Review paper

Teaching ecology at university—Inspiration for change

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HIGHLIGHTS

- Inspiration for change for researchers teaching ecology at university.
- Holistic scope and aims to present an overview of suggestions.
- Ideas and suggestions based on several different teaching philosophies and methods.
- Teach students how to think and act like a professional ecologist.

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ABSTRACT

How do you, as a university lecturer, change from teacher-centered teaching to a more student-centered, active teaching? This paper aims to inspire you to make a change, big or small, to increase your students' engagement and learning, by presenting suggestions on what you can do. The ideas and suggestions synthesized here are based on several different teaching philosophies and methods, which are well tested and shown to be effective in the right setting. The selection of suggestions is believed to be specifically suitable for ecology.

The paper includes suggestions on how to plan a course or a lecture by setting a good learning environment. Both pre-lecture activities and during-lecture activities are included, with a focus on activities to engage students and encourage increased discussion and reflections, as well as what to think about when choosing learning activities and how and why it is important to teach students to think and act like professionals in ecology. While changing teaching methods takes investment of time, time that is limited for many researchers, even small changes in your teaching can make big differences in learning, and the investment will hopefully pay back by making teaching more fun and rewarding. The suggestions presented are understandable without being being conversant in the ‘education literature’, but will provide you with a vocabulary of teaching activities that will be useful if you are inspired to find more information and learn more about teaching.

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1. Introduction

Science education is transforming, and a large shift in pedagogical approach has taken place during the last 30 years. The traditional model, in which the teacher lectures, the students listens and takes notes, with little time to reflect or seek clarification, is outdated, and in contrast with current knowledge of effective science teaching. Research shows that the change to more engaged scientific teaching techniques which involve active-learning strategies to engage students in the process of science, and use teaching methods demonstrated to reach different students, is a widely-accepted reform, but adoption is slow (Handelsman et al., 2004). This needed shift in teaching practice from students just learning a knowledge-base of scientific facts to developing deeper understandings of major concepts within a scientific discipline (Tanner and Allen, 2005), brings many challenges, not least for the individual lecturer. Many universities also retain lectures as their central instructional method, maybe because it is economically effective, tradition, the design of the university, or that lectures can be good (Lom, 2012). Thus, traditional lectures are the way most of us teach, have taught, or were taught when we attended university.

This paper is especially focused on researchers teaching ecology at university. Many researchers that are teaching have had only a few weeks of pedagogical training, if any, which adds to the challenges of advancing and developing one’s scientific teaching. I think many recognize what Patricia Pérez-Cornejo is saying in her recent Science article; “My later scientific training left me well equipped to work in a lab…. But it never prepared me for another responsibility that is now part of my job as a professor: teaching”. or “I wondered how I could teach them anything valuable” (Pérez-Cornejo, 2016). She had the opportunity to work with a mentor, a researcher in education, to develop her teaching skills. These types of collaboration between researchers teaching ecology and researchers in University teaching should be encouraged and facilitated as a means to improve University teaching, and make teaching more rewarding. In many cases funding for teaching is mostly for undergraduate teaching, even in many ‘research-focused’ universities. Further, many ecologists that are engaged in higher-level teaching have little exposure to research on teaching and learning (D’Avanzo, 2003) and the amount of institutional support and access to literature to improve teaching and learning varies greatly across the globe. These might be reasons why many researchers are unaware of new teaching strategies and methods, while others might feel intimidated or insecure on how to change (Handelsman et al., 2004). It takes time to deepen the knowledge in teaching (D’Avanzo, 2003), therefore time constraint is another factor that may affect the ability to change and use new teaching strategies and methods. Further, many faculty do not teach students how to use scientific/ecological principles and to think like practicing biologists/ecologists, likely because this is automated thinking among researchers or assumed to be already understood by the students (D’Avanzo et al., 2008). Most students in biological sciences are required to attend at least one ecology class; teaching ecology at university therefore ranges from large introductory classes, with sometimes up to 300 students, to very specific topics with very few students. The most effective teaching takes class size into account and is tailored to the situation.

So, are there ways to shift to a more active, student-centered teaching – just as one individual – even if there is little support from the department or the university? This paper has a holistic scope and aims to present an overview of suggestions, big and small, high- and low-tech, which can increase students’ engagement and learning, ranging from changing small elements to how to plan a whole course or lecture. These suggestions may be useful for both junior and more senior lecturers interested in change. Maybe the change is to insert one new element in your presentation or to include many new ideas and techniques. This “change” or interest in change may hopefully also stimulate teachers to think and learn more deeply about teaching and learning ecology.

2. Context

Active, student-centered learning and teaching have been shown in multiple research lines to be more effective than traditional lectures (Bransford, 2000; Freeman et al., 2014; Handelsman et al., 2004). It also seems that more extensively student-centered teaching with many active-learning pedagogies, consistent formative assessment, and cooperative groups improves learning compared to more moderate student-centered teaching in biology (Connell et al., 2016).

This paper is by no means an original description of active student-centered learning and teaching, as the ideas and suggestions gathered here are well-tested and described in the literature, see e.g. Handelsman et al. (2004) and Dirks (2011), but these suggestions are chosen to be included in this paper for their potential relevance and value while teaching ecology. The amount of available literature in biology and ecology education in higher education is steadily increasing (DeHaan, 2010; “Introductory Biology Project”). There are plenty of general resources for improved teaching at university available, see for example the book ‘Teaching for Quality Learning at University: What the Student Does’ by Biggs and Tang (2011). Other suggested literature especially focused on biology and ecology are: the book by Pickett et al. (2007) about ecological...
understanding; a review of education research in the biological sciences by DeHaan (2010); a paper about 50 key biology education terms by Miller and Tanner (2015). Knapp and D’Avanzo (2010) present seven Pedagogical Principles of Ecology. To increase the knowledge about learning theories and their application to teaching, D’Avanzo (2003), provides some helpful introductory references, and provides good and well-tried examples of how to recognize and change misconceptions among students in ecology.

Many papers about teaching in ecology and science in general, not surprisingly, describe education theories or research on learning, without mentioning how to do it in practice, or with very narrow research focus. This paper focuses on what you can do rather than the theories behind. Many educators want to make their students more active during the learning process, but they do not know what to do and where to start, and wants to be inspired.

This paper can hopefully help to fill this need, i.e. provide a wide variety of practical ideas how to inspire and renew the way of teaching. It is recommended to start small, and gradually change the way you teach (Tachibana, 2015). This is especially the case if you do not want the teaching to take too much time away from the research. Despond not, small changes can also be very effective and make a big difference in both teaching and learning. The rapid technological development we are experiencing is really expanding the possibilities of teaching and we should take of advantage of that.

3. A good learning environment

A good start when planning a course or a lecture is to ensure constructive alignment between the intended learning goals, the assessments, and the learning activities to provide a good learning environment (Biggs and Tang, 2011). An effective way to do so is to use the principle of backward course design (Hodges, 2012; Wiggins and McTighe, 2005). This backward course design suggests, in short, to start with articulating the intended learning goals; the next step is to determine how students will demonstrate what they learnt (how to assess what they have achieved) and lastly decide class format and activities to facilitate students to achieve the goals, i.e. aligning the learning goals, assessments, and activities. These suggestions are applicable if you are designing a whole course, parts of a course, but also for single lectures (Table 1). So, before the lecture or course: set up the intended learning goals, what is it that you want your students to learn, decide how they will be assessed (the more authentic the better) or ask the course leader how they will be assessed and then plan the activities to help the students learn (Fig. 1). This will likely save you time when preparing the learning activities and help outline what to include in your lecture or course.

3.1. Intended learning outcome

The first step in backward course design is to decide the intended learning outcome for the students: I suggest they should reflect the ways of thinking and practicing in ecology. For example: foundational knowledge; experimental and other practical skills: learning in the field; higher level thinking and understanding (i.e. analyzing, evaluating and creating); and “higher level” skills like arguing a case (Anderson and Hounsell, 2007; McCune and Hounsell, 2005). I tend to set up many detailed intended learning outcomes, as it may facilitate the choice of assessment methods and learning activities and what material to include when teaching. For example, in a lecture about marine protected area governance, some of the intended learning outcome could be: define and explain Marine Protected Area (MPA), define and explain governance and management, apply different types of governance on MPAs, analyze and evaluate how well different types of MPA governance work in different settings and create or imagine a well governed MPA in a specific setting. These intended learning outcomes, including both lower level thinking (i.e. remembering, understanding, and applying) and higher level thinking (i.e. analyzing, evaluating and creating), makes sure all thinking behaviors which underlie learning are included Bloom revised taxonomy by Anderson and Krathwohl, 2001 (in Krathwohl, 2002). These thinking behaviors are also fundamental skills to become an expert in the subject, i.e. ecology. Depending on the level you teach, among early year students the variation in knowledge is probably the biggest, and the groups larger than in more advanced classes. Regardless of level at the university I suggest that the intended learning outcomes should include simple to more complex and challenging types of thinking. For more examples of intended learning outcomes see Table 1.

3.2. Assessments

The second step when creating a good learning environment is to decide how to assess what the students have learned. The idea is to make the assessment methods varied, as authentic as possible, and that the questions reflect what you want the students to learn. Additionally, it is a good idea to investigate how the students are picturing the exams and reflect if it is the right examination method (personal communication Stefan Ekecrantz). It is advisable to use several assessments methods to assess conceptual understanding, e.g. only essay exams might not reveal common student misconceptions (Kober, 2015). Variation of assessment techniques is also good to avoid that some have learned how to study for a specific assessment method (and not to learn). Examples of activities that could be used for assessment are oral presentations, writing assignments, review others writing, discussion seminars, posters, writing own questions, answer other students’ questions and role-play. Peer review, where students review each other’s writing, can have many benefits for the students. For example, they learn how to review, and end up with improved quality of their final draft (Simpson and Clifton, 2016).
feedback

2) Assessment

As authentic as possible
Questions should reflect what you want the students to learn.
Assessments are random samples, the larger the better.

Examples of assessments:
- Written exam
- Essay
- Oral presentations
- Writing assignments
- Review others writing
- Discussion seminars
- Posters
- Writing own questions
- Answer other students questions
- Role play
- Panel debate
- Lab report
- Classroom Assessment Techniques (CATS) incl. e.g.:
  - Pro and con grid
  - Concept maps
  - Directed paraphrasing
  - Problem recognition task
  - Application cards

3) Learning activities

Try to be varied, include activities to activate students
* Highly suitable for pre-lecture
- Lectures
- Essay writing
- Group work
- Group presentations
- Individual presentations
- Case studies
- Labs
- Role play
- Peer review*
- One-minute paper (write quick response to question)
- Muddiest point* (write down what was most difficult)
- Think pair share (think, discuss in pairs, then in class)
- Classroom assessment and feedback
- Debates
- Interactive demonstrations
- Articulate reasoning (problem solving aloud)
- Charting* (create figures/graphs)
- Concept maps* (graphically organize information)
- Authentic projects*
- PowerPoint*
- TED-Ed video*
- YouTube video*
- Video lecture*
- Website*
- Picture* (e.g. identify environmental problems)
- Radio program*
- Game* (e.g. over Fishing, plenty of free games online)
- Scientific paper* (to read, evaluate, find information etc)
- Movie*
- Book*
- Recall of real experience, prompted to*
- Write questions*
- Answer questions*
- Problems to solve
- Field excursion (could also be done by the student before class, e.g. visit a museum, visit a botanical garden etc)
- Technical aids:
  - Clickers
  - Digital wall

Fig. 1. Backward course design, step 1 intended learning outcome, step 2 assessment and step 3 learning activities. Each step has a set of suggestions that could be useful when planning and preparing courses and lectures in ecology. There is large diversity among students, try to account for that when planning and preparing lectures. Consider feedback, both self-evaluation and student evaluations to make your course or lecture even better next time.

There are also many types of Classroom Assessment Techniques (CATS; Angelo and Cross, 1993), which are typically used as ungraded activities conducted in the classroom setting and as a tool for the teacher to get feedback for improved teaching. I think CATS could also be graded and used towards final grades. Morgan et al. (2004) have written a student assessment handbook that could be useful for further reading.

Continuing with the example of MPA governance, potential assessment techniques could be an oral presentation of a specific MPA (different for each student, if many students divide them into groups where each student have one MPA) where students present the governance mode of “their” MPA, point out and discuss pros and cons and provide suggestions of improvement for more efficient protection. Another suggestion is a panel discussion (with role-play) where students argue for their park, e.g. why they should receive funding for their park.

3.3 Learning activities

The third step in the backward course design is to prepare your learning activities, and this is where you can get the students to actively engage in the subject in its various shapes and learn to master the skills, strategies and conventions in the field of ecology (Martin et al., 2009). One strategy for active learning is to connect what the students already know with what we want them to learn. This also improves the students’ ability to apply their knowledge in novel situations (Bransford, 2000; Handelsman et al., 2004). One example is to start the lecture with something from a current newspaper or relate to significant previous events (e.g. Fukushima nuclear disaster). Hoskinson et al. (2014), present three recommendations to increase your chances of success in student-centered courses. (1) Focus on big ideas and competencies, instead of “what topics to cover”. (2) Cultivate productive interactions (for this to work there might be a need to explicitly teach collaboration skills, and structure class activities that promote collaboration). (3) Let the students think about thinking (metacognition—mental skill knowing what we know and what we do not know), as this helps developing habits of planning, monitoring, and evaluating their own learning (metacognition—Tanner, 2012).
Table 1
Three examples of backward "lecture" design, of varying level and number of students. These examples are fairly detailed to provide an overview of how lesson planning can be done, the focus is on intended learning outcomes and activities.

| Course: Management of Aquatic Resources in the Tropics, Level: Master program |
| Background: The students are already divided into working groups, there are about 25 students in this class. Every Monday and Friday the course leader lectures. Tuesday to Thursday guest lectures are invited. This is a guest lecture. |
| Lecture: The intertidal zone, 2 h (effective teaching time 100 min) + a seminar on the intertidal zone, 50 min. |
| Intended learning outcomes (ILO) Define the intertidal zone; Understand the basic processes of the intertidal system including tides; Ecological and social processes in the intertidal zone, incl. present ecosystems; typical species; typical human activities; threats; research; monitoring; management; discuss and evaluate potential management approaches. Compare different intertidal systems. |
| Assessment: The course use the following methods to assess the students; written exam, a 4–5 pages report, seminars where they discuss scientific papers and an oral presentation. There might be a possibility to write one question for the large exam, and a possibility to write about the intertidal zone as a topic in the report. No formal assessment will be done during the lecture; attendance is noted for the seminar. |
| Learning activities: Days before the lecture, distribute two scientific papers that should be read before the seminar, task: to mark a passage that is particularly interesting, that may be read out loud. Digital presentation (as a base for the whole lecture); start with striking images; Recall of experience (has anyone seen a tropical intertidal zone); lecture definitions of intertidal, beehive, video of intertidal and tidal range; explain about tides; think-pair-share about tide charts—how they work; discuss pictures of typical ecosystems and use of intertidal, threats – digital wall everyone posts likely threats – follow up with land and ocean based threats. Introduce some current intertidal research and monitoring. Brainstorm about interesting research that could be done (depending on how it goes include beehive). Compare tropical intertidal systems as well as non-tropical, let students help in the comparison. Lecture about management, post question potential constraints minute paper, talk about constraints, talk about potential solutions – articulate reasoning – to aloud explain how they think about solutions. Wrap up with asking what was too simple and the most interesting part of the lecture. Seminar: Let students choose which paper to start with, ask someone to read an interesting passage, let everyone comment on it. Post 3 questions, think-pair-share. In groups discuss how the research in the papers could have been done better, and what was good. |

| Course: Ecology, Level: Introductory |
| Background: 250 students, large lecture hall. Chosen by many as “easy route”. |
| Lecture: Ecological Theory: Island Biogeography (IB), 2 h (100 min) |
| Intended learning outcomes: Basic understanding of IB. Understand and define important related vocabulary. Apply IB to conservation. |
| Assessment: The course use the following methods to assess the students; written final exam and 5 short tests. |
| Learning activities: Digital presentation, show video that introduces the concept, show important vocabulary, introduce the ILOs. Beehive, what you already know about IB. In groups use clickers (mobile phone or laptop is enough if no clickers available) post statements discuss why they choose which. Define IB. Examples, historic and cool. Beehive in groups. Post clicker questions. Muddiest point. Some history and background of IB. Show few examples and model of IB. With guidance compare, analyze and evaluate a few examples (of different quality) in groups/neighbors. Use clickers to check that they are following. Relate to conservation. End with short overview video of IB. One minute paper, why is this important to learn about? Few people to share. |

There are many and various learning activities that can be used at university, of which some are more common than others (one reason for this might be tradition; this is how we have always done it). The purpose here is to briefly introduce several activities, demonstrate the wide variety, and when equipped with the name of these activities, to facilitate further research on how to conduct them. Instructions for most activities are easy to find online: even though it is rare to find examples of how to apply them in university ecology teaching, the descriptions provide an excellent base.

Typical common learning activities are lectures, essay writing, group work, labs, and student and group presentations. Maybe less common are for example: case studies; role-play; beehive (discuss in pairs or groups); peer review;
all students have the same apriori necessary, nor always useful, to do all the learning offacts before the lecture. Other potentially useful activities to engage students are minute papers (students write response to a question in 1–2 min), short quiz, jigsaw (several groups solutions needed to complete the task/puzzle), round table (each student adds relevant info to the paper being passes around), think-pair-share (think alone, discuss in pairs, then in class), and reader’s theater (students read relevant text out loud). The last six examples are well described by Lom (2012). More learning activities are included in Fig. 1.

Here are some examples of how these activities can be used. A jigsaw activity in a large class: first, each group reviews one management approach (e.g. natural resource; single species; traditional; ecosystem; or active adaptive management), then new groups are formed with at least one member from each of the previous groups, so all management approaches are represented, then possible pros and cons of the different approaches are discussed for a specific park. Depending on the time available and the goal, the activity could end with a discussion, a report or a presentation. A classic example of role-play is the class is divided and assigned to be pro or con climate change, they read up and then discuss and debate as the whole class or in groups depending on the number of students. During a seminar, a reader’s theater activity could be that a student identifies a passage they found interesting (e.g. some interesting conclusion, or a spectacular finding) and reads it out loud to the group, who then have to comment on it. This could be done to break the dominance of the ‘teacher’ talking, or to start engaging students, or just to shift focus. For more details or examples of learning activities see for example Oblinger and Oblinger (2005) and Martin et al. (2009). More ideas how activities can be used are presented in Table 1.

Further, there are many interesting ways of teaching; some examples are Problem Based Learning (PBL) and authentic inquiry or adaptations of them. The idea behind PBL is that students, while working in groups, learn about a subject through the experience of solving an open-ended problem. The tutor facilitates learning by supporting, guiding, and monitoring the learning process while students identify what they already know, what they need to know, and how and where to access new information that may lead to the resolution of the problem (Savery and Duffy, 1995; Schmidt et al., 2011). Authentic inquiry focuses on connecting the learner to the real world: it begins with the learner’s interest and experience, and the questions/problems—the process to solve the problems, as well as the results, should be authentic. The teacher provides opportunities for students to construct their own knowledge, while the student learns through e.g. problem solving, critical thinking, and reflections (Gasper and Gardner, 2013).

To enable reflection and discussions during lectures, not only feeding the students with information, it is crucial to include activities that allow for that. Often, the amount of time you have with the students is limited. In addition to the examples above, one approach to deal with this dilemma is to have the students prepared (knowledge-wise) when they come to the lecture, and for even better results also ask them questions before the lecture. This type of teaching is often called flipped classroom or just in Time Teaching (JiTT). Research has shown that this type of teaching improves the students learning (see e.g. Bergmann and Sams, 2012; Braseby, 2014; Estes et al., 2014; Gross et al., 2015; Mazur, 2009). The main thing is to get the students engaged before the lecture, to allow for more discussion and reflection in class (not to be confused with online distance learning). You could say that they should do the “home work” before the lecture and not after. This type of teaching opens up for planning and preparing for pre-lecture activities.

3.3.1. Pre-lecture activities

There are many pre-lecture activities to engage students in learning before class; see Fig. 1 for examples. It is not necessary, nor always useful, to do all the learning of facts before the lecture, but it can be very helpful to ensure that all students have the same a priori knowledge base.

When trying this fairly new concept of engaging the students in learning before the lecture, it is possible to start (and forever continue) on a small scale. For example, a pre-lecture activity could be providing the students with material showing one 5 min video clip (e.g. from YouTube about ecosystem services) and three questions that need to be answered before the lecture.

Depending on how much time you have for preparation of your lecture (including pre-lecture) and the intended learning outcome, the work the students should do before the lecture can vary, but should include questions that they need to answer or reflect about before the lecture to make the learning more effective according to the literature. The questions and answers can then be used to identify any difficulties that students may have, to understand what needs to be explained further in class. To succeed with these pre-lecture activities it is very important to clearly explain to the students the importance of going through the material and answering the questions before the lecture. It might be new to the students and it can take a while for the students to get used to it. If the course organizer will not allow such pre-lecture activities, you can still prepare your lecture to be more student–active, by for example include beehives and one-minute papers.

Having the students conduct pre-lecture activities (that are provided by the teacher) allows them to learn facts at their own pace, rewind where needed, take breaks, go through the material again, listen to the online lecture again, get time to reflect and so forth. If a student drifts off in class there is not much room to repeat the last five minutes of lecture. The learning of facts before class enables more time in class to be used for activities that aid deeper thinking and reflection where a teacher is present and can guide them. So, instead of the students sitting alone after class trying to reflect about what they learned during the lecture or when reading the book, they now do the fact intake before class and discuss and reflect when the teacher is present.
Using our example of MPA governance, you could compile a few short YouTube videos defining governance and MPAs, present a few written definitions, provide links to relevant papers or chapters in a book and ask a few questions about the topic. This material could be made or compiled in e.g. a digital presentation or google form (free and very user-friendly and you get a summary of the replies) that is shared with the students. If access to internet is limited, papers with definitions, text with authentic examples of MPA governance and questions on the material could be distributed to the students before the next lecture.

3.3.2. During-lecture activities

Take the opportunity during the lecture to actively engage students and allow them to discuss while they are surrounded by their peers and have a teacher to guide them. During a lecture there are many ways to engage students actively, for example through roleplay, debate, one-minute paper, think-pair-share, concept maps (for more examples see Fig. 1).

There are also many teaching-friendly technologies available, which can be very helpful to get the students more active and engaged (see e.g. Brewer, 2004). One example is a common digital wall where you and students can post information in real time (see e.g. https://padlet.com; AnswerGarden). These types of digital wall have many possible usages, for example during lecture gather information that students finds, or during group work to share findings and easily make it visible to all. In low-tech environments the black board or regular papers could be used. Another example is clickers that can be useful in the right setting (see e.g. Crossgrove and Curran, 2008; Mazur, 2009). Clickers (classroom response system) are similar to a remote control that students use to respond to questions. These clickers can be used for different purposes, e.g. testing if students understand; introducing a new idea; making sure everyone grasps a concept (personal communication Sören Holst). Clickers are possible to buy, but there are also several free software that can be used on mobile or computer devices (see for example webclicker.org; socrative; mentimeter; NetClick). Clickers are especially useful in large classes, both to engage students and get a better understanding of the learning situation. Other low-tech solutions could be for students to write on small notes that get compiled on the black board, or raise hands for yes/no.

Potential learning activities during the lecture could be to start with a short recap of what they should have done before class, look at the questions together, and discuss them. Then introduce some more advanced information and include relevant videos, show a picture and discuss it, and use e.g. clickers or a digital wall to check that the students understand. A muddiest point (highlight what was most difficult) towards the end could be useful, and thereafter discuss and explain the most difficult things that they encountered during the lecture. Further reading with advice on lecturing (including more traditional lecturing) are for example Adsit (2012), Brown and Manogue (2001) and Wilson and Hampton (2004).

3.3.3. What to think about when choosing learning activities?

Learning takes time, especially when knowledge is troublesome, therefore, it is important to allow it to take time, to be discussed and as a teacher provide guidance and tutoring to overcome the problems. We as teachers should try to tune our teaching to target the difficulties and thus help students understand the difficulties (Hill, 2010; Perkins, 2006).

The student’s ability to learn differs and is likely related to their motivational factors; prior knowledge; epistemological beliefs; values and attitudes; learning strategies and cognitive engagement; reasoning abilities; and social factors. In a constructivist view it is important to connect students’ prior knowledge to the new content to be taught (Limón, 2001; Antony Burden personal communication), as talking about something that they have no experience of will be very challenging. To make students more interested, and help them relate to things they already know, it is advisable to try to connect what you are teaching to the real world, interesting events, their prior knowledge (if you are aware) or something else, so the students can recall background knowledge applicable to the topic (Chamany et al., 2008).

4. Learning to think like a professional

If we want our students to become professional ecologists, we need to teach them to think and act like professionals, and for the students to do so they need to learn, practice and be guided through the process. One way of teaching students how to think like a professional is to share your methods and ways of thinking. Sharing the answers the following questions with your students will take you a good step of the way: How do I (we) do it as an expert? How do I think? What do I do? Which metacognitive operations do I use? What fruitful metaphors do I use? (Pace and Middendorf, 2004; personal communication Lotta Jons). Maybe it is a cartoon in your mind that organizes the information or a dynamic movie, or that you look for a YouTube clip when trying to understand something (Zolan et al., 2004).

If we want our students to possess skills that you need as a professional ecologist, for example collaboration, interdisciplinary thinking, and strong communication skills, they need to practice those skills (see e.g. Bestelmeyer et al., 2015). The choice of learning activities can be very helpful in this process. Thinking like a professional can help students to move beyond the memorization of facts to a deeper understanding of biological processes, described in the decoding the disciplines approach (Zolan et al., 2004). Further, I think Gordon Uno has a very valid point when he suggests to move beyond simply teaching facts that are known, to using that information to illustrate and teach broader principles that help students learn and understand in different contexts which is not yet known (Roehr, 2012). This definitely increases the pressure on the teacher, but if done the students will be well prepared for the field.
One example why it is important to teach the students to think like a professional is that there might be one or many obstacles that will not allow them to move further in the learning, and we therefore need to share our knowledge of how this obstacle can be removed. For example, a student does not understand (or misunderstands) what governance means, in such a situation it would be useful for the student to know how to overcome this problem, so if the lecturer describes what a ‘professional’ would do to learn what governance means the student is provided with examples of how to tackle the problem instead of just getting an explanation of what it is.

5. Conclusion

In conclusion, there is large diversity among students, both in knowledge and interest in learning, and to be able to reach more students variation is important: varied learning activities and varied assessments. It seems to be most important to have students actively engage with activities that deepen conceptual understanding, no matter where they do it (in or out of class) for higher learning gains (Jensen et al., 2015). To create a positive learning environment, constructive alignment is very helpful when planning lectures and courses, i.e. align intended learning goals, the assessments, and the learning activities. This is effectively done with the principle of backward course design. If we want our students to become professionals within our subject we need to teach them how to think and act like a professional. We need to use authentic examples and assignments to prepare them better for the real world. I hope this paper can inspire you to try something new in your teaching, maybe to include a two-minute bee hive during your next lecture, test clickers, or a more substantial change, but do a change that works for you and that you think will benefit your students.

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