Case studies in a physiology course on the autonomic nervous system: design, implementation, and evaluation

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Zimmermann M. Case studies in a physiology course on the autonomic nervous system: design, implementation, and evaluation. Adv Physiol Educ 34: 59–64, 2010; doi:10.1152/advan.00004.2010.—The introduction of case studies on the autonomic nervous system in a fourth-semester physiology course unit for Pharmacy students is described in this article. This article considers how these case studies were developed and presents their content. Moreover, it reflects on their implementation and, finally, the reception of such a transformation among the students as well as the tutor’s perception. Specifically, the following issues were addressed. First, how were the course unit and, within the course unit, case study components organized? Second, how was the transformation of the course unit from an originally interactive but rather teacher-centered lecture to an interactive course module achieved? Third, how were the case studies structured, what questions were asked, and what were the answers expected from the students; what additional information was provided by the tutor? Fourth, how did the implementation of these case studies work out in the actual course, i.e., how did the tutor guide the students in this interactive session and how did the students tackle the problems? Finally, how was the integration of interactive modules received by the students and what was their learning experience (as assessed by questionnaires) and learning success (as assessed through the final course exam)? Equally, the tutor’s perception of this transformation and its implementation is described.

The physiology course held for Pharmacy students in their fourth and final semester of basic studies (“Grundstudium”) at Goethe University Frankfurt was largely theory based up to summer 2008, with this being understandable given that the large amount of material to be covered for the preparation of the State examinations directly after the fourth semester is more easily covered in ex cathedra teaching units. However, despite our efforts to provide high-quality lectures, it was our perception, as also confirmed by others (2), that only a limited portion of the actual material covered was effectively learned and properly understood by the students when such a teaching style was used. Given that teaching experience has shown that active teaching methods generally lead to a higher level of knowledge (13), we decided to restructure this physiology course to better prepare the students for problem solving and support them in self-directed learning. Therefore, we reoriented the methods of knowledge transfer in the physiology course toward more applied and active teaching and introduced computer-based teaching modules into some of the course units from the winter 2008/2009 semester onward (28).

In this context, the course unit on the ANS was not considered for the introduction of a computer-based module given that the available setups did not include a suitable training program to complement the course unit on the ANS. However, it was desirable to introduce a similarly interactive component in the course so as to further the students’ understanding of the complex subject. Therefore, the discussion of case studies was established in this course unit.

In the present article, I want to share the experiences of the establishment of such case studies to involve the students in the development of their own ideas, active problem solving, and how to present information as well as to reflect on how the changes introduced were received by the students (as well as by the tutor). Specifically, the following issues are addressed: 1) how were the course unit and, within the course unit, case study components organized; 2) how was the transformation of the course unit achieved; 3) how were the case studies designed and structured; 4) how did the implementation of the studies work out in the actual course, i.e., how did the tutor support and direct the students during their work on the case studies; and 5) how did the students receive these interactive modules, what was their learning experience, and how their learning success in the final course exam after such an active involvement.

PROCEDURES AND METHODS

Organization of the Course Unit

This course unit was part of a course on Human Physiology for Pharmacy students, which was held during their last semester of four semesters of basic studies (“Grundstudium”). This course expands on...
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various key topics, one of which is the ANS. Each course unit is given to groups of 20–25 students and is repeated 3 times/semester to teach the material to the whole student cohort. The time available is 4 academic hours. For more information on the physiology course in question, see Ref. 28. During the first 2.5 academic hours, the tutor introduces key features of the ANS using PowerPoint presentation slides. The lecturing style is deliberately as interactive as possible, i.e., students are requested to answer questions throughout; these questions refer to knowledge they should have assimilated in lectures on “Human Anatomy and Physiology” that are given before the physiology course, during the second and third semesters of the curriculum. Furthermore, the interactive lecture is interspersed with multiple-choice questions that have been taken from previous State exams to prepare the students for the type of questions they will encounter during the independent, national exams directly after the fourth and final semester of their basic studies. Generally, the entire class is confronted with the relevant questions and requested to think about the correct solution. The students are free to participate, but once a student has given an answer, potential corrections or further clarifications are specifically addressed to that student. Notably, before the tutor will give away the answer, the entire class is challenged to contribute to the problem solving.

After this lecture unit, active problem solving was asked of the students. In short, the students grouped themselves into teams of 4 or 5 students/group and were handed brief descriptions of pathophysiological symptoms followed by questions regarding the physiological systems and biochemical pathways involved. Students were asked to answer the relevant questions based on the knowledge acquired during the course unit and discussed within their team. Specifically, they were asked to give a short presentation to the entire course group after the discussion session had finished, whereby they were requested to first present the problem they had to work on to the entire course group and then outline their solutions as well as the reasons for their suggestions. In this way, at least two students of each team had to do some active lecturing to the class. During the final presentations, the whole class was challenged to participate in a discussion regarding the suitability of the solutions as proposed by the various subgroups.

Organization of the Case Studies Section

Students were encouraged to be seated around one desk to literally form a discussion group. Furthermore, they were deliberately told not to refer to the textbooks they had brought to the course but only to consider the notes of the course so as to properly familiarize themselves with that material. In a brief introduction to the interactive session, the tutor asked the students to prepare their answers as a short presentation to be given to the entire class at the end of the group discussion section; she also encouraged the students to ask questions throughout the discussion time.

Students were given ~10 min to familiarize themselves with the case to work on before the tutor provided potential clarification or additional information where necessary. After an additional 5–10 min, the tutor began to actively facilitate problem solving to ensure that all groups made appropriate steps toward problem solving and the preparation of the presentation. The discussion session took ~25 min before all students were asked to get ready for the presentations. These were given one by one with the tutor adding additional comments and also summarizing the key facts on slides to the entire class. After the discussion regarding the four cases, the tutor gave a brief summary on the material taught and the general learning objectives in her concluding remarks.

Course Content: Material Covered in the Theoretical Part of the Course Unit

The specific learning objectives of the course unit were as follows. First, explain the general anatomic organisation of the ANS; specifically, compare and contrast the anatomic features of the sympathetic and parasympathetic divisions with respect to the location of their preganglionic neurons and ganglia. Second, describe the process of neurotransmission in the ANS considering, in particular, the two-neuron system of impulse transmission. Third, gain an overview and understanding of the neurotransmitters of the ANS; in particular, attribute these transmitters to both the neurons that release them and the receptors that bind them and describe how impulse transmission is ended in each case. Finally, contrast the overall and specific functions of the sympathetic division with those of the parasympathetic nervous system. Major emphasis was placed on objectives 3 and 4, since anatomic aspects had been covered already in the second- and third-semester classroom lectures.

In general, the lecture material (in particular, the figures on the PowerPoint slides) was based on a couple of physiology textbooks (4, 25). Notably, a password-protected script on the department’s homepage was made available to the students before the course. Importantly, this script did not contain all the information given during the course but left gaps where it was planned to prompt the students with specific questions or problems (see above).

Specifically, the following key topics were addressed in the first part of the course unit: the general anatomic organization and process of neurotransmission in the ANS, the neurotransmitters and their receptors in the ANS, and the overall and specific functions of the ANS.

General anatomic organization and the process of neurotransmission in the ANS. Considering that anatomic facts play a major part in the second- and third-semester lectures before the fourth-semester physiology course, the course unit mainly focused on aspects of neurotransmission in the two divisions of the ANS. In fact, general organization and main anatomic differences were discussed within the first ~15 min, with the aim being to bring the ANS in general back into the students’ focus. The major learning objectives regarding this brief subsection of the course unit are shown in Table 1.

Neurotransmitters and their receptors in the ANS. To further the students’ understanding of the process of neurotransmission in the ANS, the aspects of 1) ganglionic cholinergic (nicotinic) transmission, 2) postganglionic adrenergic transmission and 3) postganglionic muscarinic transmission were discussed in detail over the course of ~1

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Table 1. General organization of the ANS

<table>
<thead>
<tr>
<th>Sympathetic Division</th>
<th>Parasympathetic Division</th>
</tr>
</thead>
<tbody>
<tr>
<td>Origin in the thoracic and lumbar regions of the spinal cord</td>
<td>Origin in the brain stem and sacral region of the spinal cord</td>
</tr>
<tr>
<td>Ganglia located in the paravertebral ganglion chain</td>
<td>Ganglia located near or within target tissue</td>
</tr>
<tr>
<td>Short cholinergic preganglionic fibers and long adrenergic postganglionic fibers</td>
<td>Long cholinergic preganglionic fibers and short cholinergic postganglionic fibers</td>
</tr>
<tr>
<td>Primary neurotransmitter of preganglionic neurons is norepinephrine</td>
<td>Primary neurotransmitter of postganglionic neurons is acetylcholine</td>
</tr>
<tr>
<td>Predominates during emergency “fight-or-flight” reactions and during exercise, exams, and excitement</td>
<td>Predominates during quiet resting conditions (“rest and digest”)</td>
</tr>
</tbody>
</table>

Shown are key distinguishing features of the sympathetic division compared with the parasympathetic division of the autonomic nervous system (ANS). For a more comprehensive table, see Ref. 11.
compared with the parasympathetic division of the ANS.

8. Glycogenolysis and lipolysis

7. Increase of blood circulation in skeletal muscle, decrease in skin, kidney and gastrointestinal tract

6. Block of sphincters

5. Increase of blood pressure

4. Dilation of bronchi

3. Increase of heart rate and contractility

2. Dilatation of bronchi

1. Ergotrophic reaction: “fight or flight”

Specifically, two slides listing the ergotrophic compared with the parasympathetic effects summarized the “fight-or-flight” response compared with the “rest-and-digest” actions supported by the relevant division (Table 2). Furthermore, a synopsis attributing the effect of the sympathetic division (Table 2). Additionally, two slides listing the ergotrophic compared with the parasympathetic nervous systems. Specifically, the effects associated with the activation of the relevant receptor subtype in the single organ were shown. The overall and specific effects of the sympathetic division compared with the parasympathetic division of the ANS.

h. See the Supplemental Material for this article for an extensive description of the material taught in this section.

Overall and specific functions of the ANS. While the functional differences between the two subdivisions had been alluded to in various places already, the contrast between the two systems was elaborated in the subsequent ~30-min-long section of the lecture. Specifically, two slides listing the ergotrophic compared with the trophotrophic effects summarized the “fight-or-flight” response compared with the “rest-and-digest” actions supported by the relevant division (Table 2). Furthermore, a synopsis attributing the effect of the relevant division to the specific receptor subtype in the single organ gave the student the opportunity to think through the differences between the two systems (Table 3).

Evaluation of Student Reception and Learning Success

The students’ reception of the introduction of case studies was assessed as part of a general evaluation of the physiology course, a detailed description of which can be found elsewhere (28). Briefly, after the regular summer 2008 semester course, when case studies had not been used as yet, the first evaluation of the physiology course took place. To this end, students were given a questionnaire where subsets of six specific questions explored the students’ perception of each of the individual eight course units; a separate section gave room for the students’ personal comments and critique. Questionnaires were handed out after the winter 2008/2009 semester and after the final evaluation seminar in the summer 2009 semester.

Specifically, the questions regarding the course unit on the ANS addressed the following issues: variety of teaching material, course character, the tutor’s dedication to the students’ questions, opportunity for open discussion, scope for personal design, and course unit organization. Rating points on a scale from 1 to 5 were to be given for every question asked in this section. All questions were worded so that a rating mark at the high end of the scale consistently suggested the student’s acceptance of the introduction of the interactive case studies. A separate section gave the students room for personal comments and suggestions and encouraged constructive criticism to find out about their subjective learning experiences.

The number of students participating in the Physiology course varied in each evaluation semester, since Goethe University Frankfurt accepts two student intakes per academic year; the summer intake is traditionally notably smaller, as reflected in the smaller number of students participating in the course in winter 2008/2009. The number of students taking part in the course unit evaluation was 62 students in summer 2008, 38 students in winter 2008/2009, and 50 students in summer 2009.

Statistical comparison of the anonymous final exam results was carried out using an unpaired t-test assuming a Gaussian distribution of data for the two independent groups of students in summer 2008 and summer 2009.

Transformation of the Course

In the summer 2008 semester course, the lecture on the ANS was interspersed with frequent questions. Specifically, where applicable, multiple-choice questions that had been the object of previous State examinations were discussed. Given that correctly answering such questions was of great interest for the students, they actively participated in the discussion regarding these problems. Clearly, this measure already strongly enhanced the tutor-student interaction. In a second instance, some questions addressed anatomic and functional differences between the sympathetic and parasympathetic divisions of the ANS.

Most of the questions, however, were centered around issues of neurotransmission in the ANS. In particular, after the discussion on adrenergic postganglionic transmission, the nature of therapeutic agents for the treatment of asthma was debated. The treatment of hypertension was also an object of consideration. Other questions

Table 2. Overall and specific effects of the ANS

<table>
<thead>
<tr>
<th>Sympathetic Division</th>
<th>Parasympathetic Division</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ergotrophic reaction: “fight or flight”</td>
<td>1. Trophotrophic reaction: “rest and digest”</td>
</tr>
<tr>
<td>2. Increase of heart rate and contractility</td>
<td>2. Decrease of heart rate</td>
</tr>
<tr>
<td>3. Dilation of bronchi</td>
<td>3. Contraction of bronchi</td>
</tr>
<tr>
<td>4. Increase of blood pressure (vasoconstriction)</td>
<td>4. Weak influence on blood pressure</td>
</tr>
<tr>
<td>5. Increase of blood circulation in skeletal muscle, decrease in skin, kidney and gastrointestinal tract</td>
<td>5. Gastrointestinal stimulation: increase of motility and secretion</td>
</tr>
<tr>
<td>6. Block of sphincters</td>
<td>6. Ureters and defecation</td>
</tr>
<tr>
<td>7. Glycogenolysis and lipolysis</td>
<td>7. Glycogen storage</td>
</tr>
<tr>
<td>8. Mydriasis</td>
<td>8. Miosis and lacrimation</td>
</tr>
</tbody>
</table>

Shown are the overall and specific effects of the sympathetic division compared with the parasympathetic division of the ANS.

Table 3. Specific effects of the ANS

<table>
<thead>
<tr>
<th>Sympathetic Division</th>
<th>Parasympathetic Division</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effect of Activation</td>
<td>Receptor</td>
</tr>
<tr>
<td>Dilation</td>
<td>$\alpha_1$</td>
</tr>
<tr>
<td>Dilation</td>
<td>$\beta_2$</td>
</tr>
<tr>
<td>Inhibition</td>
<td>$\alpha_1$</td>
</tr>
<tr>
<td>Inhibition of Motility</td>
<td>$\alpha_1, \alpha_2, \beta_2$</td>
</tr>
<tr>
<td>Inhibition of Motility</td>
<td>$\alpha_1, \alpha_2, \beta_1, \beta_2$</td>
</tr>
<tr>
<td>Tocolysis</td>
<td>$\beta_2$</td>
</tr>
<tr>
<td>Decrease of tone</td>
<td>$\beta_2$</td>
</tr>
<tr>
<td>Increase of tone</td>
<td>$\alpha_1$</td>
</tr>
<tr>
<td>Constriction</td>
<td>$\alpha_1, \alpha_2$</td>
</tr>
<tr>
<td>Increase of heart rate</td>
<td>$\beta_1$</td>
</tr>
<tr>
<td>Increase of contractility</td>
<td>$\beta_1$</td>
</tr>
<tr>
<td>Increase of transmission</td>
<td>$\beta_1$</td>
</tr>
<tr>
<td>Increase of contractility</td>
<td>$\beta_1$</td>
</tr>
<tr>
<td>Viscous saliva</td>
<td>$\alpha_1$</td>
</tr>
</tbody>
</table>

Shown are the specific effects of the sympathetic and parasympathetic nervous systems. Specifically, the effects associated with the activation of the relevant receptor in the effector organs are shown.
focused on potential options of intervention to overcome cholinergic deficits as they occur in neurodegenerative diseases. The examples chosen were 1) the inhibition of acetylcholinesterase and 2) the use of muscarinic agonists to illustrate the physiological effects and collateral events after intervention in the parasympathetic division. Finally, questions on the pathophysiological symptoms after an atropine or organophosphate intoxication were considered.

In this context, it is important to note that pharmacological aspects were not at the center of these discussions. Instead, the focus was placed on the application of the knowledge that the students had assimilated regarding the physiological aspects of the transmission cascades discussed. This is to say, the reasons for and consequences of intervention at adrenergic and muscarinic receptors were examined in detail. However, the relevance of our considerations for the pharmacological issues that the students would be confronted with later in the advanced studies of their curriculum were frequently pointed out. In the same vein, reference was made to the pharmacological significance of the physiological aspects discussed.

The students were keen to participate in the discussions throughout the course. Of note, sometimes the discussion among students developed even in front of the class. Such a positive experience encouraged the tutor to expand the interactive part of the lecture to a coherent component of a full hour of the course unit from winter 2008/2009 onward. In addition, the parallel introduction of interactive computer-based modules in other course units was hoped to enhance the students’ expectation to be actively involved in the knowledge transfer in a dedicated unit of the course. Therefore, some of the problems and questions mentioned above were restructured to create specific case studies that the students were confronted with in the final 60 min of the course on the ANS. Notably, to ensure that a discussion among the students within their team would develop independently from the active support of the tutor, supplementary guidelines were given on some of the work sheets. These guidelines were additional questions that the students were meant to consider to ease their way into the problem they had to work on. The case study problems and relevant additional tips are shown in the Appendix, whereas the expected answers and some notes on frequent misconceptions and additional information can be found in the Supplemental Material. Importantly, a strongly and consistently interactive lecturing style was still used throughout the part of the course before the interactive module to “prepare and accustom” the students to actively participate in the knowledge transfer.

EVALUATION AND DISCUSSION

Case studies have successfully been used in physiology teaching for a long time (3, 5, 17). In particular, they are useful tools to not only illustrate complex topics (1, 8, 16) but also to actively involve students in the knowledge transfer process and support them in effectively assimilating the material to be covered (20, 26, 27). Moreover, specific topics can be illustrated within the same class room without the need for particular equipment or tools, animal licenses, or laboratory space. Furthermore, as shown, such interactive elements enrich the traditional lecture remarkably (19) and support the students to actively engage in the knowledge transfer (and, as a consequence, with the material taught), which heightens attention and motivation and, eventually, promotes learning (9). At the same time, the advantage of a system combining lecturing and interactive elements clearly lies in the fact that one part of the course unit is teacher centered while the case study module is student centered. In this way, key facts are conveyed in the traditional style but students, nevertheless, take responsibility for their own learning (18, 23).

However (and closely linked to the above), the success of such an interactive approach decisively depends on 1) an increased, and working, interchange between the lecturer and students, which is mandatory for effective learning and teaching; and 2) a significant engagement from the students, which is a key element in making active learning activities truly work. Notably, in a course where other units use also interactive modules, the students already expected to actively contribute to the knowledge transfer and even hoped to be challenged to take responsibility through problem-based, self-directed learning (22).

The fact that the presented case studies as an integral part of the ANS course unit within the physiology course were well received can be gathered from the evaluation carried out. While the overall rating of the course unit did increase only slightly over the evaluation period (summer 2008: 21.98 ± 5.19 points, winter 2008/2009: 22.68 ± 3.86 points, and summer 2009: 23.00 ± 4.82 points), a notable increase in rating points was found for the categories that directly address the changes made to the course unit. In fact, ratings increased specifically for the categories of diversified teaching material (summer 2008: 2.93 ± 1.01 points, winter 2008/2009: 3.59 ± 0.76 points, and summer 2009: 3.59 ± 0.69 points) and scope for personal design (summer 2008: 2.85 ± 1.10 points, winter 2008/2009: 3.32 ± 1.20 points, and summer 2009: 3.19 ± 1.04 points), supporting the general perception that practical classes enhanced the students’ learning experience. For detailed ratings of the course unit, see Table 4. Moreover, specific remarks given by the students in the free comments area in a separate section of the questionnaire unanimously welcomed the ANS case studies already in winter 2008/2009, when they were used the first time—and when the tutor also had to gauge how to best implement such changes. Specifically, students judged rather positively, writing critiques such as “well designed course unit with topics to work on autonomously,” “I liked the interactive section in the ANS course and took a lot out of it,” or “The ANS group work was enjoyable and diversified.” To understand if such a positive subjective learning experience was paired with an improvement of objective learning success, the results that students obtained in the section of questions regarding the ANS in the final physiology course exam were analyzed. These results improved significantly from an average of 48.12 ± 14.09% to 67.54 ± 22.85% from summer 2008 to summer 2009 (P < 0.001), suggesting that the changes meaningfully supported the students in their assimilation of knowl-

Table 4. Ratings of the ANS course unit obtained from the student questionnaires

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Diversified teaching material</td>
<td>2.93 ± 1.01</td>
<td>3.59 ± 0.76</td>
<td>3.59 ± 0.69</td>
</tr>
<tr>
<td>Course character</td>
<td>3.92 ± 1.02</td>
<td>3.78 ± 0.89</td>
<td>4.08 ± 0.86</td>
</tr>
<tr>
<td>Tutor’s dedication to student questions</td>
<td>4.38 ± 0.84</td>
<td>4.14 ± 0.75</td>
<td>4.33 ± 0.72</td>
</tr>
<tr>
<td>Opportunity for open discussion</td>
<td>3.69 ± 1.07</td>
<td>3.62 ± 1.04</td>
<td>3.65 ± 0.97</td>
</tr>
<tr>
<td>Scope for personal design</td>
<td>2.85 ± 1.10</td>
<td>3.32 ± 1.20</td>
<td>3.19 ± 1.04</td>
</tr>
<tr>
<td>Organization</td>
<td>4.21 ± 0.86</td>
<td>4.22 ± 0.82</td>
<td>4.16 ± 0.85</td>
</tr>
<tr>
<td>Total score</td>
<td>21.98 ± 5.19</td>
<td>22.68 ± 3.86</td>
<td>23.00 ± 4.82</td>
</tr>
</tbody>
</table>

Values are means ± SD. Students indicated a score between 1 (poor) and 5 (good). There were positive trends for the categories of diversified teaching material and scope for personal design.
edge. To appreciate this outcome, it is important to note that 1) exam questions addressed similar issues in both evaluation cohorts (summer 2008 vs. summer 2009) and 2) it is the course leader’s policy not to give out any exam questions from previous years to the students for exam preparation.

At the same time, an interactive module requires the tutor to be open and prepared for questions from the students. In fact, once the students were ready to be confronted with questions (and lost their anxiety to answer them in front of the class), they more readily asked questions. Furthermore, a tutor would need to bring some flexibility concerning how much and what kind of support might need to be given to each individual group of students. In fact, having used these case studies over two semesters so far (in winter 2008/2009 and summer 2009), it becomes clear where students have more difficulties in understanding specific issues regarding the ANS. Furthermore, it proves useful to clearly tell students what is expected from them and also why certain approaches were chosen (24). In particular, to begin with, students gave the impression of being rather apprehensive about giving a short presentation to the entire class after having had only ~25 min to prepare themselves. Indeed, their fear was obviously rooted in the worry to be marked for such a presentation. When the benefits of such an approach were clearly explained, and the informal character of the small teaching group was emphasized, the students seemed to become more relaxed. In fact, some groups even used the blackboard to summarize the key points they wanted to make in their brief expose.

Of course, one weakness of the use of such interactive models could be that the students group into teams that already have learned to effectively work together in other practical courses, laboratory work, or seminars. This is to say, weaker students might find themselves as outsiders in a group or even be grouped together and, thus, not supported in their assimilation of knowledge and their efforts to take part in the problem solving. However, in other studies (6, 7), it has been shown that low-performing students are neither carried by their high-performing peers nor do they drag down the scores of the high performers (6, 7). Furthermore, the tutor has the opportunity to observe the student teams in their discussion dynamics for ~10 min before taking the initiative to 1) support them in finding their way into the questions and 2) involve the quieter students in the discussion by addressing specific questions to them. In fact, the experience with the present course modifications showed that such students will often readily participate in the small-group discussion and lose some of their apprehension to speak in front of the class. In any event, however, a tutor must be prepared to take a highly active role in leading the interactive module by offering additional guidance and providing confirmatory feedback (12). Furthermore, to give weaker students the chance to fully follow the material covered in the interactive unit, the tutor must comprehensively round up the session and clearly summarize the key learning objectives to the entire class.

In this article, I have presented some case studies that I successfully used in a 4-academic hour-long course unit on the ANS. Furthermore, I have shared some aspects of the process of how these case studies were designed, in the hope to encourage tutors who are looking for alternative ways to teach characteristics of the ANS. In addition, I have reflected on experiences with the implementation of this interactive course component and have given insights into how the students received (and perceived) these changes.

Taken together, introducing such case studies can be a suitable and straightforward alternative to computer-based modules in supporting our efforts to involve students more strongly in teaching. It goes without saying that interactivity is not a matter of course but that the tutor has to challenge the students right from the outset to actively participate in problem solving, so as to break down the barrier between the students in the classroom and the lecturer at the front. Nevertheless, the acceptance of such an endeavour among students is high, as is the satisfaction on the part of the tutor, who receives much more direct feedback from the class compared with when entirely teaching in the traditional style.

APPENDIX: CASE STUDY PROBLEMS AND ADDITIONAL TIPS

Case Study 1: Organophosphate Intoxication

Questions. The following questions were provided:
1. What symptoms do you expect following intoxication with organophosphates?
2. How do you explain these symptoms from a biochemical-physiological viewpoint?
3. What kind of therapeutic intervention do you suggest? Justify your ideas.

Additional tips. The following tips were provided:
1. What are organophosphates?
2. What is, based on their chemical classification, their effect?
3. Which receptors play a role in the scenario to be considered?

Case Study 2: Atropine Intoxication

Questions. The following questions were provided:
1. What symptoms do you expect after intoxication with atropine?
2. How do you justify these symptoms from a biochemical-physiological point of view?
3. What kind of therapeutic intervention would you suggest?

Explain your ideas.

Additional tips. The following additional tips were provided:
1. Where and how does atropine exert its effect?
2. Which receptors play a role in the scenario to be considered?

Case Study 3: Raynaud’s Phenomenon

Description. The following is a description of the pathological syndrome as taken from a textbook (25):

“In Raynaud’s phenomenon the digits (fingers and toes) become ischemic (lack blood) after exposure to cold or with emotional stress. The condition is due to excessive sympathetic stimulation of smooth muscle in the arterioles of the digits and a heightened response to stimuli that cause vasoconstriction.”

Questions. The following questions were provided:
1. Infer from the symptoms as described what receptors are involved in the phenomenon. Justify your assumption(s).
2. What therapeutic measures do you suggest based on what you have learned in today’s course and how did you come to such conclusions?
3. Do you expect collateral effects? If so, what effects do you imagine and why would they occur?

Case Study 4: the Sympathetic Nervous System and Blood Pressure

Questions. The following questions were provided:
1. Conclude—based only on what you have learned in today’s course—which receptors are involved in the symptoms of high blood pressure. Justify your assumptions.
2. What therapeutic approaches seem to result from the material covered in today’s course? Explain your conclusions.
3. Do you expect collateral effects? What effects do you expect and why would they come into play?
4. Under what circumstances should such drugs not be used and why?

ACKNOWLEDGMENTS

The author thankfully acknowledge the keenness of all students who participated in the evaluation of the course to support her in her efforts to make physiology more meaningful and amenable. The author is grateful to J. Klein, who made lecture slides available and welcomed and supported the idea to introduce case studies, giving knowledgeable advice on the case study design and preparation of the manuscript.

DISCLOSURES

No conflicts of interest are declared by the author.

REFERENCES