Enhanced student experience: an analysis of subjective evaluation and objective learning success after the transformation of a pharmaceutical physiology course

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THE PURPOSE OF THIS ARTICLE is to contribute to the discussion regarding the advantages of active over passive teaching strategies in supporting students in the successful acquisition of knowledge, specifically in the context that the comprehensive coverage of material is not necessarily leading to a better understanding of the matters taught (6). In fact, several previous studies (4, 5, 13, 14, 21) have described the positive impact of introducing practically oriented teaching modules to formerly mainly traditional and passive (ex cathedra) lecturing units over a wide range of subjects.

The German pharmacy curriculum is very dense, putting a high strain on students who want to complete their studies within the officially planned number of eight semesters. Indeed, students are confronted with an intense plan of courses, seminars, lectures, and laboratory work that does not leave room for much else other than exam preparation—this is an issue that also applies to the curricula of other healthcare professions (1, 10, 23). In fact, in view of this concentrated schedule, moving forward in the curriculum is generally mainly focused on quickly acquiring large amounts of facts to pass the exam, clearly at the expense of a deeper, long-lasting understanding of the core messages.

Therefore, special compulsory courses are incorporated into the study program with the desire to deepen knowledge and understanding of specific topics that have previously been taught in lectures. In particular, pharmacy students are taught “human anatomy and physiology” during a 1-yr lecture course in semesters 2 and 3 of the first 4 semesters of their 10-semester-long curriculum. (These first 4 terms are referred to as “Grundstudium,” i.e., basic studies; at the end of their basic studies, students must pass their first “Staatsexamen,” i.e., State exam, to proceed onto the “Hauptstudium,” i.e., advanced studies. Semesters 1–8 are university-based, whereas the last 2 semesters are dedicated to professional education outside the university.) An additional physiology course held during the fourth and final semester of their basic studies addresses core physiological topics. As stated above, this course is the subject of this article is meant to support the students in deepening and widening their knowledge of these topics, since they are central to the understanding of pharmacological mechanisms that will be addressed later in the advanced studies.

Before 2008, this course was largely lecture based, 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. As such, the course units that are given to smaller groups of only 20–25 students at a time frequently simply reiterated material already presented during the lectures preceding the physiology course. Despite the course tutors’ efforts to provide high-quality lectures, it was the course leaders’ perception that only a limited portion of the actual material covered was effectively learned and properly understood by the students (6). Given that the pharmacy students enrolling in the fourth-semester course had previously attended two semesters of physiology lectures, the students should already possess significant basic knowledge such that they can be expected to be capable of building on this previously acquired knowledge. Nevertheless, it has been shown that even experienced students do not necessarily meet expectations regarding background knowledge (24) but rather show low retention of scientific issues, with this fact most likely relating to the passive lecture style traditionally used in physiology courses (22). In fact, teaching experience has shown that active teaching methods generally lead to a higher order of knowledge (19).

In this context, our aim was to reorganize and restructure the fourth-semester physiology course on a broad basis with the
motivation being to prepare the students to not only assimilate facts but to learn and understand how to integrate and apply them. As a first aspect, we wanted to reorient the methods of knowledge transfer in the physiology course toward more applied and active teaching. More specifically, we introduced practical modules into several course units, integrating computer-based teaching modules into three of the eight course units, since computerized experimentation has many advantages for teaching physiological processes (17). Importantly, such educational approaches have proven successful in teaching matters such as basic principles of neuroscience (2) or physiological concepts (16, 25). At the same time, we introduced case studies in two of the eight course sessions to give students the opportunity to actively apply the passively taught material to new problems. Enriching the course units with case studies was meant to further the students’ knowledge of the matters taught through discussion and enhance their appreciation of the relevance of physiological mechanisms and pathophysiological alterations (9, 12). The implementation of these changes was supported by two meetings per semester (one held at the beginning and one at the end of the semester) with all course tutors to give them the opportunity to discuss their teaching experiences and aspects, positive or negative, associated with establishing the new methods of teaching. As a final change, we increased the pass mark for the exam that the students must pass at the beginning (and end) of the fourth semester to proceed to take the physiology course from 50% to 60% to ensure an advanced qualification of the students when they begin the specialized course. Our intention, and hypothesis, was that a combination of higher qualification from the outset with a teaching style that aims to engage much more with the students should lead to a more successful assimilation of knowledge.

We followed the introduction of these changes over a time span of three semesters (summer 2008, winter 2008/2009, and summer 2009) by means of an evaluation questionnaire for the students participating in the course (note that there are two intakes of pharmacy students per year). The questionnaire asked for their feedback on specific issues, which they could rate quantitatively, and gave them room for personal comments and criticism. Student responses were then shared in the regular meetings with the tutors, so as to identify potential further areas for improvement of the course. Finally, an objective assessment of our efforts to enhance the students’ attention, learning abilities, and knowledge through the transformation of the course was possible by looking at the final physiology course exam results at the end of the fourth semester as well as the results obtained in the independent, national State examination that directly follows the basic studies after the fourth semester.

EXPERIMENTAL PROCEDURES

The physiology course within the pharmacy curriculum. During their first 2 yr of basic pharmacy studies, students attend lectures on human anatomy, physiology, and some aspects of pathophysiology (attendance at the lectures is noncompulsory, although the students must pass exams in the lectured material to proceed). Specifically, they follow lectures spread over the second and third semester (there are 2 semesters/year) for a total of 84 academic hours. During the fourth semester, a separate physiology course expands on the following key topics: the central as well as the autonomic nervous system, the heart as well as the cardiovascular system, the gastrointestinal organs, lung function, and the immune as well as reproductive system. The course is taught within a time span of 4–5 wk and comprises a total of 64 academic hours (attendance at these course units is compulsory). Some of the course units are taught by PhD students, others by members of academic staff; the course unit on the heart was taught by an external professor. To guarantee a minimum of anatomical and physiological understanding, a written exam of multiple-choice questions testing the students’ knowledge of the material taught in the second- and third-semester lecture courses must be passed before students are admitted to the fourth-semester course.

Equally, a similar exam is held at the end of the course to assess the students’ grasp of the topics covered in the course. Passing this exam is mandatory for obtaining a “Schein” (certificate) that is necessary for admission to the first part of the independent, national pharmacy State examination that concludes the basic studies.

Computer-based teaching units. The core of the computer-assisted system as used in the course was the PowerLab data-acquisition unit, which was used in conjunction with LabTutor software and equipment (all AD Instruments, Heidelberg, Germany). Experiments carried out with this system comprised the following: 1) the recording of an electroencephalogram under various conditions (e.g., rest or motion, eye movement, and loud music) to elaborate the course unit on the central nervous system and give the students hands-on insight into the close connection between periphery and central control; 2) the measurement of blood pressure by means of different methods (upper vs. lower arm, thumb) to enliven the unit on the cardiovascular system and further the students’ understanding of the meaning of the parameters assessed; and 3) spirometric assessments (partly involving the obstruction of the extended artificial airways to imitate the situation of an asthmatic patient) to illustrate lung function and respiratory capacity also under impaired conditions.

As was the case before 2008, each course unit continued to comprise 4 academic hours, the first 2 academic hours of which were used to give a theoretical introduction to the subject, with the focus being placed on the preparation of the practical module to follow in the second half of the course. The class then adjourned to the practical class room, where experimental work was carried out. Students worked in groups of four to five around one of the four available data-acquisition setups. Notably, even though the system itself provided guidance through the experiment, the course unit tutor was available to support the students throughout the entire practical session. The computer-assisted system automatically records the results obtained by the student. These outcomes are then summarized in a protocol to be printed off and discussed during the final hour of the course unit, with this procedure ensuring that potential misconceptions are clarified. Furthermore, course unit tutors used this roundup session to summarize the main learning outcomes and give students the opportunity to check on their understanding of the material.

Case studies. Case studies were introduced into the course units on the autonomic nervous system as well as the immune system (cases referred to, e.g., intoxication with organophosphates or atropine, with the aim being to illustrate the transmitter cascades involved and the interplay between the subunits of the autonomic nervous system; cases on various types of allergies were meant to support the students’ effort to apply their knowledge to actual clinical occurrences). Specifically, the first 2.5 teaching hours were dedicated to a theoretical presentation of the material to be covered. The remaining time was used to give a theoretical introduction to the subject, with the focus being placed on the preparation of the practical module to follow in the second half of the course. The class then adjourned to the practical class room, where experimental work was carried out. Students worked in groups of four to five around one of the four available data-acquisition setups. Notably, even though the system itself provided guidance through the experiment, the course unit tutor was available to support the students throughout the entire practical session. The computer-assisted system automatically records the results obtained by the student. These outcomes are then summarized in a protocol to be printed off and discussed during the final hour of the course unit, with this procedure ensuring that potential misconceptions are clarified. Furthermore, course unit tutors used this roundup session to summarize the main learning outcomes and give students the opportunity to check on their understanding of the material.
solutions as well as the reasons for their suggestions. 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.

Preparation and design of the study. Computer-based teaching modules were officially introduced in the class in the winter 2008/2009 semester. However, measures to reorient the settings of the physiology course started already during the summer before that winter semester when all course tutors tested the computer-based equipment class independently. After the regular summer 2008 semester course, when neither computer-based modules nor case studies were used, the first evaluation of the physiology course took place. To this end, students were given a questionnaire where the following aspects were addressed: first, how well did students accept the course as a whole? For this purpose, specific questions relating to the practical orientation of the course and its differences compared with the preceding physiology lectures were asked. Furthermore, subsets of six specific questions explored the students’ perception of each of the individual eight course units. Equally, questionnaires were handed out after the winter 2008/2009 semester and after the final evaluation semester in summer 2009. A comparison of evaluation outcomes was carried out for the summer 2008 and 2009 semesters, whereas the winter 2008/2009 semester was considered a test run whose evaluation should guide us in how and where to modify the changes we had introduced. Given that the evaluation played an important part in organizing and structuring the physiology course toward practical modules, the respective questionnaires were analyzed, and the results were communicated to the course tutors after the end of each semester. This procedure gave an opportunity to discuss the students’ rating of the course in general and the various units in particular and to draw on their criticism to modify and adapt the changes as introduced from the winter 2008/2009 semester to the final evaluation after the summer 2009 semester. For the completion of our evaluation by objective means, we additionally compared the students’ final exam results as obtained after the 2008 and 2009 semesters. In addition, we compared the summer 2008 and summer 2009 State exam results in the category of physiology.

Evaluation cohorts. The number of students participating in the physiology course varied in each evaluation semester. Goethe University Frankfurt accepts two student intakes per academic year, where the summer intake is traditionally considerably smaller than the group admitted for the winter semester. This fact was reflected by the smaller number of students participating in the fourth-semester physiology course in winter 2008/2009. The total number of students participating in the course evaluation per semester was 62 students in summer 2008, 38 students in winter 2008/2009, and 50 students in summer 2009.

Questionnaire and evaluation. The questionnaire consisted of three main sections: the first two multiple-choice question-based sections addressed 1) the students’ perception of the physiology course in general and 2) that of each of the eight separate course units, whereas the third section gave the students room to give their personal comments and suggestions and encouraged constructive criticism to find out about their subjective learning experience. In the first section, the following categories were addressed: specialization compared with the physiology lectures, practical orientation, variety of teaching material, course character, avoidance of ex cathedra teaching, the tutors’ dedication to the students’ questions, the opportunity for open discussion, scope for personal design, depth of the material covered, breadth of the material covered, organization, worthwhileness of the course, and individual benefit of attendance. The questions asked in the second section of the questionnaire addressed, separately for each of the eight course units, the following issues: variety of teaching material, course character, the tutors’ dedication to the students’ questions, the 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 these first two sections. Hereby, 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 interactive modules (see Supplemental Material for the original German text and English translation of the questions in the questionnaire).1

It is to be noted that, in an introductory section to the physiology course, students were informed about our intentions to 1) establish interactive sessions in various course units and 2) evaluate their acceptance of these changes and the physiology course as a whole at the end of the course. Importantly, they were free to participate in the anonymous evaluation and filled out an informed consent for the data acquired to be used as described. Student intake in summer semesters is traditionally lower; hence, only 40 students (38 of which participated in the evaluation) attended the relevant fourth-semester course in winter 2008/2009. Final exam results were treated anonymously.

Data analysis. Questionnaires were analysed by adding up the rating marks for the various subcategories. Where applicable, percentage points are given to further the appreciation of the results obtained. Data referring to the physiology course in its entirety were collected from the ratings given to all eight course units. Where the changes regarding the introduction of computer-based modules or case studies were discussed, data obtained for the course unit on the heart was not considered, given that interactive sessions had been part of the course unit ever since.

Statistical comparison of the exam results from summer 2008 versus summer 2009 was carried out using Student’s t-test for independent sets of data, assuming a Gaussian distribution of data as well as differences in variance (20). Statistical analysis of means of the various evaluation categories (categories A–M) throughout the evaluation period (summer 2008, winter 2008/2009, and summer 2009) was carried out using the Kruskal-Wallis test, which is suitable for a comparison of three unmatched groups (20). Where necessary, data were expressed as percentages of total points to correct for the different numbers of students participating in the evaluation from semester to semester. However, all data points are reported as means ± SD unless otherwise stated.

RESULTS

The physiology course in its entirety benefited from the changes established. Introducing the changes as outlined was well received by the students in that it had a positive effect on the overall rating of the course when the rating in summer 2008 was compared with that of summer 2009. In fact, the total percentage points that the students gave for the course (as calculated from the average of points of all categories in Table 1) increased from an average of 62.69 ± 10.74% to 71.42 ± 9.39% (means ± SD) from the first semester of evaluation in summer 2008 to the final evaluation semester in summer 2009.

To gain a deeper insight into the influence of the changes on various specific aspects of the course, we asked the students to rate the course in its entirety according to specific subcategories that explored facets such as its interactive character and differences with the lecture courses in the previous semesters. An overview of the information discussed in the following is shown in Table 1; correspondingly, Fig. 1 shows a visual impression of the successful transformation of the course. Most importantly, the students especially appreciated the increased

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1 Supplementary Material for this article is available at the Advances in Physiology Education website. The table shows questions as asked in the questionnaire (in their original German version as well as in English (in italics)). For a straightforward comparison with the figures and tables, category and subcategory identifications (categories A-M or subcategories 1–6) precede the relevant questions.
Table 1. Ratings from the student questionnaires on the physiology course as a whole

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Summer 2008</th>
<th>Winter 2008/2009</th>
<th>Summer 2009</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Specialization compared with lectures</td>
<td>2.86 ± 0.75</td>
<td>3.45 ± 0.75</td>
<td>3.26 ± 0.95</td>
<td>0.001</td>
</tr>
<tr>
<td>B</td>
<td>Practical organization</td>
<td>2.79 ± 0.38</td>
<td>3.29 ± 0.80</td>
<td>3.38 ± 0.70</td>
<td>0.001</td>
</tr>
<tr>
<td>C</td>
<td>Diversified teaching material</td>
<td>2.35 ± 0.87</td>
<td>3.33 ± 0.76</td>
<td>3.40 ± 0.76</td>
<td>0.001</td>
</tr>
<tr>
<td>D</td>
<td>Course character</td>
<td>3.06 ± 0.97</td>
<td>3.27 ± 0.87</td>
<td>3.64 ± 0.90</td>
<td>0.013</td>
</tr>
<tr>
<td>E</td>
<td>Avoidance of ex cathedra teaching</td>
<td>2.79 ± 1.15</td>
<td>3.14 ± 0.93</td>
<td>4.41 ± 0.90</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>Tutors’ dedication to students’ questions</td>
<td>4.02 ± 0.98</td>
<td>4.39 ± 0.60</td>
<td>4.58 ± 0.60</td>
<td>0.002</td>
</tr>
<tr>
<td>G</td>
<td>Opportunity for open discussion</td>
<td>2.69 ± 0.97</td>
<td>3.16 ± 1.08</td>
<td>3.18 ± 1.04</td>
<td>0.019</td>
</tr>
<tr>
<td>H</td>
<td>Scope for personal design</td>
<td>2.16 ± 0.94</td>
<td>2.49 ± 0.93</td>
<td>2.44 ± 0.91</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>Depth of the material covered</td>
<td>3.28 ± 0.86</td>
<td>3.61 ± 0.72</td>
<td>3.27 ± 1.04</td>
<td></td>
</tr>
<tr>
<td>J</td>
<td>Breadth of the material covered</td>
<td>3.65 ± 0.75</td>
<td>3.37 ± 0.67</td>
<td>3.58 ± 0.70</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>Organization</td>
<td>3.66 ± 0.90</td>
<td>3.74 ± 0.83</td>
<td>3.96 ± 0.76</td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>Worthwhileness of the course</td>
<td>3.21 ± 0.98</td>
<td>3.37 ± 0.82</td>
<td>3.74 ± 0.92</td>
<td>0.021</td>
</tr>
<tr>
<td>M</td>
<td>Individual benefit of attendance</td>
<td>3.13 ± 0.97</td>
<td>3.53 ± 0.86</td>
<td>3.56 ± 1.05</td>
<td>0.024</td>
</tr>
</tbody>
</table>

Values are means ± SD. On the questionnaire, students could indicate a score between 1 (poor) and 5 (good). P values resulting from the comparison of mean ranks to reveal statistically significant trends are shown.

diversity of teaching material and methods (category C). In fact, as can be gathered from the results shown in Fig. 1, the rating improved by >1 rating point, corresponding to 21% points, from 2.35 ± 0.87 points in the summer 2008 semester to 3.40 ± 0.76 points in the summer 2009 semester for this category (Fig. 1, category C, open vs. solid bar). Only slightly less prominent were the positively judged developments in the subcategories of practical orientation (category B) and course character (category D). More specifically, the ratings of these categories improved by ~0.6 points, i.e., by >10% points [Fig. 1, category B, open vs. solid bar (2.79 ± 0.38 vs. 3.38 ± 0.7 points); and category D, open vs. solid bar (3.06 ± 0.97 vs. 3.64 ± 0.9 points)]. Furthermore, the students positively noted the tutors’ efforts to dedicate more time to their questions, as reflected in an increase of 0.56 rating points [Fig. 1, category F, open vs. solid bar (4.02 ± 0.98 vs. 4.58 ± 0.6 points)], as well as the opportunity for open discussion, which was marked by a 0.49-point increase on the rating scale [Fig. 1, category G, open vs. solid bar (2.69 ± 0.97 vs. 3.18 ± 1.04 points)].

Notably, the students’ positive judgement and increased acceptance of this compulsory physiology course was particularly reflected by their increased readiness to recommend the worthwhileness of the course to their fellow students [Fig. 1, category L, open vs. solid bar (3.21 ± 0.98 vs. 3.74 ± 0.92 points)]. In the same vein, they judged the course as more beneficial [Fig. 1, category M, open vs. solid bar (3.13 ± 0.97 vs. 3.56 ± 1.05 points)].

A statistical analysis of the mean ranks in the various rating subcategories (categories A-M) revealed a significant upward trend in 8 of the 13 categories. For the specific results of the Kruskal-Wallis test, see Table 1.

The separate course units benefited from introducing inter-

Fig. 1. Rating of the physiology course in its entirety. The course improved in all categories when the rating in each category was compared for summer 2008 (SSem 2008; open bars), winter 2008/2009 (WSem 2008/2009; shaded bars), and summer 2009 (SSem 2009; solid bars). The categories were as follows: specialization compared with the physiology lectures (category A), practical orientation (category B), diversified teaching material (category C), course character (category D), avoidance of ex cathedra teaching (category E), tutors’ dedication to the students’ questions (category F), opportunity for open discussion (category G), scope for personal design (category H), depth of the material covered (category I), breadth of the material covered (category J), organization (category K), worthwhileness of the course (category L), and individual benefit of attendance (category M). The positive development over the evaluation period (summer 2008 vs. winter 2008/2009 vs. summer 2009, open vs. shaded vs. solid bars) of the course became particularly clear from the ratings of categories C, D, F, K, and L. The exact values displayed are shown in Table 1.
active modules. The rating categories discussed so far concerned the physiology course as a whole, i.e., the rating described gave insight into the general perception of the course. We also asked the students for their specific (and separate) rating of the eight different course units so as to gain a deeper awareness of how those were judged. In this context, we asked them to rank the units according to six separate categories. Those comprised 1) diversified teaching material, 2) the actual course character of the course unit, 3) the tutor’s dedication to the students’ questions, 4) the opportunity for open discussion, 5) scope for personal design, and 6) the organization of the specific course units.

Specifically, we were keen to understand if the improvements to the physiology course as such, as they were judged by the students, were owed specifically to the introduction of computer-based teaching modules or if practically oriented and interactive teaching strategies in general made the difference. To this end, we separately looked at the rating of the three course units that had introduced computer-based modules from winter 2008/2009 onward, i.e., the course units on the central nervous system, cardiovascular system, and lung function. At the same time, we analyzed the ratings of the course units that used case studies in their teaching repertoire. All results of the evaluation are shown in Table 2. In the following paragraphs, however, we took a “snapshot” of the evaluation in summer 2009 and compared the different courses for this final evaluation semester.

From Fig. 2 and Table 2 it can be gathered that, at the end of the evaluation period, courses that had established such interactive modules were rated more highly in all six subcategories when they were compared with those courses where teaching continued in the traditional manner. Most remarkably, students acknowledged our efforts to involve them more in the actual course progression. More specifically, in the subcategory of scope for personal design, they gave remarkably higher ratings, up to 27% points more, to courses introducing interactive elements [Fig. 2, subcategory 5, shaded vs. open bar (case studies: 3.59 ± 1.06 vs. computer-based modules: 3.60 ± 0.98)] than to those using the ex cathedra teaching style [Fig. 2, subcategory 5, solid bar (no change: 2.24 ± 0.93)]. In the same vein, students rewarded our efforts to introduce diversified teaching material, a category where the rating reached 3.77 ± 0.88 and 4.18 ± 0.82 points for course units introducing case studies and computer-based modules, respectively, compared with only 2.78 ± 0.97 points for courses that lectured wholly traditionally (Fig. 2, subcategory 1).

Taken together, the results shown in Fig. 2 and Table 2 reveal that courses drawing on alternative teaching methods generally benefitted from these changes in all six subcategories in that differences in the evaluation of units that used computer systems compared with case studies were rather marginal. In fact, the differences in the subcategories of course character [Fig. 2, subcategory 2, open vs. shaded bar (computer-based modules: 4.07 ± 0.87 vs. case studies: 4.08 ± 1.07 points)], the tutor’s dedication to the students’ questions (Fig. 2, subcategory 3; open vs. shaded bar [computer-based modules: 4.33 ± 0.78 vs. case studies: 4.07 ± 1.05 points]), and opportunity for open discussion (Fig. 2, subcategory 4, open vs. shaded bar [computer-based modules: 3.48 ± 1.02 vs. case studies: 3.60 ± 1.08 points]) were negligible, suggesting that establishing interactive modules in general made the difference to how students experienced and, eventually, rated the separate course units. In contrast, all course units that continued to draw on ex cathedra teaching obtained noticeably lower rating marks when compared with the course units using computer-based modules or case studies (Fig. 2, solid bars).

All tutors and course units benefitted from the transformation. Given that we had introduced not only changes to the course unit organization itself but also to the coordination of the course, we were interested to see if the separate course units, and, with them, their tutors, benefitted from our efforts, independent from the alterations they had introduced. In other words, we wanted to see if a positive development was also noticeable for courses that kept lecturing in the traditional way. Figure 3 shows our results, which demonstrate that, within their teaching style category (traditional, Fig. 3A; case studies, Fig. 3B; and computer-based modules, Fig. 3C), all course units improved without exception in all rating subcategories when we compared the relevant rating at the beginning of evaluation (summer 2008) with that of the end of evaluation

Table 2. Ratings of course units that introduced either case studies or computer-based modules compared with those preferring the ex cathedra teaching style

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<tbody>
<tr>
<td>1</td>
<td>Diversified teaching material</td>
<td>Ex cathedra teaching: 2.25 ± 0.93</td>
<td>Case studies*: 2.79 ± 0.98</td>
<td>Computer-based modules*: 3.02 ± 1.00</td>
</tr>
<tr>
<td>2</td>
<td>Course character</td>
<td>Ex cathedra teaching: 2.35 ± 1.02</td>
<td>Case studies*: 3.53 ± 1.08</td>
<td>Computer-based modules*: 3.38 ± 0.98</td>
</tr>
<tr>
<td>3</td>
<td>Tutors’ dedication to students’ questions</td>
<td>Ex cathedra teaching: 2.64 ± 1.12</td>
<td>Case studies*: 3.97 ± 1.09</td>
<td>Computer-based modules*: 3.76 ± 1.00</td>
</tr>
<tr>
<td>4</td>
<td>Opportunity for open discussion</td>
<td>Ex cathedra teaching: 2.19 ± 0.97</td>
<td>Case studies*: 3.35 ± 1.14</td>
<td>Computer-based modules*: 3.17 ± 0.95</td>
</tr>
<tr>
<td>5</td>
<td>Scope for personal design</td>
<td>Ex cathedra teaching: 1.96 ± 0.90</td>
<td>Case studies*: 2.67 ± 1.04</td>
<td>Computer-based modules*: 2.57 ± 0.95</td>
</tr>
<tr>
<td>6</td>
<td>Organization</td>
<td>Ex cathedra teaching: 2.90 ± 1.18</td>
<td>Case studies*: 3.76 ± 1.12</td>
<td>Computer-based modules*: 3.91 ± 0.85</td>
</tr>
</tbody>
</table>

Values are means ± SD. Shown are the ratings from the beginning of the evaluation period (summer 2008), when innovations had not taken effect yet, through the final evaluation semester (summer 2009). *Not yet implemented.
How We Teach

Fig. 2. Ratings of course units in specific subcategories that introduced interactive modules compared with those of units preferring the ex cathedra teaching style. Shown are the ratings from the final evaluation period in summer 2009 of course units that introduced computer-based modules (CB; open bars) compared with those using case studies (CS; shaded bars) and units that continued using the ex cathedra teaching style (NC; solid bars). Units that used mainly the ex cathedra teaching style were rated remarkably lower in all six subcategories compared with units that established practical classes. The categories of evaluation were as follows: diversified teaching material (subcategory 1), course character (subcategory 2), tutors’ dedication to the students’ question (subcategory 3), opportunity for open discussion (subcategory 4), scope for personal design (subcategory 5), and organization (subcategory 6). The exact values displayed are shown in Table 2.

In line with the above discussion, clear improvement was noticed where computer-based teaching material was introduced in that the overall average course unit rating gained a total of 1.16 points, corresponding to 20% points within the year of evaluation [Fig. 3C, subcategory 1, solid vs. dark shaded bar (3.02 ± 1.00 vs. 4.18 ± 0.82 points)]. This maximal increase notably topped the ranking of courses introducing case studies. In fact, here, an improvement by 0.98 points was noted [Fig. 3B, subcategory 1, solid vs. shaded bar (2.79 ± 0.98 vs. 3.77 ± 0.88 points)]. Furthermore, students rated the opportunity for scope of personal design more highly in courses that established computer-based teaching modules, with the marks going up by 1.03 points, i.e., >20% points [Fig. 3C, subcategory 5, solid vs. dark shaded bar (2.57 ± 0.95 vs. 3.60 ± 0.98 points)]. The same was true for courses introducing case studies, where the rating increased by 0.95 points, i.e., 18% points [Fig. 3B, subcategory 5, solid vs. shaded bar (2.67 ± 1.04 vs. 3.59 ± 1.06 points)]. Nevertheless, the course units that kept to a traditional and, hence, more passive lecturing style visibly improved their rating in all six subcategories in summer 2009 when the marks were compared with those obtained at the beginning (summer 2008) of the evaluation period (Fig. 3A).

The students benefitted from our efforts. To support this evaluation, which used the students’ highly valuable, although subjective, impressions and opinions, we sought objective means by which to assess the success of our efforts to further learning experience and success. Therefore, we challenged the assumption that the material would be more readily available in the end of course exams by looking at the final physiology course exam results from the summer 2008 and 2009 semesters. In actual fact, the students’ results improved significantly from summer 2008 to summer 2009. Specifically, in summer 2008, students obtained an average of 61.88 ± 10.57% of all points, whereas the year after 69.96 ± 14.01% were reached (summer 2008 vs. summer 2009, P < 0.001), thus suggesting that the subjective positive appreciation of the practical orientation of the course was accompanied by objectively assessable learning success.

Even more convincing was the improvement of the results that the students obtained in the independent, national State exam. Here, the results improved from an average of 60.5 ± 16.5 points in summer 2008 to an average of 69.8 ± 16.6 points in summer 2009 (summer 2008 vs. summer 2009, P < 0.001). Importantly, the average over all subjects examined did not notably change (summer 2008: 62.15 ± 8.48 points and summer 2009: 61.95 ± 7.85 points), suggesting that the improvement in the physiology subsection of questions was specifically owed to the students’ preparation in this subject. Equal noteworthy was the fact that the physiology exam results at Goethe University Frankfurt ranked remarkably above the national average in summer 2009 comparing with summer 2008 (summer 2008, national vs. Goethe University Frankfurt: 61.1 ± 15.7 vs. 60.5 ± 16.5 points; and summer 2009, national vs. Goethe University Frankfurt: 63.3 ± 15.2 vs. 69.8 ± 16.6 points).

DISCUSSION

With the intention of successfully transforming a physiology course directed at pharmacy students in their fourth semester of 10 semesters of intense studies into a more interactive class, we restructured the course on a broad basis. Among others, we reoriented the methods of knowledge transfer to more applied and active teaching by introducing interactive modules in five of the eight course sessions. Furthermore, we established regular meetings for all course tutors to give them the opportunity to discuss their teaching experiences and aspects, positive or negative, associated with establishing the new methods of teaching. To gauge the influence of introducing these changes, we asked the students for their opinion and comments on our efforts. More specifically, we asked them to rate the physiology course as a whole as well as the eight course units separately according to different subcategories. Together with this quantitative subjective data, we also collected qualitative information, in terms of their personal critiques and sugges-
Here, we outline how the introduction of these modifications had a positive impact on the course development and its reception by the student cohort. First, we demonstrate that, in the eyes of the students, the course as a whole benefitted from its transformation to a more engaging and communicative class. Second, we show that the setting up of interactive modules, i.e., both computer-based teaching as well as case studies, enhanced the students’ appreciation of the relevant course units, a fact that manifested itself in both qualitative and quantitative subjective data collected through the questionnaire. Third, additional data demonstrate that the regular meetings with the tutors seemingly encourage them to work on their teaching style, with this further improving the students’ perception and evaluation of the course unit, independent from the introduction of practical modules. Finally, we show that the changes in their entirety furthered the students’ understanding of basic physiological principles, a finding that can be gauged from the objective learning success as manifested in the results of the exam held at the end of the relevant evaluation semester as well as those obtained in the State exam equally held after the fourth and final semester of basic studies.

As has become clear from looking at the rating points for the eight course units, the introduction of experimental, computer-based teaching modules as well as case studies made a remarkable difference in how students rated the course in general and various course units in particular. Importantly, this finding confirms those of previous studies in which case-oriented problem-solving tutorials have successfully been combined with traditional didactic lecture modules (11) and computer-based teaching modules could improve problem-solving abilities (15). In this context, the low rating marks (in all six subcategories) of courses that continued to prefer the ex cathedra teaching style are particularly telling, in that differences of up to 1.35 rating marks, i.e., 27% points were noted [Fig. 2, subcategory 5, solid vs. shaded bar (no change: 2.24 ± 0.93 vs. case studies: 3.59 ± 1.06 points)].

Notably, the course units where the ex cathedra teaching style was used throughout the evaluation period were rated already lower in summer 2008, when none of the tutors had made alterations to their teaching style as yet (Fig. 3A). This finding may be attributed to the fact that the tutors who continued with their ex cathedra style during the entire evaluation period were generally less experienced in lecturing and, hence, potentially less confident to introduce changes similar to their colleagues. At the same time, however, those ex cathedra course units, nevertheless, were ranked slightly more favorably at the end of the evaluation period in summer 2009, with this observation being in line with the improvements of the computer-based units and those using case studies from the beginning to end of the evaluation period (Fig. 3). This finding then suggests that working on the course design and teaching strategy in general boosted, first, how the students perceived the structure and design of the course units, and, second, how they valued the opportunities offered by the diverse use of teaching material and practical modules. Moreover, tutor performance must have been perceived more positively given that also ex cathedra teaching style units were rated more positively at the end of the evaluation period. Of course, we assume that such feedback may partly be ascribed to the overall improvements that the course was credited with, given that the teaching environment likely influences the students’ rating of tutors (3).

Nevertheless, we mainly attribute this positive evaluation to the strategies that are used to further tutor-tutor interactions before and after the relevant semesters. Such a hypothesis is in...
How We Teach

SUCCESSFUL TRANSFORMATION OF A PHYSIOLOGY COURSE

line with findings that describe how the students’ ratings of the tutors’ ability to give feedback vary in function of the tutors’ training (3). In fact, regular meetings gave all tutors the opportunity to discuss their experiences regarding issues such as student feedback or difficulties in encouraging open discussion during the course time. Discussing personal experiences as well as didactic strategies and methods during a dedicated meeting encouraged all tutors likewise to work on their performance and try out different ways of teaching or lecturing. In this context, it is of note that all tutors keenly engaged in the dialogue and unanimously expressed their appreciation of such meetings.

That such meetings proved fruitful over the entire period of evaluation is demonstrated by the results shown in Fig. 1, where the development of the course rating over the full period of evaluation from summer 2008 (open bars) through winter 2008/2009 (shaded bars) to, finally, summer 2009 (solid bars) is shown for the rating of the course as a whole for all rating categories. The steady and continuous improvement of the course is particularly obvious for the categories of course performance and try out different ways of teaching or lecturing. In this context, it is of note that all tutors keenly engaged in the dialogue and unanimously expressed their appreciation of such meetings.

To challenge the assumption that the assimilated facts would be more readily available for further exams, we compared the final physiology course exam results as well as the State exam results from the summer 2008 and 2009 semesters and noted that in summer 2009, significantly higher marks were reached, thus suggesting that the subjective positive evaluation of the practical orientation of the course was accompanied by objectively assessable learning success. In this context, it is, however, of note that students attending the course in summer 2009 seemed generally better prepared right from the start in that the pass mark of the initial exams was set to 60% instead of 50%, with this circumstance suggesting that experienced students retain more information. This finding seemingly supports the previously raised hypothesis that students may benefit from their advanced qualification if they were given the opportunity to actively engage with the knowledge transfer (24). That students learned to apply the material taught to new situations that they have not previously encountered became clear during the discussion sessions that directly followed the practical teaching modules, when students had to explain what they had learned and found out. A formal assessment of knowledge transfer will involve the establishment of essay questions in the final exam or, indeed, the introduction of oral exams for the physiology course semesters to come. In any event, when the first students who attended this modified course reach the seventh semester, when pharmacological issues are being broached that build on our basic course, we shall have additional means to judge if our efforts have truly borne fruit on a long-term basis.

In this context, one could object that raising the pass mark for entry into the course may be a contributory factor in changing the characteristics of the cohort of students and, hence, the improved outcomes in learning experience and success. However, increasing the pass mark did not make the course elective in that all pharmacy students must pass the course before being admitted to the State examinations. Weaker students might not attend the course with the cohort...
they originally belonged to but one or two semesters later, still as weaker students of their (new) group.

On the background of the data presented here, we are convinced that the positive outcome in terms of student evaluation as well as learning success is attributable to a strategy combining changes to the curriculum of the course as well as the style of delivering the material and our effort to give opportunity for informal professional learning to the course tutors. In fact, in view of the quantitative and qualitative data obtained from the evaluation of questionnaires that assessed the students’ view of the course, we conclude that our efforts to direct a previously mainly theory-based course that was marked by passive teaching style and ex cathedra lecturing toward a proper “practical course experience” have proven successful. Indeed, we feel encouraged to persevere in our endeavor to restructure the course given that the students’ subjective positive impressions were paralleled by a significant improvement of their objective learning success. Specifically, following students’ suggestions, we are considering the introduction of further computer stations to reduce the number of students working per setup. In addition, we plan to establish case study modules in the remaining course units and will continue to further the exchange of opinion and experience among the course tutors to especially support those who wish to become involved in changing their course structure with the final aim being to support students in developing a deeper understanding of how physiological phenomena occur, to finally overcome the mere memorizing of data, which is unfortunately and mistakenly considered to be the appropriate preparation for an exam.

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**DISCLOSURES**

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