1. Background

I am employed as a Lector in Microbiology in the Institute of Chemistry and Molecular Biology. I currently teach two courses in Microbiology and am a researcher in the regulation of gene expression in bacteria with a recent focus on antibiotic resistance. In addition, I am a member the PIL (Pedagogic Development and Interactive Learning) unit at the University and am actively involved in improving the educational quality at the University. I have taught Microbiology courses at all university levels both in Sweden and abroad, and as part of my work with PIL, I teach pedagogics to researchers at Natural Sciences and Sahlgrenska. I am presently expanding my teaching to include an open online course concerning the problem of antibiotic resistance.

2. Higher education courses and study programmes

Subject Related Courses

As detailed in appendix A, I have received a B.S. in Molecular Genetics (University of Rochester, 1983), a PhD in Cell and Molecular Biology studying the effect of temperature on protein synthesis in bacteria (University of Michigan, 1993) and a Docent in Microbiology (Gothenburg University, 2002). All of these programs contained courses which qualify me to teach within my specialization of Microbiology and Molecular Biology. In addition, I have published more than 25 original research articles in Molecular Microbiology in international journals.

Pedagogic Courses

I am in the process of completing courses to obtain a Master's (magisterexamen) degree in Higher education. I have completed HPE101, 103, 201, 302, am currently completing HPE401 and will register for HPE303 in the Fall (Appendix B). I am also the course leader for HPE102. My aim is begin my project work (examensarbete) in the summer of 2016.

3. Experience of teaching and supervision within higher education

Teaching

Over the last decade, my teaching load has fluctuated between 50-70% of my time. I have taught first year students, advanced undergraduate (B.S.) students, Master's students and PhD students as listed in Appendix C. Additionally, I am course leader of HPE102 (Natural Sciences) which is a pedagogic development course primarily aimed at early career researchers (forskarassistant) but also open to PhD students, Postdoctoral students, Lectors and Professors. My work in these courses are described more fully in the next sections.

Supervision

Supervision of students is an integral part of teaching in a university setting and I prefer to always have one or more undergraduate students in the lab. I have supervised more than 30 BS and MS projects to completion during my time at GU (Appendix D). Additionally, I have been primary supervisor for two completed PhD students and am currently co-supervisor for one PhD student. I currently have three BS students completing their 15 hp project work and have committed to two Master's students (60 hp) beginning in the Fall of 2015.

4. Pedagogic Activities-Description, reflection and development

<u>Teaching philosophy</u>

The core of my teaching approach centers on several principles:

1. Active Learning. Students actively engaged with course material learn more deeply and remember the material better than passive students.
2. Scientific Method. Material should always be presented in terms of evidence and experimentation.
3. Docendo discimus, 'When we teach, we learn'. Having students explain concepts to each other leads to more efficient learning than by my explaining concepts.
4. Motivation. Motivating students through enthusiasm and excitement in the topic is a prerequisite to learning.
5. Less is more. Students who learn a topic well and in depth have a greater conceptual understanding than those who learn many topics superficially.
6. Inquiry Based Laboratories. Laboratories should aim to teach students experimental design and data analysis as much as techniques and engage their scientific curiosity.

I have previously written detailed reflections on two of my teaching experiences, that of course development and teaching in BIO510 (Prokaryotic Molecular Microbiology) and my experience as a STINT fellow at Williams College, USA, teaching a course in Microbiology. I have included these two papers in Appendices 1 and 2. In this section, I will focus more generally on my path from my first teaching assignment to my current teaching activities, highlighting some of the milestones in the development of my teaching philosophy.

When I received my first major teaching assignment (course leader of a 15 hp course in Microbiology), I had worked as a researcher for 15 years with almost no teaching experience and next to no interest in being a teacher or studying pedagogics. Like many natural science researchers, I am sad to say I had a view of teaching as a second rate activity: something one has to do to be able to keep one's job as a researcher at a university but otherwise uninteresting. In addition, I had no experience as a student outside that of the lecture format. I still remember being stunned when a professor who taught me in my last year of university asked me if everything was clear in the day's lecture. Stunned, because I had never actually spoken to any of my lecturers in the sciences in 4 years of education.

In other words, I was primed to become a stunningly bad university teacher!

However, I quickly learned that lecturing in the absence of feedback from the students is both very dull and ineffective. I had the experience that many teachers can relate to where I gave a brilliantly clear lecture on a topic (in my opinion) only to discover on the exam that my students, at best, could only mimic what I had told them with no evidence of deeper understanding or, at worst, had forgotten the topic entirely. In other words, I discovered the principle that it was not important what I said in the classroom that was relevant, but rather what the students learned. In pedagogics terms (as I learned later), I began to shift my teaching from being teacher-centered to student-centered.

Over time, I began to change more and more of my classroom hours into various types of active learning activities. Note, I prefer the term active learning over many others as I feel terms such as problem based learning can be misunderstood and can mean different things to different people. Active learning includes any activity where the students are actively interacting with the course material (e.g., Handelsman, et al. 2007). Initially, I designed my courses to include both formal lectures and student-led presentations. These were very popular and I was impressed with how much work my students did in these courses. The student-led presentations in particular led me to see the value of using peer-teaching as the 'teachers' learned the material very well and generally could explain it well to the class. Of course, I am also always an active participant in these discussions so I can be sure the class as a whole learns the material. I saw a clear improvement in how well the students could do on exam questions that required deeper understanding. Additionally, this format gave the students experience in the so-called secondary skills of oral and written presentation, self-directed literature research and data analysis.

Over time, though, I have begun to incorporate more varied activities into my courses. A personal favorite is the interrupted case study (Herreid, 2005) where students work through a problem or research topic in a stepwise manner. This allows them time to think through each step of the problem carefully and in their own manner before the teacher checks on understanding and allows them to continue to the next step. An example of this type of exercise is attached in Appendix E1: Adaptive mutations. I have also begun to use more and more internet resources, usually assigned as homework, which then can be discussed in class (a flipped classroom format).

It was at this point in my teaching career (about 6 years in) that I won the Gothenburg University pedagogics prize for innovative teaching. I mention this not just to be proud, but it was at this point that other people started asking what exactly I was doing in my courses! It was also when I first started to become interested in pedagogics as a research topic. This became a transformative moment in my path. First, I realized that there was an entire field of pedagogics describing much of what I had learned over the last years (and much more!), though generally written in a format that was inaccessible to natural science researchers/lecturers. I began to study pedagogics and be able to connect my own observations to published literature and research. Second, I now began to get opportunities (most recently in HPE102) to describe to others what I had learned.

Next, I will summarize what I find most fundamental in teaching science and describe my work in teaching others about these fundamentals.

What I have learned (so far):

Science is often perceived as a dry, fact filled subject. There are complicated names, difficult concepts about things we cannot see, big books full of mathematics or formulas. It is no wonder many people find it intimidating and/or boring. But science is actually a way of thinking about the world; a way of organizing our knowledge and discovering new information. It is a process, not a static set of information. Every researcher knows this and is fully invested in using the scientific method to advance our understanding of the natural world. Yet, when we teach we often make the mistake of distilling science into those facts or theories we know rather than teaching the process. Why do we do this?

When I ask teachers at the university this question, I am usually told that there is so much information for our students to learn, there is no time to do anything but tell the students that information. There is no time for deeper understanding or the scientific method in the classroom. This, I think, is a fundamental error.

The National Academy of Sciences (1999) summarized three pedagogic principles that should be considered in any scientific teaching and below is my interpretation of these principles.

1. Students come to class with preconceptions. Students do not absorb new information in a pure an unadulterated way: new information is placed into a framework of preexisting knowledge and if that framework is incorrect or incomplete, misconceptions can occur. An example of this (when it goes poorly) might be a case of a student seeing the random movements of a particle under the microscope due to small currents in the fluid and interpreting it as purposeful directed movement or even life. The student lacks a foundation of information about how very small particles might move in this environment and thus constructs their own explanation in context of what they do know.
2. Students must learn new facts but also organize these facts in a contextual framework. Memorizing facts without context is a) very difficult and b) does not lead to deeper understanding of organizing principles. An example of this might be the attempt to remove evolution from the teaching of Biology. Biology without evolution is a collection of very cool facts, but it does not allow you to make predictions about new information or to interpret known facts. Placing the information in the context of the underlying principle allows us to learn the information more easily and to extend our knowledge of both general biology and evolution
3. Metacognition. Simply put, a student needs to think about what they have learned and recognize what they do not understand. Dialogue between teacher and student can encourage metacognition.

In a practical sense, the way in which I use these concepts in everyday teaching is first that all information is presented in terms of the scientific method. This both gives context and connects the new information to previous knowledge. In other words, teaching with the scientific method aligns very closely with a constructivist view of teaching and learning (constructivism is reviewed in Biggs and Tang, 2007). We start with the question, we discuss the experiments and data and make conclusions. Students learn not only the 'facts' but also the method of interpretation (experimental design, data analysis, etc.). This can be most effectively done, in my experience, using active learning. This view has been recently supported by a large meta-analysis of active learning vs. lecture formats in science classes (Freeman, et al., 2014). Secondly, metacognition is encouraged by creating learning environments which require the students to explain concepts to their peers or teachers, and by encouraging questions. Finally, students are assessed primarily on their ability to apply conceptual information which encourages them to learn the concepts. Students tend to focus on learning those things which are assessed. In the attached paper, I describe in detail how I implemented these principles in one course (Appendix 1).

Teaching how to teach

For the last 5 years I have been invited to teach HPE102 (Higher Education in Natural Sciences) and have taught approximately 200 students in this course aimed at new lecturers at the university (forskareassistant/postdoc level). This has been a very challenging course because the majority of the students are at the same point in their career development that I was when I was handed my first course. In other words, the majority view themselves as researchers and that is where their passion and interest lies. This required course takes their very valuable time away from doing research. Thus, this is generally not the happiest group on day 1 of the course! (However, this negative attitude is diminishing gradually as the course gains a positive reputation.)

How does one teach how to teach to a group with little interest? The lessons I have learned teaching Microbiology have served me well in designing this course. First, what do the students need to learn and how can I most effectively get them to learn it? In my opinion, I think the most important lesson to teach in this course are the concepts I listed in the previous section: Science should be taught using the scientific method as a foundation, students need to be encouraged to take an active role in their own learning and assessment needs to align with the learning objectives of the course. How does one teach this? Teaching the students what is meant by the concepts of active learning, constructivism, etc., is relatively simple and can be taught in many ways, but there is a second related goal here. Even if the HPE102 students know about these concepts, they are not usually convinced of its value. This leads to the more challenging part of teaching this course: how can I convince natural science researchers that they can improve their teaching by applying these concepts and that this is a worthwhile endeavor?

With these goals and concerns in mind I teach this course very much like I would teach my Microbiology courses. In other words, we use active learning techniques to demonstrate the methods and place them in context of pedagogic principles. The students thus can see how the methods work and can connect these experiences with their theoretical knowledge of pedagogics. In other words, to teach 'active learning', I use 'active learning'.

A second aspect of this course relates to teaching using the scientific method. Researchers in natural sciences generally find pedagogics literature to be 'fluffy' and insubstantial. We like data and evidence. For that reason, the literature I assign in this course relies heavily on evidence based research articles whenever possible.

In summary, the overall structure of this course is that it contains three interrelated themes: first, a theoretical perspective of learning theory and pedagogics, second, in class active learning activities to demonstrate the power of these theories and third, practice topics to allow the students to a) design a course and b) test an activity in their own field with a test class. The reaction to this course has been very positive. The course evaluations are always extremely positive overall (One course report is included in Appendix I), though I have tested and removed individual classes that did not go as well over the years. Even more rewarding, I receive many emails or other personal communications each year thanking me for the course and saying how a researcher has incorporated one of the course ideas into their own course and seen positive results.

Despite this being the most difficult course to teach it has quickly become the most rewarding since I can see I am making an impact at the university outside my own microbiology students.

<u>Teaching with a theme</u>

After teaching Microbiology (BIO275) for many years, I decided it was time to make a major change in 2008. I did this for two reasons. First, I began to find myself getting bored teaching the same topic in the same way. This is bad not only for me, but more importantly, enthusiasm is an absolute requirement for effective teaching. Second, I wanted to make the course more concrete and tied to current problems rather than abstract to increase student interest as well as learning. It occurred to me that I could redesign my course with the theme of antibiotic resistance.

Antibiotic resistance reaching crisis proportions (WHO, 2014) and this problem is increasingly being covered by the mainstream media. Thus, the majority of my students would have at least casual acquaintance with this issue and many would have concerns about the problem. In addition, it *is* a crisis and knowledge about this problem needs to be disseminated, especially to biology students who may decide on careers in research.

To design this course I started with two design principles. First, I made a list of the topics and related learning objectives that were included in the existing course and then link each of these with an aspect of research or knowledge about the problem, mechanism or potential approaches to the problem of antibiotic resistance. For example, instead of teaching about horizontal gene transfer in the abstract, we can learn how inhibition of horizontal gene transfer might be a good approach to decreasing the spread of antibiotic resistance. The second design principle I used was to treat this as an extended, directed variation of problem based learning. I start the class by giving them a video about the problem of antibiotic resistance and ask them to brainstorm on the question 'If I gave you a million dollars of research funding to address this problem, what would you need to learn before you could design a research program?' The students work on this alone at first and then in small groups in the classroom. This is similar to the early steps in a traditional PBL session where the students decide what they need to learn (Wood, 2003). Then, as a class we create a common list of topics and issues we need to learn to become researchers in this field. I, of course, have my own list but usually all of the topics I want to address are suggested by the students.

Now we have established the topic-based learning objectives for the course as a group. Note, I have further learning objectives such as data analysis, critical reading of research articles, etc., but these are built-in to the methodologies we use for the remainder of the course. Because I have begun the course with a real world problem and have gotten the students to define their own learning objectives, I already have from the very beginning a class that is very invested in the course. I now, explain the methodology we will use to study these topics as we go through the course (few lectures, in-class activities, flipped classroom activities and student-led presentations and discussions). The last three weeks of the course are devoted to topics that do not fit into the theme but using the same teaching methodology.

I want to emphasize also that this course uses the principle of 'Less is More' or perhaps I should say 'Learning one thing deeply is better than learning many things superficially'. My aim in this course (and all my courses) is to teach the students how to learn new material using the scientific method. I know most of the students will not become researchers in antibiotic resistance, but the foundation they learn in this course will enable them to study any branch of microbiology or indeed science in general. The students are given a copy of the teaching philosophy regarding this point at the start of the course (an example is included in Appendix E6).

This course has been very well received. The students are very interested and active and the course evaluations are very positive. I will mention below some future work I will do in this course.

<u>Research and Teaching</u>

An ideal that most modern universities strive to meet is that good teaching is best done by active researchers. We all know that there are problems in the implementation of this ideal but the concept of a University Lector as an inspired teacher and internationally recognized researcher is, in my view, a worthy goal. Often we speak of how research can improve teaching: by making sure the researcher is up-to-date in the field and passionate about their topic. In other words, the students can benefit from having good researchers as teachers. What we don't speak much about though is how teaching can inform and help research. This explains part of the reason there is a conflict between research and teaching at many research universities.

As I stated above in the summary of my teaching philosophy, I strongly feel that 'To teach is to learn'. I've indicated how I use that philosophy in creating learning environments for my students, but it also applies to the course leader. Explaining concepts to students can both help us to think about our topics at a deeper level and occasionally make us aware of fundamental issues in our field. In addition, teaching outside our own narrow specialty can make us more aware of how our field connects with other topics.

I have thought a lot about this issue in recent years in light of my research interests. I have focused on relatively obscure though fascinating questions regarding global gene regulation in bacteria for all of my career. However, after teaching the new antibiotic resistance themed Microbiology course for a couple of years and reading much on this topic, I came to the realization that much of my previous work has prepared me to apply my knowledge and research time to this problem. To this end, I have two collaborations regarding the problem of resistance and am actively applying for funding with other collaborators to expand the time I can devote to this problem. This was a completely unexpected turn of events which only came about because I decided to redesign my course in Microbiology!

Future work

I have lots of ideas and too little time, but there are several pedagogic projects I am committing to pursue in the immediate future.

Open educational resource on Antibiotic Resistance. I am creating a course/resource in collaboration with PIL on the topic of antibiotic resistance. The material for this is directly related to my microbiology course, but it is aimed at the general public with little science background. This was originally envisioned as a MOOC but we have decided to create a site with a combination of a course and more static resources (see section 9). I am also applying for funding to include this in a proposed antibiotic resistance center at GU (UGOT Challenges).

Redesign of the Laboratory for Microbiology. The Microbiology lab will be changed to incorporate labs of the 'Small World Initiative: Crowdsourcing the Discovery of Antibiotics' (http://cst.yale.edu/swi). This initiative aims to allow students to contribute to the global search for new antibiotics produced by soil bacteria. Many common antibiotics were identified this way and most scientists agree that the potential of this environment is not saturated. This group at Yale University has made available basic lab protocols to allow teachers to easily write a version of this lab into their courses. In addition, the information can be uploaded to their web site as a resource for researchers in antibiotic resistance. In the long term, I would be interested in helping introduce this into high school (gymnasium) courses and expanding the program into the chemistry courses at GU.

Publishing of Resources Finally, I am very motivated to write up both some of my resources for teaching for publication as well as writing papers to be used in the HPE102 course. As I mentioned, the literature for HPE102 is a difficult issue as much of the pedagogic literature is rather inaccessible to science researchers.

5. Development of teaching materials and other student learning resources

As described above, I use a variety of teaching methods in my courses. Additionally, it is vitally important that the subject matter remain current. For this reason, I have developed most of the teaching materials for my courses. Generally, I use a given resource for only a limited number of years and freshen my material on a rotating basis. The types of resources I have developed are described below and examples are included in Appendix E.

Worksheets and activities to supplement or replace lectures

I have created a number of activities for many courses designed to help the students work through difficult concepts. These are generally done in a flipped classroom type setting where the students prepare before the class and then we work through the activity together. An example of this is the interrupted case study included in Appendix E1: Adaptive Mutations. This is a topic which is very subtle which is why it often fails as a lecture. I can give the lecture and students think they understand, but they have not thought through the subtleties of the problem and the experiments. This worksheet gives them time to think through the problem and allows me to play the role of the facilitator during the class. Other worksheets are assigned to the students to do at home using internet resources including videos to move review topics out of the classroom to give us more time in the class for more advanced topics. Finally, some activities are designed to inject more interest in the students in what can be considered a dry topic. An example of this is ‘Natural Born Killers: a debate activity on Phage Therapy’ (Appendix E2). All of these types of activities are generally seen as positive by the students and based on their assessments, increase their knowledge in the subject.

Research Paper Based Case Studies

As described above, one approach I find very useful is student presentations and discussions of original research articles. This is because the students leading the discussion have a good opportunity to learn by teaching and the remainder of the class is usually very involved in discussing the papers. In general, I have a core of papers I reuse many times as they are ‘tried and tested’ and cover central issues in the topic. However, it is equally important that the material is updated regularly to keep the topic up to date with the latest research trends. For that reason, I generally update between 30% and 50% of the research articles each year. Attached is the list of case studies for BIO510 (PMM) for 2015 (Appendix E7: Case studies, Prok Mol Micro 2015). As one can see, the first half of the articles are generally older and are those that are kept more or less constant from year to year. These cover core concepts (and are well written!). The second half of the articles are all within the last few years to teach the latest trends in the topic.

Lab manuals

I have written many lab manuals over the last 15 years. Most of these have been developed from scratch. Three of these are included in Appendix E and they demonstrate different ways of approaching the lab course. Throughout my development of these course materials I have always focused on 'what will the students learn?' in these exercises. Many people assume that the purpose of doing laboratory exercises is to learn methods, practice using equipment and generally gain practical laboratory experience. Although these are often valuable learning outcomes, in my opinion they are only a small part of the value of laboratories. Methodology and equipment changes very rapidly in a science such as molecular biology. Methods I learned 30 years ago are mostly irrelevant now and even those used 5 or 10 years ago have been abandoned. If this is true, why do practical laboratories? Labs function to teach the students an approach to scientific research. Concepts such as control experiments, good laboratory practice (GLP), record keeping, sterile technique, experimental design and data analysis are always important regardless of the current methodologies. Experimental lab work can also be very fun and motivational. In addition, I also hold with the concept of 'Less is More' in terms of laboratories. It is important that students gain a deep understanding of what they are doing in the lab so that they can apply it to new techniques and topics. This idea is supported by the educational literature where inquiry based labs have been shown to increase learning in both the topic of the lab but also related topics (Luckie, et al, 2012). Thus, when I design a laboratory I always think how the lab will aid the students in developing the skills for scientific experimentation in general. Ideally, the students would have an inquiry based lab which allows and requires them to at least partially design their experiment, though the time needed for this has to be balanced with financial and personnel considerations.

The lab, The effect of growth media… (Appendix E5), was developed for the first year course called Genes and Signals. This course was designed for up to 60 students and needed to be done within a short period of time with a small number of lab assistants. Thus, it was important that the lab manual be quite simple and straightforward. However, as described above, I think the pedagogic value of laboratories can be lost if the lab is simply a cookbook lab. To balance simplicity with deeper understanding, the students are given minimal introduction of what to expect from the lab, though if they have done the reading and attended the lectures, they could easily predict most of the results. What is not obvious to the students is that one of the results (media with lactose vs. glucose plus IPTG) will give an unexpected result. In analyzing their results for the very short lab report, they should notice that this result does not fit with the information that they have been told and they should also be able to make a reasonable hypothesis to explain the result. After the lab reports are turned in we discuss this result and make sure the entire class understands the implication of their results.

The second lab, Microbiology (Appendix E3), is the latest version of the lab used during my STINT fellowship in the US and is a variation of the lab used in BIO275 at GU. This lab combines more directed lab protocols interjected with small questions and predictions to be sure the students understand what they are doing in the lab with an independent project that was very open. This was possible as I had a small class and sufficient laboratory assistants for the independent project. The students were being taught basic methods and data analysis in the first labs and then moved forward to design their own experiments in the project. The students became very motivated in this independent project and asked to be able to put in extra lab time to improve or extend their results.

Finally, an older lab manual from the master's level course, BIO510 is included (appendix E4). This course includes a laboratory project which goes throughout the entire 9 weeks of the course. The students are working on a 'real' project with no set answers. Specifically, each student pair is testing a set of mutants which may alter gene expression. Each pair has completely different mutants. Again, a balance between the practicalities of lab assistant hours/class size and the pedagogic value of independent projects is illustrated in this lab. The entire class is doing the same methods/experiments which makes it relatively easy to prepare and control the lab, but each group is working on a different mutant which means different results will be obtained by each lab group. Additionally, this lab addresses a real research problem which increases the student's sense of doing real science. It should be noted that I have not included the latest lab manual for this course because I have taken this approach a bit further now. Students now are given an overall outline of their research project, but they are given general experimental protocols not ones specifically written for this lab. In other words, they may be given the plasmid isolation protocol published by a company and need to adapt it to their specific experiment. This is done to mimic a real research environment to both increase student's interest and to prepare them for future research.

6. Experience of leading, administering and developing courses and study programmes

I have developed multiple courses at the university as listed in Appendix F. A short summary of these courses is given below and two example course evaluations are included in Appendix I.

<u>BIO275, Microbiology</u>

This is a course for 3rd year students, primarily those studying in the Molecular Biology program and a significant number of international students. This course was originally developed in 1999 and used a variety of active learning techniques including student presentations as well as original lab protocols. One of these labs is a short inquiry based lab project which gives the students a sense of true discovery in the laboratory. In 2008, I completely redesigned this course along the theme of antibiotic resistance, as described above.

I also ran this Microbiology course as a distance course for several years. It was a hybrid course with all of the theoretical work done in an online environment and labs run on the weekends. I developed all the modified course material for this course and attempted to make the course as interactive as possible in this environment. To run this course I needed to use external software (first Moodle and later TikiWiki) as our course management system did not support this interactive environment. It was an interesting experience for me to compare the learning in this environment with the campus course I had already run for many years. I presented the results of my research on this on a poster at the American Society of Microbiology (ASMCUE) meeting in 2007.

Genes and Signals, 15 hp

This was a course for 1st year students in Molecular Biology. My aim was to teach the principles of genetics and gene regulation in a wide variety of model organisms. Each week of the course concerned a different organism represented by researchers in our department, ranging from bacteria to man. We attempted to illustrate the commonalities between these disparate organisms as well as emphasize the advantages of studying each model organism. The format of the course was a combination of lectures (with discussion), laboratories and four small student presentations of research topics or problem solving. The course was quite successful and the students gave it very good student evaluations, but unfortunately the course was discontinued when the molecular biology program was folded into the biology program.

BIO510, Prokaryotic Molecular Microbiology, 15 hp

This course evolved from the course Molecular Microbiology which I co-taught from 1999-2003. It is an advanced Master's level course which attracts a large number of international students. It is described in detail in appendix 1.

HPE102, Higher Education Pedagogics for Natural Science, 5 hp

This course was designed by me in 2009 and has undergone many modifications but as described above (section 5) it aims to give researchers both inspiration to teach better at the university and the tools and knowledge to do so.

Other activities:

I was a member of GRUNDA (the undergraduate advisory committee for Natural Sciences) from 2009-2012. A major part of the work of this committee was to survey education at our faculty and internationally and make suggestions for changes in the educational environment. This was an extremely educational assignment for me as it gave me an opportunity to learn about education at all the institutes in Natural Sciences and meet with their representatives to get different perspectives on both the positive and negative aspects of teaching at GU. A major result of this work was a report recommending a number of concrete changes in policies at the faculty including the controversial suggestion that we teach courses concurrently rather than sequentially to improve student outcomes.

I am currently a member of the education advisory committee in my department giving advice on issues related to shrinking budgets, a lack of laboratory assistants and other crises as well as contributing advice on course development.

Future Work

In addition to the work I am already doing, I would very much like the opportunity to work together with the course leaders of the first year Biology and Chemistry courses to implement an inquiry based laboratory in these courses. There is already some interest in this and I will apply for supplemental funding to help us do this. I was inspired to do this because of my experience in observing the inquiry based laboratory in the first year Biology course at Williams College (see appendix 2) and based on the impressive studies of this approach over a decades long 'experiment' at the Michigan State University (Luckie, et al, 2012). Essentially these studies and my experience have shown that we likely underestimate our student's ability to actively engage with experimental design. A drastically increased inquiry based approach can improve student learning as well as student motivation.

7. Development, depth of study, research and dissemination of knowledge including specialization in teaching and learning in higher education

In addition to the work in HPE102 which I am able to use to spread my pedagogic knowledge within the faculty of natural sciences, I have participated in the PIL discussions around these courses for many years. Further, I have spoken at GU online about educational issues.

I have been invited to design and run a workshop in Education for the department of Microbiology and Immunology at Sahlgrenska Academy which I did in 2013. Similarly, I participated in a workshop on education for the Marine Sciences program and created a session of 'Inspiration for Better Teaching' in 2015. I have taught many times as part first of the PhD course on teaching and later in the PhD introductory course. In both courses, my focus has been on teaching in the laboratory setting.

I have published one paper on pedagogics to date in an international journal (Nowrouziand and Farewell, 2013) and a version of the attached paper on course development in BIO510 (Appendix 1) has been accepted to be published through PIL on their new resources in education web site. Further, this paper and another about the antibiotic resistance themed Microbiology course are in preparation to be submitted to an international journal. Finally, as part of my coursework in HPE401 I am writing a meta-analysis of research in virtual laboratory experiments and aim to submit that for publication as well.

8. Pedagogic activities outside the university

I have participated in a number of venues outside the university setting including supervision of high school (gymnasium) students in small projects, hosting visits from high school students and speaking at local high schools (listed in appendix H). Further, I have spoken about Microbiology at the Science festival in Gothenburg (Vetenskåpsfestivalan) and spoken about education at the European Microbiology (FEMS) annual conference (2009, 2015). I organized a session on Education at the FEMS meeting in 2009. I was an invited speaker to the local Rotary Club in 2015 where I spoke about active learning.

The largest pedagogic activity I have had outside our university is my STINT fellowship. I taught at Williams College in the Fall of 2014. I have described my reflections on this experience as well as some concrete ideas of changes to our educational mission in the attached STINT report (Appendix 2).

I am involved in two ongoing activities regarding educating the general public on issues concerning Microbiology. First, I began a twitter account on Microbiology News in 2014 (www.twitter.com/MicrobiolNews). This is primarily intended to be integrated into my course web site (and has been for the last two courses) but is open to the general public. Second, I am creating an online educational resource (MOOC) on the critical problem of Antibiotic Resistance for the general public.

MOOCs (massive, open, online courses) are an interesting and controversial development in the world of higher education. Many criticisms have been leveled against MOOCS mostly stating that they should not replace more traditional university education. I agree, but I fear that the backlash against MOOCs will promote 'throwing the baby out with the bathwater'. In other words, I think MOOCs can serve a purpose, and should not be dismissed because they cannot do everything (see my interview on MOOCs here: http://www.medarbetarportalen.gu.se/aktuellt/gu-journalen/arkiv/2014/nummer-3-14/hon-ar-redo-for-varlden-/). A MOOC for the general public on the biology of antibiotic resistance is of great importance to increase awareness of this critical situation. I have recently decided to combine the MOOC with a more general web site with links to further information on the problem of antibiotic resistance. This work is ongoing and expected to be opened to the public by October, 2015.

9. Other pedagogical qualifications

I have been the recipient of Pedagogic Prizes twice. In 2005, I received the GU individual award for innovation in my course Prokaryotic Molecular Microbiology (BIO510). In 2014, I received the pedagogics prize in the faculty of Natural Sciences for my work in the pedagogics course, HPE102. The motivation for each of these awards is included in appendix I.

10. Appendices

Appendix 1: Development of a course in Prokaryotic Molecular Microbiology
Appendix 2: STINT Report

Separate File:

Appendix A: Natural Science qualifications (Research CV)
Appendix B: Courses taken in Pedagogics
Appendix C: Teaching Experience
Appendix D: Supervision Experience
Appendix E: Examples of Developed Course Materials
- E1: Adaptive Mutations, Interrupted case study
- E2: Natural Born Killers: a debate activity on Phage Therapy
- E3: Microbiology Lab Manual (2014)
- E4: Prokaryotic Molecular Microbiology Lab Manual (2008)
- E5: Effect of Growth Media… Lab Manual
- E6: The case study approach
- E7: Case study papers, Prokaryotic Molecular Microbiology (2015)

Appendix F: Course Development (Table)
Appendix G: Research and Dissemination of Pedagogic Knowledge
Appendix H: Pedagogic activities outside the university (Table)
Appendix I: Pedagogic Prize Motivations and Course Evaluations

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Appendix 1

Development of and Reflections on a course in Molecular Microbiology

Anne Farewell, November 2012

1. Abstract

A common approach to teaching in natural science is to simply use the traditional lecture format to transmit information from lecturer to student. This format can work reasonably well with a charismatic teacher and students who are self-motivated to both listen in class and spend hours after class learning the material. Although I was taught this way and began my career teaching this way, there are at multiple problems with this methodology. Besides the obvious problems of non-charismatic lecturers or unmotivated students, students' classroom time is not spent learning, but rather recording information. Granted students may memorize parts of the information in class but most of the learning is done outside of class. In the age of massive readily available sources of information available online and in books, it can and should be questioned whether this is an efficient use of classroom time. In addition, this approach does little to encourage scientific thinking and problem solving. Students need training to reason in a scientific manner, e.g., forming hypotheses, experimentation, and data analysis.

In this paper, I will describe in detail one of the courses I have developed, Prokaryotic Molecular Microbiology, which has been running since 2005. I will discuss how different aspects of the course are supported by the pedagogic literature and discuss the practical aspects and results (in terms of student evaluations and student performance) of this course.

2. Science Education

Most definitions of science describe a system of knowledge or knowledge obtained through a systematic method (or scientific method). For example, the Merriam-Webster dictionary (http://www.merriam-webster.com/):

- **3 a:** knowledge or a system of knowledge covering general truths or the operation of general laws especially as obtained and tested through scientific method **b:** such knowledge or such a system of knowledge concerned with the physical world and its phenomena"

In other words, most definitions of science include the method of gaining knowledge as well as the knowledge itself in the word science. This may be self-evident for many of us in the sciences, but it lies at the center of our educational problems in science. Science is not an unrelated set of facts that can be memorized. Rather it is a framework of understanding into which facts can be inserted or deduced.

Teaching science then is very easily modeled on a constructivist platform of education (for a thorough discussion of constructivism see Biggs and Tang 2007). A major point of constructivism is that students construct knowledge by connecting it to prior knowledge and frameworks. Science works much the same way. Science uses previous knowledge to create hypothesis and experiments and new information is incorporated into a framework of understanding of the topic. Occasionally, in history, new information will change the framework entirely but most often new information can be tied to previous ideas and usually will lead to new connections and further predictions.

Given this very close relationship between a popular learning theory and the scientific method, how then could we be failing to teach science to our students? There is a general consensus that in most countries, education in the STEM topics is failing to produce students with the skills and interest in science needed for an increasingly technological world (e.g., Alberts, 2005, Merkel, 2012, Savkar &Lokere, 2010, Natl Res. Council, 1997, 2003, Wood, 2009). The reasons for this are complicated and sometimes politically charged, but a major reason is that science is not often taught with this constructivist way of thinking. Often, students are presented with fact-based lectures which fail to engage the students' previous knowledge and fail to encourage creation of a mental framework to increase conceptual knowledge of the topic.

This failure has been documented most thoroughly in the physics classroom using data gathered using the Force Concept Inventory (FCI, Hestenes, et al 1992). The FCI is used to test students' knowledge of basic concepts and misconceptions on Newtonian physics. The data clearly show that although students can solve exam questions requiring mathematics, they are simply memorizing the equations without deeply understanding of the underlying concepts. This has led some universities to change the way in which physics is taught to encourage conceptual knowledge and deep understanding in addition to memorization of equations. Similar problems have been documented in biology courses (Wood, 2009 and references therein): students know key vocabulary and can repeat key concepts but lack the ability to apply this knowledge to new problems or demonstrate a clear understanding of basic concepts.

3. This Work

The aim of this paper is to describe and reflect on the development of a Master's level course in Microbiology that tries to integrate the scientific method into every aspect of the course. Specifically, the course uses a case study approach as well as an inquiry/research based laboratory. The aim of this course structure was to avoid the problems mentioned above and encourage lifelong learning of biological concepts and scientific thinking.

4. Course Introduction

Prokaryotic Molecular Microbiology (PMM) is a 15 hp course taken by students in the first year of their master's degree or the last year of their Bachelor's degree. The student composition of PMM is a mixture of Swedish native students, Swedish nonnative students and exchange students from both EU and non-EU countries. Class size has varied greatly due to changes in the total number of applicants to all science related courses. From 2000-2006, the course generally was full with 16 or more students. The last several years we have typically only had 10 students per year.

Students at this level are about to enter a master's level laboratory project (ex-jobb) of typically 60 hp (9 months). Subsequently, the majority of these students intend to either enter a research based PhD program or research focused employment. For this reason, the course was developed with the intention to introduce students to current methods and topics in prokaryotic molecular microbiology and prepare them for a research career. The first is straightforward and could be done with many pedagogical techniques. The second though is more complicated. Some of the issues I wanted to address in this course were:

- Students must be able to read current research articles

- Students must be able to both preform experiments but also interpret their (usually) imperfect data.
- Students must be able to design experiments based on hypothesis and previous work.
- Students should be able to work in groups to facilitate problem-solving as well as experimental work.
- Students should be able to explain their work both orally and in written papers.

To this end the course was designed as summarized below in section 9.

5. The Case Study Approach

The Case Study method in its broadest definition is ‘telling a story with an educational message’ (Herreid, 1994). As such, case studies span a wide range of methodologies and approaches from a lecture format to problem based learning. In science teaching the most accessible way to explain a case study formatted course is that it uses specific examples of research topics to teach general principles. The story is the research topic.

Anyone who writes a scientific paper or gives a scientific lecture knows the importance of telling a ‘good story’ and that story is a very powerful educational tool. Stories draw the student into the topic by making them curious about the end results in much the same way as a mystery novel draws the reader into the story as they become more invested in the characters and ultimately they want to know what really happened. An interesting scientific paper or topic can inspire the students to engage more in a topic than a (boring) recitation of facts.

In this course, the case studies are original research articles chosen to illustrate the required concepts or knowledge I want the students to learn in the course. Because they are very specific, it is important that the students make the connections between the specific topic and the general principles. If the students do not do that on their own, I, as the teacher, always conclude the presentations with a mini-lecture designed to make that connection explicitly for the class.

In this course the students work in pairs to present two different topics during the course. They generally are given the topics about 2 weeks before the presentation and are expected to work on the topic for approximately 20 hours before they present. During the presentations, the class is not passive. Each class, 4 students are randomly chosen to ask questions about the topic; this is done to a) keep the class involved and b) increase discussion to increase understanding of the topic.

I am often asked, ‘why don’t I just lecture about these topics?’ I could lecture about the topics more efficiently, cover more material and possibly give clearer explanations that the students generally give. This is true, but the more important question is ‘would the students learn as much if I lectured?’ Evidence suggests that this is not the case. Students in a traditional lecture setting are given no opportunity to use their critical skills of analysis, they are not problem solving, nor learning to read research papers and they certainly not gaining practice in presentation. In other words, they *might* gain equal knowledge of the topic by my lecturing but little or none of the important transferable skills listed in section 4. Indeed, evidence suggests that students exposed to pure lecturing do not gain as much knowledge of the topic and understanding of the concepts. For example, one study documented 30% normalized learning gains in a developmental biology course by substituting 30-40% of the traditional lectures with more student centered activities (Knight and Wood, 2005). Several other studies within biology courses have similarly found increased learning with less lecturing (e.g., Armstrong, et al 2007, Freeman, et al, 2007, Smith, et al 2005, Udovic et al 2002). The effectiveness of case studies in science specifically, rather than other types of student centered activities, have less documentation, but that literature is positive (e.g. Dori, et al 2003, Yadav, et al, 2007)

<u>6. Exam</u>

The exam was introduced to PMM in 2005 to meet a specific assessment requirement. A major course aim is to teach how to read research papers, analyse data and extract information for future studies or research. The case study presentations and their assessment aims to mold the student's development in this regard, but since the assessment is based primarily of the student's oral presentation, usually done in pairs, I felt an individual assessment of the student's progression in these learning objectives was needed at the end of the course. To this end, I developed an exam modeled on the interrupted case study. As far as I am aware this is an unusual *(unique)* assessment tool, so I will explain it in detail.

The interrupted case study (Herreid, 2005) is somewhat similar to classic PBL except that it focuses more on problem solving and less on information retrieval. Information is given out piecemeal to students for analysis and discussion before the next set of information is given out. For example, students may be given the introduction to a research article and asked to define the research problem and state the author's hypothesis. This can be done in small groups, in class or as homework. Once this step is accomplished and discussed with the teacher, the next set of information is given out. For example, the methodology used in the article might be given out and the students asked to design an experiment using the methodology to test the hypothesis. Once this has been discussed the article's experimental design will be presented to the class and they will be asked to predict the results if the author's hypotheses are correct. Lastly, data will be presented and the students will be asked to interpret the results and make conclusions. This last step can of course be repeated with each experiment in the article.

It should be obvious based on this description, that the interrupted case study is designed to reinforce the student's use of the scientific method. The scientific method is explicitly demonstrated at every step. The beauty of this pedagogic method is that most research articles can be easily adapted to this form of teaching with minimal preparation time on the part of the course leader and because the majority of time for the methodology is spent on small student groups, it does not require significant in-class time, unless the teacher feels this would work better in class. I have used this sort of case study only sparingly in my courses; my impression is that it is a method that works most effectively if only used 1-3 times in a given course, because the workload on the part of the students is very high. I suspect if overused it might lead to students becoming exhausted with the approach and not putting in as much effort over time, however, it should be possible to redesign it slightly to be used more regularly.

However, I have used this approach to design an exam format. As I stated above, I want to assess whether my students have learned to critically read an original research in the course topic. Each year, I find a recent paper whose topic has not been explicitly discussed in the class, but which overlaps with regard to methodology and approaches to the class topics. This paper is then edited to create a kind of interrupted case study (without the interruptions!). The students are given parts of the paper, and asked to make hypothesis, analyse data, and make conclusions. The exam itself becomes a 'teaching moment' in that the students have not read about this topic previously and will learn about the topic by doing the exam. Because the topic is new to the students, it also means I can make this an 'open book' exam. Students can bring any textbooks, notes, etc that they would like. They are only limited by not being able to use the internet during the exam. The reason for this limitation is that they would easily find the actual article which would be a great advantage in the exam as it would remove much of the thinking needed to complete it.

7. Inquiry Based Laboratories

Laboratories can serve several objectives. The most obvious is to train students in experimental techniques. Although this is important, focusing only on this aspect is a lost opportunity for teaching student's other skills can enhance the students' learning and employability. Specifically, experimental design, data analysis, the scientific method, as well as general skills such of working as a team can be added to laboratory classes to teach multiple skills at once. I would argue that it is these second set of skills which will remain most relevant for many students throughout their career as experimental techniques often are replaced by newer methods or automated systems. As an example, I was taught how to sequence DNA when I was a student. The methodology I used has been completely replaced by automated machine based services using very different basic principles. What I did learn in those laboratories was how to interpret my data and how to design an experiment. At their worst, traditional labs teach only methodology and do not even attempt to train higher functions.

Inquiry based laboratories aim to incorporate the skills I describe above into student labs. Essentially an inquiry based laboratory, from the students' point of view, starts with a problem or question in the topic. Students then need to first gather information about the problem to define it in a clear and specific manner, then design an experiment and do the experiment. Finally data is analyzed and conclusions made. Substantial evidence exists that inquiry based labs increase student's motivation and improves student outcomes with respect to data analysis and experimental design (Myers 2003, Luckie 2004, Wood 2009). A variation of this type of laboratory is a research based laboratory where the student's results are completely unknown and tied to active research questions. There is some recent evidence that these types of labs are even better at teaching students the secondary skills mentioned above as well as improving the retention of students in the sciences (Russell 2010, Russell et al 2007).

From the teacher's point of view, usually these labs can be designed with small modifications to pre-existing 'cookbook' laboratories chosen for a specific technique or topic. Simply by rewriting the lab, one can incorporate student thinking and inquiry. For example, rather than simply giving student's the recipe and having them blindly follow it, the framework of the lab can be changed so that it is phrased as a question. The actual lab work will be identical, but the students will need to think about the aims/questions and why they are doing the protocols.

As a simple example of what I am describing, we can use the gram stain of bacteria. Different bacteria score as positive or negative in this very common test. A 'cookbook' way of demonstrating this lab would be to give the students the ingredients and have them follow the protocol. The inquiry based approach would be to give the students the problem of unknown bacteria and ask them to design the experimental protocol using the gram stain method. The students would need to realize that they should use controls, i.e., known gram positive and negative strains, as well as their unknown in order to make valid conclusions. This addition to the lab would take trivial amounts of extra time if organized properly but adds a major learning element to the lab.

Since PMM is a class of at most 16 students and they are the master's level, we can extend this way of thinking even further. Each year the students have a single problem based lab to work on. The labs meet almost every day for approximately 8 weeks. The overall project is for the entire class. For example, we may look at the effect of 10 different conditions on gene expression as a class. Each pair of students will be assigned 3 of those conditions to examine during the lab (there is always at least some overlap so every condition is always examined by at least 2 student groups). Thus during the laboratory, everyone will likely be using the same methodology (e.g., cloning a gene) but the precise genes or conditions in each student group is different. The reason for doing this is that it gives the students a sense of 'ownership' over their work. From the point of view of lab organization, supplies, and lab assistant time in teaching methods, there is only a slight increase since there needs to be some flexibility in the precise schedule for each group (e.g., one group may need to repeat an experiment).

The problems addressed in the laboratory are 'real'. By that I mean that the final results are not known by anyone and have never been published. I always try to choose problems where I know they should get a result, but the actual experiment has never been done. Example of the labs will be attached in an appendix, but as an example, one year the students tested the effect of a set of *E. coli* mutants on expression of the gene *uspB* under several conditions. From the literature, I expected all of these mutants to have some effect, but no one knew how the different conditions would be altered by the mutations. This use of a real scientific problem is used to increase the student's excitement and interest in the laboratory.

8. Poster

The poster is used to supplement the content of the course with newer information and according to the students' interests. The students are given two choices when choosing their topic. They can choose a topic within the field that interests them and I will help them find an appropriate recent starting research article for their poster. Alternatively, the students are given a list of recent research articles covering topics that were not explicitly discussed in the course. Most of these articles have been chosen by me by skimming the last 6 months of the appropriate journals or using recommendations in the Faculty of 1000 website (http://f1000.com/prime). The students then have the responsibility to read the article and do background reading to create a poster that explains the topic to the class. Besides, giving the opportunity to present more material to the class, this work teaches the students to focus their presentation to the most essential points. A poster generally includes only 3-4 key experiments whereas a typical research article can include 10-20. The poster is an individual task and the students will present their work on the last day of class. The remainder of the class will ask questions at this presentation.

9. Overall Format of the Course

The information in this section is given to the students at the start of the course.

This course uses an 'active learning' approach which means that course content will be guided by the course leader, but that much of the learning in this course will require active participation from the students. This means that attendance in all parts of the course is mandatory except under exceptional circumstances. The aim of using this 'active learning' approach is to give the students a deeper understanding both of prokaryotic molecular microbiology and scientific research. This approach will be extensively explained to the students during the introductory weeks of the course.

-Introduction: The first week of the course will be lectures introducing methods, techniques and general information about molecular microbiology. Lectures generally are interspersed with small problems.

-Case Studies: The next ~5 weeks will be devoted to case studies. Case studies will be assigned to pairs of students who will prepare a seminar on a specific research article addressing an important topic in prokaryotic molecular microbiology. The students not presenting are expected to have read the case study and come to class prepared to ask questions and discuss every case study. Points will be given both for the presentation and for participation from the remainder of the class. Following each case study the course leader or other faculty member may give a 'mini-lecture' on the general topic presented in the more specific case study.

-Laboratory: Simultaneously with the case studies, an 8 week lab will be done. This laboratory is a 'real' research project where students will learn some techniques in molecular microbiology and as importantly will learn to do research in as close to a real research setting as possible in a course. Much of this lab will be done in a self-directed format. A lab assistant will be available to give advice and guide the research, but students are expected to work independently. At the end of the lab, the students will write a research article describing what they have done and their results. Students will work in groups but will write their own lab report.

-Exam: An 'open-book' exam will be given in the second last week of the course.

-Poster Presentation: Several days before the end of the course, each student (working alone) will display a poster on a topic in prokaryotic molecular microbiology they have chosen themselves. These will be reviewed by all students and several faculty members. On the last day of the course we will have a poster session where the student presents their topic briefly (12 minutes) and faculty members and students will discuss each of the posters for approximately another 12 minutes.

Grading

Points will be accumulated throughout the course. 60 points are needed to pass ('G') and 80 points are needed for 'VG'. The maximal points for each part are as follows:

- 20 p Case study 1 (16p presentation+4p participation)
- 20 p Case study 2 (16p presentation+4p participation)
- 20 p Lab Report
- 20 p Exam
- 20 p Poster (16p poster +4p participation)

Detailed grading for the parts is described below.

10. General Reflections and Student's Perceptions on the Course

The overall student reaction to this course has been very positive with an average overall grade of between 9-10 out of 10 each year I have taught it in this format from 2005-2010*. The interesting part of the course evaluations however is not that the students gave it positive scores, but rather that they gave it positive scores at the same time that they commented that the course was very difficult, and somewhat stressful due to the heavy workload. Some typical comments illustrating this are below:

- *It was 'harder than other courses but also more satisfying'*
- *'I was a bit stressed but it was very stimulating'*
- *'I think that even if it was a lot (of work), that was good because it is then you do your best.'*

My own perception of the course mirrors these comments. I am often truly amazed that the large amounts of effort these students are motivated to put into the course and even more impressed at their development throughout the course. By the end of the course, the majority of the students are able to critically analyze published research articles on new topics, can design experiments, and have progressed to the point where I think they are ready to begin supervised research projects.

Overall I think this course shows the huge impact that motivation can make on student outcomes, as predicted by learning theory.

a) Case studies

The case studies are used primarily because trains the students in several of the learning objectives. Besides the obvious, mastery of the topic, the approach emphasizes the scientific method, trains them in reading research papers and gives them practice in presentation skills. Because for most people, oral presentations are frightening, there is a huge intrinsic motivation for the student to come to class prepared and to do a good job.

The requirement to ask questions of other student presentations is crucial to this methodology. I participated in one earlier version of this course which did not have this requirement and it was awful. The students paid little attention to the presentations and the general mood was one of boredom and depression. In contrast, by the mid-point of PMM, I find myself having to stop students from discussing so much just so that we can get through the material in the allotted time. Generally a 45 minute presentation becomes close to 1.5 hours (excluding a break) with the questions. Thus, half of the time is actual discussion of the topic. The rewarding of points for questions allows this to evolve during the course. During the first few classes, students are generally hesitant and asking a minimum of questions, but as their confidence grows in their own analytical abilities, the questions come more often and often without reward. (Only some of the students get points for questions each session.)

The case studies are not without flaws however. One particular problem is that students do not always come prepared, by reading the paper, to discuss the topics of other students. I have not found an easy way to fix this problem, but the requirement for asking questions generally motivates the students to at least participate in the discussion and listen carefully to the presentation. Attendance at all the case studies is mandatory and the 'punishment' for missing a case is that the student must write a one page summary of the topic. In general, this works quite well to guarantee full participation.

One must also be aware a problem that can arise and that is when when a student does a terrible job at presenting the material in a case study. My obligation is to the class as a whole and I am always prepared to step in and explain the topic to the class. I try to do this in the nicest way possible but it must be done in my opinion.

b) Laboratories

The labs are generally positively received and I think they are crucial to the overall success of the course. The idea of doing real research is inspirational to most of the students and can be very positively reinforcing. Substantial evidence exists that inquiry based laboratories like this one leads to better learning outcomes (e.g., Myers, 2003), however, the laboratory tends to be the most complicated aspect of this course. Because I try to mimic a 'real' project as much as possible, failures and mistakes occur. To some extent, I think this is fine as the failures and mistakes are part of real science! However, some years we have had too many problems with the lab work which tends to frustrate rather than inspire the students. In addition, because I change the topic of the lab often, some year's we have had too much work for the students to do in the lab. It is a balancing act and I find I have to be ready to improvise every year. Finally, it should be noted that the lab assistants are crucial to the success of this lab approach. Disinterested lab assistants can ruin a traditional lab and can be even more destructive in this sort of lab. For this reason I try involve the lab assistants in the planning of the lab at the earliest possible time so that they are invested in its success.

c) Assessment

The assessment in this course in formative: students receive feedback from each part of the course as quickly as possible after the activity. The grades for each case study and exam are given within a few days of the presentation or exam. The lab report and poster are due on the last day of the course and are graded after. It is particularly clear that the fact that the students get feedback from their first case study early in the course is important in their development. Students who have done poorly hear what they did wrong and those on the right track are encouraged to continue in that path.

The grading for the different activities is subdivided into a clear rubric which is given to the students. For the case study (total 16 points), they are scored on 4 equal aspects: effort (i.e., amount of research), understanding (i.e., ability to answer questions, demonstrate understanding of topic), presentation (clarity of slides, organization of talk, etc) and the last 4 points for their written summary. Similarly there is a rubric for the poster that includes the poster itself, their presentation and ability to answer questions about the poster.

In general I found that having these clear grading schemes along with written comments on each activity have led to little dissatisfaction or disputes about grading. I think it is important to have such a clear scoring rubric since grading a presentation could become quite subjective, or appear that way.

d) Final thoughts

Overall this course conforms to current learning theory and the conclusions from studies from the National Research Council (1997. 1999, 2003) as well as numerous respected scientists. The course demonstrates how it is possible to maximize student's learning in the research university using no more time than a traditional course.

Development of this course has mirrored the development of my role as a university lecturer. A version of this course began in 2000 and I redesigned it in the format described here in 2005. There have been numerous small changes throughout the years: for example, the development of the more detailed grading rubric and the exam format as well as changes in the laboratory. Future work in this course will be halted in 2014 because a lack of funding for education has forced us to eliminate almost half of our courses**. This course was one of the first I designed and the lessons learned have been and will continue to be used for future course development.

For me, personally, developing and teaching this course has led to an interest in pedagogics and why certain things work. I stumbled upon many didactic techniques over the years but only afterword became aware of the pedagogic literature supporting these techniques. I hope that future study of the pedagogic literature will allow me to develop further as a teacher and develop new and interesting courses!

**Note: I am excluding years 2011 and 2012 because I was on sick leave after an accident and the course had numerous problems due to unprepared emergency substitute teachers and general disorganization. It still had fairly positive evaluations but I don't think it is representative.*

***Note: This course did not get cancelled due to an influx of international students and will continue to be developed (April, 2015)*

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Appendix 2

Reflections on Pedagogy and University Education: Williams College Teaching Sabbatical

Anne Farewell, January 2015

Introduction

Williams College is an elite undergraduate college in rural Northwestern Massachusetts with 2000 students. My responsibility at Williams in the Fall of 2014 was primarily to organize and teach Microbiology (BIO315) with its associated labs. In addition, I participated in the discussions regarding the recently reorganized BIO101 laboratory course and observed those labs.

> BIO315 attracted 12 students and was scheduled three times per week for 50 minutes; the lab was a single 3 hour session for half the students at a time. Therefore my teaching hours were 9 hours per week (I taught this course alone). The class was primarily made up of Juniors with a few Seniors (3rd and 4th year students) and included mostly biology or pre-med students though students with other majors were also represented. The prerequisites for this course were 3 courses in biology (equivalent of 22,5 hp).
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> BIO101 is a large class of approximately 200 students (both science majors and non-majors) and the lab was taught in 8 sections. The lab was recently redesigned using an inquiry based pedagogy and I participated in discussions about the success/failure of the aspects of the approach as well as sitting in on multiple lab sessions and speaking with teaching assistants and students.

Williams College is a ‘classic’ liberal arts college with a long tradition of educating the whole person rather than training students for a defined career choice. As such, distribution requirements are significant. Science majors must take 3 courses (22.5 hp) in humanities and 3 courses in social sciences as well as two courses designated as being writing intensive, one including quantitative reasoning and one fulfilling a diversity requirement. Furthermore, students could graduate with a major in biology, for example, with approximately 1 years’ worth of biology courses (67,5 hp), though related topics (chemistry, mathematics, etc.) will be required as well. In addition, prerequisites for many 300 level courses (3rd year) are rather minimal in comparison to a typical Swedish university allowing students who are majoring in other topics to more easily take advanced courses.

In addition to teaching my course at Williams, I participated in faculty meetings, biology department meetings, science education meetings and twice weekly new employee discussions. On average I spent 3-5 hours per week in these activities and many of the reflections below stem from these activities.

Preparation

I visited Williams in April to meet with faculty members, secure housing and generally be introduced to the environment. This was essential in gathering information to make my stay in the Fall successful. I was made to feel very welcome and practical matters were arranged very easily thanks to the department head and dean of the college. In mid-August I returned to Williams to begin preparation for my course. Because I had a lab course and was responsible for all the preparation of practical materials this was the bare minimum of time needed before my class began on Sept 4. In retrospect I would have done better to arrive earlier.

The course I was going to teach was equivalent to BIO275 that I teach at Gothenburg University so much of the lecture/classroom material had been prepared before I came to Williams. However, it was difficult to get a clear sense of the level of the students and their background knowledge before I began teaching and got to know the students myself. Before the course began I was told repeatedly that 'Williams students are the best and can handle more than any typical student I might be used to'. That may be true but did not really help me plan my course! I'll discuss more about this below. In the end, I ended up changing most of what I had planned as I got to know the students. This created a very intense work schedule for me.

Students

The student population at Williams was significantly different from the student population here in Sweden in several key areas. (I should note here that I am generalizing from my own experience and discussions with other faculty).

First, the students were very homogeneous compared to GU. At GU, in the 3rd year and Master's program I have a large percentage of non-Swedish students and the students from Sweden can be from many different universities and backgrounds. As such their background knowledge, English skills, laboratory skills and study skills vary dramatically. In addition, since GU does has a very minimal screening process for applicants to university, our students come with a wide variation in skills and abilities from high school (gymnasium). In other words, a typical class at GU generally has at least two populations of students as evidenced by assessment scores: a population whose grades will average around the G/VG border (80% in my courses) and another group whose scores a much, much lower (at or below the failing limit). I see students at GU who unfortunately are unprepared for their courses: with motivation, hard work and guidance they can catch up though that is not as common as one would like. Because of the extreme competition for admissions at Williams this issue simply does not exist. The admitted students are certainly capable of doing the coursework and have been very successful in the high school studies. The effect of this selection may be reflected in the very high rate of graduation at Williams (>90% of starting students will complete their degree). The effect of this homogeneity, as a teacher, is that all of my time was focused on a similar population group rather than needing to split my time between the 'good' students and the 'bad' students who have very different needs. Higher criteria for acceptance to the university in Sweden would be a huge benefit, in my opinion, to allow us to focus on prepared students. It would also signal to prospective students that they may need to study at a high school level (comvux or basår) further before entering university. Although university is tuition free in Sweden, studying in a program when not prepared is wasteful both in terms of the student's time and the loans they may take out for living expenses.

The second observation about the students at Williams is also largely a result of the admissions policy. The students are generally highly motivated to succeed, they take on more and more work, and are overachievers. This has benefits and problems especially in how the college works with these students. On the plus side, the students will work very hard in their courses and are very motivated to be the best in their field. I have never experienced a class that was so consistently well prepared for class! On the negative side though is that this comes at a cost: the students were obviously incredibly stressed. This observation is borne out by studies from health services at Williams and other elite colleges: 25% of the students seek out psychological services, primarily for stress related problems each year (Psychological Services Office; American College Health Assessment). The misuse of stimulants or cognitive enhancing drugs like Adderall (used to treat ADHD) is also clearly related to this with studies showing as many as 1 in 5 students in US Colleges use this drug to increase focus and stay awake (e.g., Benson, et al, Clin. Child Fam. Psychol. Rev. 2015). The rising cases of honor code violations in recent years (*personal communication*) may also be caused from this stress.

Why are the students so stressed? This is clearly not only a Williams College trend, but seen at many top level Colleges and Universities. There are certainly societal pressures on the students: an uncertain job market, for example. However, I think this may be made worse at Williams (and probably other elite schools) in several ways. First, I think it likely to be a selected trait by the admissions process. Based on discussions with admissions officers, students are selected both for having high test scores/grades but also for having something 'extra'. That may be an athletic or musical skill or starting a company in high school. In other words, students are selected to be overachievers (and prone to overextending themselves). A second way things may be made worse is that the students are inundated by statements that 'they are the best', 'they are the elite', etc. which means that they see themselves as needing to live up to that message. Finally, they are stressed because the teachers put more and more work on them. I heard multiple faculty members comment that 'you can throw as much as you want at them and they can handle it'. A student said he asked a faculty member 'why do you give us so much work to do in such a short amount of time?' and was told 'Because once you work this hard at Williams, all your future work will seem easy'.

For good or ill, all of this has pedagogical consequences. I usually have very strict deadlines for my assignments with measured 'punishments' for late assignments. However, after realizing how stressed my students were, I was very lenient with giving extensions on assignments. To be honest, I did not want the responsibility of pushing a student over the edge!

The second consequence is more serious. The students in my course were very good at reading literature and distilling out the main points quickly. Much better than many of my students at GU. However, they tended to have a very surface level understanding of the scientific approach. They did not tend to go deeply into how an experiment was done and had minimal knowledge of experimental design. For example, one of the assignments I used at Williams was identical to one I use at GU. Both student groups had difficulties with the assignment but the problems were reversed. The first part of the assignment was a task asking for conceptual and reasoning skills, the second essentially required reading comprehension of a research paper. At GU, my students have no problem with the first part but find the second part difficult. At Williams, it was reversed. I found the same on my midterm exam. Questions required higher level reasoning and deeper learning were surprisingly difficult for many of the Williams students. In fact, on the midterm course evaluation I received the comment that the exam was too hard and unfair because I asked for experimental design which they had never been taught. This comment and my own observations led me to change some aspects of the rest of the course to give them in class activities that forced the students to go stepwise through experiments and train them in experimental design in the context of the subject matter.

Again it should be noted that I am generalizing. Not all students had this lack of deep learning but overall there was a disconnect between the students' very advanced knowledge of the overall subject and their limited deeper understanding of experimental design and data analysis. Given the very high quality of the students at Williams, I found this rather surprising. I think this is in large part because the students have very limited time to devote to any given assignment and because this surface learning is encouraged by the pedagogical and assessment approaches commonly used (both at Williams and in high school).

Pedagogy

I am very involved in pedagogical development at the level of both my department and the faculty at GU and was very interested in examining this aspect at Williams. Since I work at a university department and faculty which is very research oriented, there is often a general lack of interest in pedagogy amongst my peers. In stark contrast, pedagogy was a common topic of conversation at Williams, both formally and informally. Broadly speaking, the Williams teaching philosophy can be summarized by the quote from a former US president about an early Williams College president ‘the ideal college is one with Mark Hopkins on one end of a log and a student on the other’ (http://wso.williams.edu/ wiki/index.php/Mark_Hopkins). One can interpret this many ways, but most faculty seem to interpret this as the best teaching is done one on one with a student in a minimalist environment. The faculty prides themselves on their close, almost familial, relationships with their students and this is encouraged by the college (e.g., funding for informal dinners, coffee, etc. with the students is easily obtained).

This vision explains a fairly negative view I observed towards online courses, and online resources in general. The thinking seems to go along the lines that online courses create distance between the faculty and students and that goes against the ethos of Williams College. Oddly though, this extends to online resources as well. Rather than seeing these resources as a supplement to the already close relationship they strive to have with their students, many faculty seemed to think it threatened this closeness. In part they may be correct. Small colleges such as Williams do have to struggle to offer enough courses and topics to meet the interests of their students and many have suggested shared courses between several small colleges to decrease costs while increasing the range of course subjects. I agree that this would be a loss for Williams. Despite this, however, I think it shortsighted not to incorporate technology into the classrooms to expand student’s resources and opportunities. Using, for example, a flipped classroom does not detract from student-teacher interaction but rather increases it by moving ‘information transfer’ outside of lecture hours and increasing the time available for discussion, feedback and clarifying concepts.

A very useful part of my experience at Williams was my observations and discussions around the BIO101 lab. This is a large course (200 students) including both science majors and non-science majors. Last year, the course administrators decided to alter the lab portion of the course making it ‘inquiry based’. Inquiry based labs attempt to move away from the standard ‘cookbook’ labs that are common in science labs and instead encourage the students to practice experimental design. This was an ambitious change in such a large course that was taught by 6 faculty members (2 in the lecture hall and 4 in lab). It was also ambitious because the lab required the students to begin designing experiments in their very first week in the course which for the majority was their very first week in college.

Each lab was designed along this general scheme over several lab sessions:

1) Introduction to topic and a simple experiment using a particular methodology
2) Introduction to experimental design and time for students to design their own experiment emphasizing the clear statement of the students’ scientific question and hypothesis as well as a detailed protocol for their experiment. A summary of this work was handed in to the teacher for comments and grading.
3) Students did their experiment (over one or two lab sessions)

4) Students presented their experiment using powerpoint slides to the lab section and answered questions from students and teacher. Students then handed in a formal lab report. Both presentations and lab reports were graded.

Overall, my impression of this format was extremely positive. Students worked in groups of four and I observed several of these groups during the experimental design part of the lab. Students clearly found this work novel and generally difficult but were very engaged in the process and the majority of groups succeeded to designing clear testable hypotheses. The teacher and lab assistant I observed during this process were simply awesome in helping lead the students to clarify their ideas using a Socratic method. To be honest when I first read the lab manual I thought it might be overambitious in that I feared many of the students would find it overwhelming in their first science course at university level but I was clearly mistaken. Likewise, the student presentations demonstrated that the students had clearly learned the basics of experimental design and data analysis.

There was some discussion about the details of this format in the department and specifically amongst the 6 teachers directly involved in the course. First, was the question of assessment in groups of 4 students. The concern was that not all the students were given the opportunity to practice every aspect of the project. In other words, one student may never do any data analysis whereas another may miss out on writing the introduction to their lab reports. This is a valid point. There are practical limitations in working with such a large class: grading 200 lab reports would become unmanageable. This also has to be balanced against the well-established pedagogic value of students working in peer groups. One answer to this problem would be to include questions related to these lab skills on the general exam for the course. Additionally, this leads me to my only major criticism of the lab and that was that it was run essentially independently of the classroom part of the course. Multiple students commented to me that it felt like they were taking two different courses. It is a shame that the two parts were not more integrated as I think that would add value to both parts of the course.

I should also mention that I ran independent projects in my Microbiology laboratory but since there were only 12 students, they were able to do individual projects, presentations and lab reports. Generally, the students did extremely well and were able to design very interesting projects on a wide range of questions (within a defined framework). This gave me the opportunity to guide each student with respect to experimental design as needed.

A final comment should be made about education at Williams and most American colleges/universities. The students took 4 courses at a time which meant that my course which would be equivalent to 7.5 hp in Europe was spread over approximately 16 weeks instead of the 4,5 weeks it would be at GU. It was very clear that this had huge advantages. Despite the fact that the students had other courses to 'distract' them, they also had much more time to assimilate the information. Overall, I was able to cover almost as much information in this 7.5 hp course as I can in a 15 hp course. In an age when concerns are being raised about alternative teaching methods decreasing the quantity of information presented, I think running courses at (at least) half-speed should be considered to balance high quality teaching against the amount of content.

Assessment

A mistake I made when organizing my course was in the way I chose to assign grades. I used a grading scheme that works very well in my courses at GU, but was very problematic at Williams. This was unfortunate as the grading scheme was designed to encourage deeper learning but in fact only stressed and frustrated the Williams students. The scheme I use is that the students accumulate points throughout the course. There are 100 points distributed for all the activities (exams, labs reports, presentations, active learning classroom activities) and they can get all or some of the allocated points for each assessment. At GU, the students need 80 points to get VG or 60 points for G. It works well in encouraging the students to work throughout the course rather than simply study in the week before the exam and gives them clear feedback on their progress.

At Williams this grading scheme was counterproductive. First, the students did not need much encouragement to do their assignments and secondly, they care very much about their precise grade. Grades are assigned as A+, A, A-, etc to E, with the average grade in a 300 level course being B+ which translates into 90%. Each grade only encompassed 3 or 4 points. In other words, losing just 1 point on a given assignment in my scheme could decrease their grade from A to A- and this was a very big deal. Many of the students plan to attend medical school after their undergraduate program at Williams (in the US, students need a Bachelor's degree before attending medical school) and a very high grade point average (close to perfect) is needed to get into med school. So, essentially, I had set up a scheme where I could not effectively use the grades as a form of feedback, as on average I could only deduct 10 points spread over the 10 or so graded assignments. I also had to be careful to grade such that my average ended up at 90%, instead of 80% as at GU (though I could have weighted it later). So, in summary, this grading scheme stressed both the students and myself and did not prove to be an effective learning tool. In retrospect, I probably would have graded as many others did which was to simply give the more broad A, B, C grades and at the end use that data to give an average precise grade.

I should note also that this student obsession with grades (justified or not) was also a topic of discussion in several of the faculty meetings I attended. There were two concerns. First, Williams wants students to study a broad range of subjects, including courses in topics that may be new to them (and thus may give them a lower grade). Students are generally inhibited in doing this because of their grade point average. One way the college has sought to address this is with limited Pass/Fail options. A second topic of discussion at Williams was grade inflation: grades are increasing at an alarming rate at both Williams and other colleges and universities. To address both these problems, the idea of making all courses Pass/fail has been raised but there is a general fear that this would make their students less attractive to universities for further studies or for employers (i.e., the perception may be that Williams might be an 'easy' school since it doesn't give grades.

First 3: New faculty orientation

After only 4 months at Williams, I feel I know more about the college's culture, policies, teaching philosophies and resources for students and faculty than I did after teaching for 5 or even 10 years at GU. I also met more diverse faculty and had a network of people I could turn to discuss a variety of issues. This is primarily due to the First 3 program and pre-school year orientations.

In the week or so before classes began, a large number of workshops, seminars and social gatherings were offered. Several of the workshops and seminars addressed topics that overlap with the university education (högskolapedogogik) courses at GU: course design, effective teaching and university policies. In addition, a longer course in course design was offered at a distance over the summer to new faculty. These introductory activities were extremely helpful especially to new faculty with limited teaching experience (personal communication from several participants). A key difference between the courses offered at GU and those at Williams is that these were offered *before* the faculty began teaching whereas most of our faculty take these courses after having taught for several years (before a docent or lektor promotion). Though some courses in pedagogics can be more valuable after some teaching experience when one can reflect on one's practices, having courses before you design your first course seems much more sensible.

During the school year, information and discussion for new faculty continued through First 3 lunches. Twice a week, lunch was organized at the faculty club (buffet style restaurant in the center of campus) where faculty in their first three years of teaching at Williams could join for discussion of various topics. Typically, an administrator or senior faculty member gave a brief (20 min) informal talk about the topic followed by discussion with the participants. The atmosphere was very casual, with faculty with classes that overlapped with the lunch arriving late or early. Examples of topics are in the table below. As you can see the topics ranged from strictly administrative, the culture at Williams and the resources available to faculty and students. A smaller number of topics related to faculty research.

Monday, 9/8	Introduction; First days
Thursday, 9/11	Negotiating Williams' Cultures
Monday, 9/15	Office Hours
Thursday, 9/18	Academic Resources
Monday, 9/22	Classroom and Team Dynamics
Thursday, 9/25	The Honor Code
Monday, 9/29	Athletics at Williams
Thursday, 10/2	The Writing Workshop
Monday 10/6	Grades, Grading, and Grade Inflation
Thursday, 10/9	Campus Safety & Security
Thursday, 10/16	The Williams Curriculum
Monday, 10/20	Plotting Your Position
Thursday, 10/23	The Dean of Students' Office
Monday, 10/27	Roll Your Own/Suggest a Topic
Thursday, 10/30	The Davis Center
Monday, 11/3	Psychological Services
Thursday, 11/6	Admissions
Monday, 11/10	SCS: History and Goals
Thursday, 11/13	Student Athletes
Monday, 11/17	Balancing Life in and out of the Classroom

These lunches were integral to my experience at Williams. I learned about many aspects of the college and was able to engage in discussions regarding teaching and learning as well as the pros and cons of college policies and culture. In my fifteen years at GU I have not met the administrators involved in admitting students to GU let alone been given the opportunity to discuss or debate the pros and cons of different policies. Additionally, I met other new faculty as well as visiting faculty who had many of the same questions and issues that I had. We were then easily able to meet outside of this more setting to discuss our experience and share ideas.

Although a 'First 3'-like system would be more difficult to arrange at a larger university (like GU), I don't see that it would be impossible and I think the value would be immeasurable. This is especially true in the more research oriented faculties like natural sciences. We already have a number of seminars in, for example, applying for grants and we have the pedagogics courses, but by incorporating these topics into a more informal, regularly scheduled lunch (or fika!), it would give new faculty an opportunity to not only learn new information but also to meet and share experiences and knowledge. Additionally, it would give new faculty a network of resources early in their career at GU. There are many resources at GU that it took me years to discover and I am guessing there are many more that I still don't know about. In the table below I've listed my own vision of what First 3 would look like for Natural sciences on Medicinareberget (my campus). I would envision a mixture of information and discussions on research related topics with teaching topics.

	Speaker	**Topic**
Week 1		Welcome to GU
Week 2	Dean of Natural Sciences	Goals for the Nat Sciences Faculty
Week 3	Docent committee chair	Pathway to docent
Week 4	PIL representative	Resources for better teaching at GU
Week 5	Grant secretary	Resources for grant applications
Week 6	Librarian	Teaching information skills/resources
Week 7	International Office Rep.	What does the international office do?
Week 8	Studierektor	Grades and policies
Week 9	Experienced supervisor	Supervising PhD students
Etc…		

Goals and Future Directions

Individual

Because I was 'forced' to substantially change my course in response to the new environment, I was able to focus on core pedagogical values in a new context. This clarified my views on what is most important in education including the focus on experimental design and conceptual knowledge. I already include this in my courses but will replace some aspects of my course sessions with different activities. I already did develop several activities for the Williams Microbiology course that can be used directly in my next Microbiology course at GU. I also created a twitter account for 'Microbiology News' which seemed to be appreciated by the students and I will continue to tweet from this account and incorporate it onto our course web site (www.twitter.com/BIO275). Finally, I designed an inquiry based lab to use at Williams which I think can be modified to use at GU.

I have not mentioned the ASE meetings that I attended at Williams which dealt with advances in science education, but several discussions at these meetings have inspired me to alter one part of the HPE102 (Higher Education in Natural Sciences). In my experience, introduction of the basics of course design from a theoretical pedagogic perspective is often not received well by researchers. However, after listening to a report about how another university did this, I think I can improve that part of the course. I also had time to read more about inquiry based labs in relation to BIO101 and will be able to use some of that material in my course.

Institutional

There are four things I would love to be implemented at Natural Sciences and GU and I will do my best to encourage these through seminars and committees I am involved in.

First is the 'First 3' system of new faculty orientation as I described in detail above. Second is to increase the level of inquiry based labs especially in the first year courses. I am a member of our institution's education advisory committee and teach a small part of the Biology program's first year so this seems possible. Lastly, on my 'wish list' and most unlikely to happen (!) is to increase admission standards and implement parallel courses.

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