

Introducing active learning strategies in toxicology teaching

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1. Introduction

In the traditional lecture, the students are passive receivers of information that is communicated by the lecturer (Walczyk and Ramsey 2003). However, accumulating evidence from the last decades of pedagogical research strongly suggest that this classical approach for learning is not very effective and do not stimulate for deeper learning and understanding (Felder, Woods et al. 2000, Prince 2004, Michael 2006). On the other hand, by introducing active learning strategies into the classroom where the students themselves are engaged in the learning process during class time, it has been shown that the retention of the material increases, the students become more motivated, and develop their skills in both thinking and writing (Freeman, Eddy et al. 2014). Furthermore, when a student catches interest in a subject, it is likely that this promotes self-motivation and self-regulation. When this is combined with the ability to be proactive and reflective, the student is also more likely to acquire deep knowledge and develop advanced analytical skills.

Although the term “active learning” is interpreted differently in the literature, it is in general defined as an instructional approach that both includes and engages students in the learning process (Bonwell and Eison 1991). This includes the introduction of activities such as class discussions, think-pair-share discussions, “clicker questions”, problem-based learning, peer-learning, and Socratic dialog, but does not refer to traditional activities like homework (Lyman 1992, Crouch and Mazur 2001, Bruff 2009).

BIO216 is a 10-credit toxicology course lectured at the University of Bergen (<http://www.uib.no/emne/BIO216>). It encompasses several aspects regarding toxicology, such as historical perspectives, absorption, distribution, and secretion of toxic compounds, biotransformation of xenobiotics, toxicant induced carcinogenesis, organ toxicology, toxicity testing, and risk assessment. The course includes various learning activities besides lecturing, including a lab course, colloquiums, graded project assignments with oral presentations, and company visits.

However, the lectures have traditionally been given in a conventional approach, i.e. the students are passive recipients of information. In order to promote an active learning environment and stimulate to student engagement and deeper learning also in the classroom, several active learning strategies were explored during the spring semester 2016. This report describes the learning activities that were introduced, and present reflections from the lecturer upon the experiences from these activities in light of student responses obtained from a questionnaire after the course ended.

2. Class setting and active learning strategies

BIO216 is usually lectured in a rather small class with a typical number of students between 10 and 25. It is assumed that active learning is particularly beneficial for small classes, and BIO216 should therefore be a well-suited course for implementing active learning strategies (Freeman, Eddy et al. 2014). In the spring semester 2016, 19 students were signed up for the course. The educational backgrounds of the students were mixed, but most of them were bachelor students in biology, molecular biology, pharmacology, or nano-technology, with no or very little experience within the field of toxicology. The active learning activities that were introduced in BIO216 were think-pair-share discussions, use of digital response systems, a collective

calculation exercise during class, thematic groupwork with oral presentations, and an organized lab-experiment during classroom teaching for illustrating toxicological principles.

2.1 Think-pair-share discussions

Lyman introduced think-pair-share as an active cooperative learning technique in 1981 (Lyman 1981). It is a three-step process where in the first step the students individually, and for a limited amount of time, reflect about a question or problem given by the lecturer. After organizing their thoughts, they move on to the next step where they discuss their answers in pairs. In the final step, the students share their answers with the whole class. This learning technique gives the students the opportunity to identify what they know and, importantly, what they do not know. Furthermore, it stimulates to interaction between the lecturer and the students, and the students can reflect on their own ideas in a very active manner. Working in pairs can also reduce stress and anxiety students may have when it comes to answering questions posed by the lecturer (Wichadee 2010). An example of a think-pair-share question that was used in the BIO216 course is: "What is the endocrine system, and how does an endocrine disruptor act?"

2.2 Digital response systems

Electronic response systems are technology that promotes and implement active

learning by interactivity (Bruff 2009). More specifically, it is software and hardware systems that provide an interface where students can submit answers to questions via a transmitter, such as a smartphone or a laptop, or a dedicated “clicker”. It allows students to anonymously commit to instructor-posed questions during class, and provides immediate feedback to both the instructor and the students. Several reports suggest that electronic response systems promote a more dynamic and interactive classroom, and importantly, may stimulate to an increase in student attendance, participation, and learning outcome (Fies and Marshall 2006, Caldwell 2007). One version of electronic response systems is Poll Everywhere, which has a free-to-use open license for up to 25 responses per poll that is created. Poll Everywhere was used in an integrated manner with PowerPoint, and students used their smartphones for answering the polls. Usually, such systems are implemented in larger classes than BIO216, but also positive results in smaller classrooms have been documented (Draper 2002). Multiple-choice polls for emphasizing important parts of the curriculum were used frequently throughout the semester, and each poll included 5 to 10 questions.

2.3 Exercises during the class (individual exercise)

Another mean of active learning that was introduced, was a calculation exercise given

to the students during class. This exercise was part of the curriculum that dealt with toxicokinetics, and specifically, different calculations should be performed around an example where a person had consumed a significant amount of windshield washer fluid. The students were left to work with the different calculations individually, and provided sufficient time to reflect about the questions and attempt to identify the approach to solve them. Some clues and necessary mathematical formulas used in toxicokinetics were provided on a slide together with the exercise, and the students were allowed to ask questions when struggling or needing some hints to move on. After approximately 30 minutes, the exercises were solved on the blackboard in plenary and the students were encouraged to volunteer (no one was forced) to come up and demonstrate their approach for reaching their answers. It is assumed that the act of solving exercises forces students to engage and learn the material, and by going through the exercises together, it increases the chance for the students to absorb the curriculum and possibly obtain a more comprehensive understanding of the material presented in the lecture.

2.4. Group work with presentations (cooperative learning)

Group work can be an effective method to motivate students, encourage active learning, and develop their skills in critical-thinking, communication, and decision-

making (Jaques 2000). Furthermore, through peer-instruction, students are able to teach each other by clarifying misconceptions and addressing misunderstandings. Students were in this case randomly put together in groups consisting of three students per group. The groups were then given different subjects within organ toxicology, such as toxicology of the heart, the kidneys, the liver, and so on. The group's tasks were to find information covering some specific areas within their assigned organ, such as cell types, toxicants, and toxicological responses. These keywords were given by the lecturer and should be specifically addressed by the groups. After working in groups in the first half of the lecture, all groups presented their findings as a PowerPoint presentation to the class during the second half of the lecture.

2.5. Classroom experiments

Classroom experiments are activities where students work in groups, or individually, and collect data through interaction with typical laboratory materials and data simulation tools, combined with a series of questions that lead to discovery-based learning. In contrast to a classroom demonstration, the students themselves are involved in collecting data or observations. Classroom experiments can help the students learn more about the material they are studying by testing hypothesis derived from the material contained in the course curriculum (Farrell, Moog et al. 1999). The

lecturer can act as a facilitator by asking leading questions and draw attention to interesting results, but it is important that the students make their own predictions and reflect upon their observations. In the BIO216 course, an imaginary situation within ecotoxicology was made up by the lecturer, but communicated to the students as a true case. The case was as follows: Male Atlantic cods were recently sampled from different locations in the Bergen area, i.e. from Store Lungegårdsvann, Øygarden, and Askøy. Store Lungegårdsvann is a highly polluted area containing quite large amounts of legacy contaminants, such as PCBs. Øygarden is considered to be far less polluted, and may be considered as a reference site. The fish sampled from Askøy were caught close to a sewage drain. The research-question was if the fish that were caught in these locations were exposed to pollutants that acted as endocrine disruptors. To answer this, students were divided into groups, and pipettes, tubes with cod plasma, and a "dipstick" (almost like a pregnancy test) were handed out. The "dipstick" is used for detecting the presence of a protein called vitellogenin in fish plasma. Vitellogenin is normally not present in male fish, but when exposed to estrogenic compounds (endocrine disruptors), the production of vitellogenin can be initiated through activation of the estrogen receptor, leading to egg production and feminization in males, which can have devastating effect on fish populations. Before the practical

part of the exercise was performed, the students were given time to make predictions of what they expected to find based on the locations for fish sampling. The results and observations made by the different groups were discussed in plenary, and the molecular mechanisms and principles behind their observations were described in detail.

3. Reflections on the experience with active learning strategies

After the BIO216 course ended in spring 2016, a web survey about the course (course evaluation) was emailed to the attending students. Several questions regarding the active learning strategies were included in the survey, and some of the reflections made by the students, and the lecturer, are presented here. Of 19 students that followed the course, 9 students responded to the web survey (the full version of the course evaluation can be found at (<https://kvalitetsbasen.app.uib.no>)).

3.1 Think-pair-share discussions

Eight out of nine students responded that their engagement increased during the lecture with the think-pair-share activity. Two of the students also commented that they prefer the discussion with another student before answering, avoiding the anxiety that can occur when the lecturer points directly at someone. This is also in agreement with other reports stating that cooperative learning approaches can reduce

learning anxiety (Wichadee 2010). Five of the students also reported that this activity increased their learning outcome, where one of these students emphasized that the best way to learn is to discuss the curriculum with others, because then you have to structure and express the material yourself. As the lecturer, I enjoyed this activity because it was a very nice tool for making the students talk, both to fellow students and to the lecturer. It has previously been reviewed in the literature that cooperative learning promotes a friendly teaching/learning atmosphere, which I think also was the case for this course (Johnson, Johnson et al. 1998). Think-pair-share discussions worked also as a nice break during the lecture, and with the correct questions it is possible to emphasize important parts of the curriculum, and with easy means engage the students in the material that is lectured.

3.2 Digital-response systems

Nine out of nine students answered that their engagement and activity increased with the use of Poll Everywhere. However, only four of the students thought that this activity increased their learning. Possible reasons for this, which also was pointed out by some of the students, may be related to distractions resulting from some technical issues and that the correct answers to the quizzes were not sufficiently explained. It was also mentioned in the survey that in such a small class as in the BIO216 course, it

could be more beneficial to rather have open discussions covering the same questions as presented in the quiz. This is a good point, but it is also possible to couple digital-response technology to other active learning approaches, such as classroom experiments or cooperative learning, providing many opportunities for combining teaching pedagogies. Among the positive experiences noted by the students was that the curriculum is memorized well when you are allowed to reflect upon different questions. Importantly, the course evaluation provided constructive feedback from the students that may help to improve the learning outcome when using digital response systems. One of these suggestions was to further extend the use of such systems and present a quiz in every lecture that repeat, refresh, and emphasize the most important parts of the curriculum.

3.3 Calculation exercise

The majority of the students replied that the calculation exercise performed during the lecture improved both their activity and their learning outcome. There was also positive feedback regarding this exercise since it demonstrated the use of mathematics in toxicology and how mathematics can be used to something useful (as expressed by a student). One of the students commented that he/she would have appreciated more time for solving the exercises. One alternative would be to hand out the exercises beforehand so the

students have more time to prepare for this activity. Furthermore, the lecturer noticed some reluctance among students in volunteering to demonstrate how they solved the exercise in front of the other students. To reduce the anxiety, maybe it would be better to promote a cooperative learning situation by organizing the students into pairs and make the students explain their strategies to each other. The session can be ended with the lecturer going through the exercises on the blackboard with input and suggestions from the students.

3.4 Group work with presentations

Near all students responded that the group work increased their activity in the lecture. However, only 50% of the students that responded to the survey replied that this activity increased their learning outcome. Notably, group work was the exercise where this lecturer was least satisfied with the implementation of the active learning activity. The activity could probably be significantly improved by e.g. being more specific about what type of information that should be gathered and presented to the other students. This can be achieved by preparing an even more detailed template for the student presentations, assuring that the essential parts of the curriculum are covered. It may also be beneficial to hand out the group exercise in some time beforehand, so the students have more time to research information and prepare more

informative presentations. Some of the students also reported that they struggled to comprehend the other student presentations, and that many students appeared to be more focused on working with their own presentation rather than listening to the others. However, numerous reports exist where the benefits of cooperative learning have been demonstrated, especially with regard to reasoning and critical thinking skills (Johnson and Johnson 1989). Thus, more careful design of this activity could possibly enhance its usability in the BIO216 course. Among the positive feedbacks was that this activity was a good arena for practicing presentation skills.

3.5 Classroom experiment

As reflected in the course survey, the students appreciated and welcomed the practical experiment that was performed during class. All students were activated, and everyone reported that the exercise increased their learning outcome (while having fun at the same time). This activity can be categorized as learning by doing, and the impression is that this practical exercise significantly enhanced the students' willingness to learn and increased their understanding of how biomarkers can be used to trace effects of environmental pollutants. However, the lecturer made one mistake during this exercise. Never(!) unveil for the students that the story and the exercise they were introduced to were just a

fabrication (preferably not even after the exercise is finished). Their engagement persists much longer when they strongly believe that they have contributed to an important discovery.

4. Concluding remarks

This was the first time this author introduced active learning strategies in classroom teaching of toxicology. Different activities were implemented, including think-pair-share discussions, use of digital response systems, a calculation exercise during class, thematic group work with oral presentations, and an organized lab-experiment during classroom teaching. As revealed by the course survey, the overall response from the students in this course was very positive. Students appreciated the variety in how the curriculum was lectured and reported that the introduced activities increased their participation and their activity during the lectures. Furthermore, the impression of the lecturer is that the added engagement during class also increased their motivation to learn, which should facilitate higher learning, better retention of the material, and the development of advanced analytical skills. Among the different activities that were tested, especially the think-pair-share and the classroom experiment stand out as valuable tools for both activating and motivating the students in a small class. Active learning strategies will be further developed and used in future toxicology

teaching in BIO216. In this regard, the fashion for obtaining the student's evaluations of the different learning activities must be reconsidered. The student responses presented in this report are based on a questionnaire that was distributed to the students after the course had ended. Only 50% of the students responded to this survey, which of course could introduce a bias when assessing such evaluations. A possible approach could be to organize separate evaluations of the different activities at the end of each lecture (or in the beginning of the next lecture) to assure that as many students as possible respond to the survey, also while they still have in mind a clear impression of the activity as well.

5. References

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