefing** (PKM/SCS) Cleaning PCR product (A.3) OD (A.3) Ligation (A.3) Transformation (A.3)	**Briefing** (PKM/SCS) PCR paternity (B) Count colonies (A.3) Set up o/n cultures for miniprep (A.3)	**Briefing** (PKMSCS) Miniprep (A.3) OD miniprep (A.3) Digest miniprep (A.3) Gel electrophoresis (A.3)
12:00-12:30	Lunch	Lunch	Lunch	Lunch	Lunch
12:30-16:00		Gel electrophoresis (A.2)	Plating (A.3)	Run PCR in ABI3130 (B)	Sequencing reaction (A.4))

Week2

	Monday 23/3	Tuesday 14/3
9:00-12:00	**Briefing** (PKM/SCS) Precipitate DNA sequencing reaction (A.4) Sequencing run on ABI3130 (A.4) PCR on somatic panel (C)	**Briefing** (PKM/SCS) Run agarose gel/analysis results (C) Sequence analysis (A.4) Discussion of results (A,B,C) (PKM/SCS)
12:00-12:30	Lunch	Lunch
12:30-16:00	qRT-PCR (D) Analysis of Paternity (B)	Analysis of qRT-PCR results (D) **Theoretical background and demonstration:** blotting techniques (SCS)

All contributions to this volume can be found at:

http://www.ind.ku.dk/publikationer/up_projekter/2008-1/

The bibliography can be found at:

http://www.ind.ku.dk/publikationer/up_projekter/kapitler/2008_vol1_bibliography.pdf/