

HOW WE TEACH | *Classroom and Laboratory Research Projects*

Teaching Animal Physiology: a 12-year experience transitioning from a classical to interactive approach with continual assessment and computer alternatives

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Kaisarevic SN, Andric SA, Kostic TS. Teaching Animal Physiology: a 12-year experience transitioning from a classical to interactive approach with continual assessment and computer alternatives. *Adv Physiol Educ* 41: 405–414, 2017; doi:10.1152/advan.00132.2016.—In response to the Bologna Declaration and contemporary trends in Animal Physiology education, the Animal Physiology course at the Faculty of Sciences, University of Novi Sad, Serbia, has evolved over a 12-yr period (2001–2012): from a classical two-semester course toward a one-semester course utilizing computer simulations of animal experiments, continual assessment, lectures, and an optional oral exam. This paper presents an overview of student achievement, the impact of reforms on learning outcomes, and lessons that we as educators learned during this process. The reforms had a positive impact on the percentage of students who completed the course within the same academic year. In addition, the percentage of students who completed the practical exam increased from 54% to >95% following the transition to a Bologna-based approach. However, average final grades declined from 8.0 to 6.8 over the same period. Students also appear reluctant to take the optional oral exam, and 82–91% of students were satisfied with the lower final grade obtained from only assessments and tests administered during the semester. In our endeavor to achieve learning outcomes set during the pre-Bologna period, while adopting contemporary teaching approaches, we sought to increase students' motivation to strive toward better performance, while ensuring that the increased quantity of students who complete the course is coupled with increased quality of education and a more in-depth understanding of animal physiology.

animal physiology; continual assessment; computer alternatives; learning outcomes; undergraduate courses

ANIMAL PHYSIOLOGY has been a mandatory course for third-year biology students at the Department of Biology and Ecology, Faculty of Sciences University of Novi Sad (UNSPMF) since its foundation in 1969. During the “classical teaching” period, Animal Physiology was a two-semester course, organized as a mixture of face-to-face lectures and laboratory classes involving animal experimentation, with assessment methodology relying solely on mandatory practical and oral exams organized at the end of the course. Beginning in academic year 2005/2006 and continuing in the years to follow, the course was gradually revised with the introduction of new teaching and

assessment approaches and implementation of an interactive course organization. This interaction is, among other changes, mostly reflected through introduction of computer simulations into laboratory classes, continual assessment during the semester, and the introduction of mandatory mini-tests as part of laboratory exercises. This resulted in more active engagement of students in the learning process and intensive communication between professors and students. An overview of the organization of the Animal Physiology course and a timeline of changes introduced between 2001/2002 and 2011/2012 is presented in Fig. 1.

During its long history, the Animal Physiology curriculum has undergone several changes; however, teaching methodology comprising a mixture of face-to-face lectures and laboratory classes involving animal experimentation remained largely unchanged until 2005. This is when the first attempt was made to align the study programs at UNSPMF with the Bologna Process, which Serbia officially joined in September 2003 by signing the Bologna Declaration, a document verified by European ministers in charge of higher education. The Bologna Process is presently followed by 48 countries and comprises a set of far-reaching reforms, aimed at the creation of a European Higher Education Area that promotes mobility of students by facilitating greater comparability and compatibility among diverse higher education systems and institutions across Europe and by enhancing their quality (3). This aim is mainly achieved through structuring higher education along three cycles (Bachelor-Master-PhD), via establishment of a system of credits (European Credit Transfer and Accumulation System) as a standard for comparing knowledge attainment and performance of students, and through implementation of a system of easily readable and comparable degrees by providing the Diploma Supplement as a standardized description of the program of study completed (3, 10). In practice, this harmonization of UNSPMF study programs with programs across the European Higher Education Area within the Bologna Process also necessitated the restructuring of existing study programs, compression of extensive two-semester courses to one semester, modernization of teaching methods, and evaluation of student performance during the semester, among other initiatives. In addition, the Law on Higher Education in Serbia, which fully implements the Bologna Declaration, came into effect in September 2005. At the same time, Animal Physiology teachers were becoming increasingly aware of students' concerns for animal welfare and their disapproval of perform-

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CLASSICAL APPROACH (exam at the end of the course, no continual assessment, practical work using animals)	INTERACTIVE APPROACH (continual assessment, mini-tests, computer alternatives...)

broader physiological education, albeit at a more basic level. To meet this requirement, the Animal Physiology course presently incorporates basic information on characteristics of excitable tissues, functional regulation of the nervous system and endocrine regulation, along with an introduction to the key principles of functional organization and regulation of all organ systems in mammals. The overall objectives and learning outcomes of the course changed in response to these modifications to the course content, but were always based on students' understanding of basic physiological principles, functional organization of animals, and mechanisms of homeostasis maintenance. Despite the changes implemented in the course curriculum and the reduction in the number of lecture hours, the teaching approach during lectures did not change considerably over the years. Teachers conducted formal *ex cathedra* lectures in front of a relatively large group of students, who were expected to take personal notes. The changes in teaching methods for lectures mainly resulted from modernization of teaching processes, including introduction of figures- and graphics-rich slide presentations instead of transparencies, and presentations of video clips and audio visual presentations of different physiological processes. Although teachers constantly encouraged interaction with students and invited them to comment and react, the lectures remained in the sphere of lecturer-controlled classes. For these reasons, changes in lectures could

not significantly influence student performance throughout the course and, therefore, are not additionally discussed and considered in the present study.

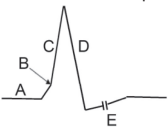
Between academic years 2001/2002 and 2004/2005, practical exams consisted of assessing student performance in a practical exercise, along with a written explanation of the observed phenomenon and related topics. Academic year 2005/2006 represents the first milestone in the range of reforms to the Animal Physiology course. For the first time, the course was organized over one semester instead of two, and "point scoring" of student activities (attendance at lectures, semester tests) was introduced, in accordance with the recommendations of the Bologna Process. Moreover, this was the first time that computer-based simulations of experiments on laboratory animals were used as a predominant teaching method during laboratory classes. In accordance with this change, laboratory work using animals was abolished at the practical exam and was substituted by three semester tests covering the topics presented during practical work. Another milestone in the course organization occurred in academic year 2008/2009. To enhance students' active involvement in the learning process and promote their greater understanding of presented topics, mandatory mini-tests covering discussed issues were intro-

duced at the end of each laboratory class. These mini-tests were designed as simple in-class activities lasting 5–10 min, contained 7–8 questions primarily pertaining to factual knowledge, but also assessing conceptual and/or procedural knowledge where applicable (examples of questions are presented in Fig. 2). Following their introduction in 2008/2009, the mini-tests were subjected to minor changes in question design and scope, which resulted in continual improvement in their quality. Apart from this, active involvement of students in the learning process was constantly stimulated by interactive teaching approaches. This required that the teacher be fully dedicated to students and constantly follow each student's progress throughout the exercise, asking for their opinion on how and why certain process occurs, while offering additional, individual explanations to students struggling with task completion and content understanding. Moreover, the class schedules were organized to ensure that there was always time left for discussion among students, prompting them to explain to each other some elements of the presented issues. We always encourage this aspect of the teaching process, since, as also noticed by Vujevic (22), the success of interactive teaching depends not only on communication between the teacher and students, but on communication among the students as well.

Example 1. Match types of membrane transport with their main characteristics/examples of transport.

1) passive transport _____	a) requires energy
2) active transport _____	b) diffusion
	c) facilitated diffusion
	d) transport opposite the concentration gradient

Example 2. Based on the picture and signs on it, put the labels next to the terms:



1. Repolarisation _____
2. Threshold _____
3. Hyperpolarisation _____
4. Depolarisation _____

Example 3. Put the letters „a->g" in a proper order, so that they describe the sequence of events in neuromuscular transmission.

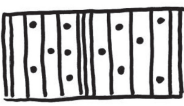
- Binding of Ach to nicotinic receptors.
- Ca²⁺ entering the terminal button of motoneuron.
- Depolarisation of membrane of terminal buttons of motoneuron.
- Exocytosis of Ach in the synaptic cleft.
- Depolarisation of the endplate membrane.
- Opening of the voltage-gated Ca²⁺ ion channels.
- Opening of the ligand-gated Na⁺/K⁺ ion channels.

Example 4. Which type of tetanic contraction will occur if action potentials on the muscle fibre membrane generate during the relaxation phase? _____

Example 5. Select the correct statement.

- Stimulation of cardiac muscle during diastole will result in a sudden increase in the heart rate.
- Stimulation of cardiac muscle during diastole will result in extrasystole and compensatory pause.
- Stimulation of cardiac muscle during diastole will not result in genesis of a new action potential and another contraction.

Example 6. According to the drawing of a part of the B-square, calculate the number of cells in 1mm³ of the sample, if the sample is diluted 100 times.



Example 7. What is the main function of neutrophil granulocytes? _____

Example 8. If the reaction contains blood serum and appropriate amount of CaCl₂, will the coagulation occur after incubation? _____

Example 9. Is the following statement true or false?
When the glucose level in blood is high, secretion of insulin from beta-cells in islets of Langerhans is stimulated.

Example 10. Link hormones with their function in organism.

a) Glucagon _____	1) Increases the heart rate, involved in the fight-or-flight response.
b) Adrenalin _____	2) Stimulates glycogenolysis in liver cells.
c) Somatostatin _____	3) Inhibits release of the growth hormone.

Fig. 2. An example of questions included in some of the mini-tests.

Another important change took place in 2008/2009, when oral exams were made optional, since students could now collect enough points during semester activities and written tests to obtain a final grade (not exceeding 8). Thus mainly students aiming for a higher grade elected to take the optional oral exam. The aforementioned written tests were composed of questions covering the complete course content and were designed similarly to the mini-test questions, thereby evaluating basic factual and conceptual knowledge. On the other hand, during the oral exam, students convey their subject knowledge through a face-to-face conversation with the teacher. Thus they are expected to show more in-depth knowledge of a specific topic and demonstrate a higher degree of conceptual and metacognitive knowledge. During the oral exam, additional questions posed by the examiner can sometimes reveal gaps in students' prior knowledge, but can also assist them in making inferences and arriving at correct answers to questions for which they were initially insufficiently prepared.

The aim of this paper is to present our 12 yr of experience during the period of reforms of the Animal Physiology course at UNSPMF, their impact on the percentage of students who successfully complete the course within the same academic year, and their final grades. We present both the benefits and pitfalls of the adopted changes and their impact on total student performance, along with the lessons we as teachers learned from our attempts to improve animal physiology education at UNSPMF.

METHODS

The data required for the present investigation were sourced from student registers for the Animal Physiology course for the academic years 2001/2002–2012/2013. The registers include data on student performance in all conducted activities (practical exam, mini-tests, semester tests, final tests, oral exam), including dates of their completion, thus providing insight into the path each student took from first class attendance to achievement of their final grade. The organization of biology studies at UNSPMF has changed over the years, such that third-year students attended courses in the frame of one to three different tracks or study profiles (Biologist, Biology Professor, and Molecular Biologist), depending on the academic year and the offered study profiles for that specific generation of students. Since Animal Physiology is a mandatory course for all study profiles, for the purpose of this study, the information pertaining to students enrolled in all available study profiles was extracted.

For each academic year, pertinent data were analyzed to provide summary information on the number of students from each study profile, time required for all enrolled students to complete the required practical activities and pass the final exam (whether within the same academic year or later), grades obtained from practical activities and final exam, and assessment format (e.g., semester tests, final test, oral exam). The 2012/2013 academic year was chosen as the end-point for analyses, because in 2013/2014 we introduced additional changes in the organization of the Animal Physiology course, the effects of which, while yet to be measured, could have affected study findings.

The data related to average student grades from practical and final exams in different academic years were statistically analyzed by one-way ANOVA, Tukey's multiple-comparison test. For statistical analyses of average students' grades from different study profiles from practical and final exams over different academic years, non-parametric Mann Whitney *U*-test (when comparing two study profiles) or one-way ANOVA, Tukey's multiple-comparison test (when comparing three study profiles) was employed.

RESULTS

Total number of students and study profiles. The number of students attending the Animal Physiology course, and their structure in terms of study programs attended, changed substantially between 2001/2002 and 2012/2013 (Fig. 3). While the course was previously attended by no more than 40 students per academic year, in 2003/2004 and 2004/2005, enrollment figures doubled, which is a direct consequence of the increased number of students who enrolled in biology studies at UNSPMF. However, the number of students who eventual enroll in Animal Physiology also depends on students' successful completion of program requirements for the first and second years of study. While there was a decline in the number of students registered in 2005/2006, from 2006/2007 onward the total number of students became relatively stable at ~100. The 2007/2008 academic year was a notable exception, as 139 students enrolled in the course.

Due to annual changes in the study programs offered at UNSPMF, the study profiles of the third-year students also changed considerably. Between 2001/2002 and 2004/2005, only Biology and Biology Professor study profiles were available. Between 2005/2006 and 2009/2010, students could also choose the Molecular Biologist study profile, while in 2010/2011 these options were abolished, resulting in all third-year students being assigned to the study profile Biologist. It is noteworthy that, between 2001/2002 and 2004/2005, Biologists represented a clear majority, whereas, with the introduction of Molecular Biologists, students became almost equally distributed among the three study profiles.

Time required for completion of practical activities and the final exam. The time required for completion of practical activities and the final exam in Animal Physiology was analyzed. We calculated the percentage of students who accomplished these activities within the same academic year or later, as shown in Figs. 4 and 5. Practical activities are represented by practical laboratory work at the end of the course (2001/2002–2004/2005) or test and mini-tests related to practical activities (2005/2006–2012/2013). Until the 2005/2006 academic year, the percentage of students in each category was rather unstable and varied over the years. However, 2006/2007 was marked by a significant increase in the number of students

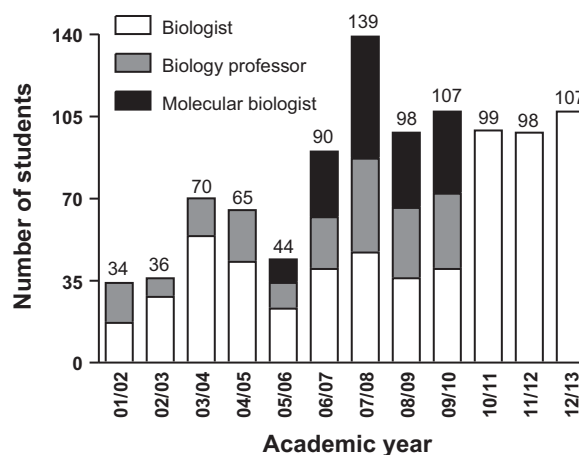


Fig. 3. Total number of students attending the Animal Physiology course and their study profiles for each academic year between 2001/2002 and 2012/2013.

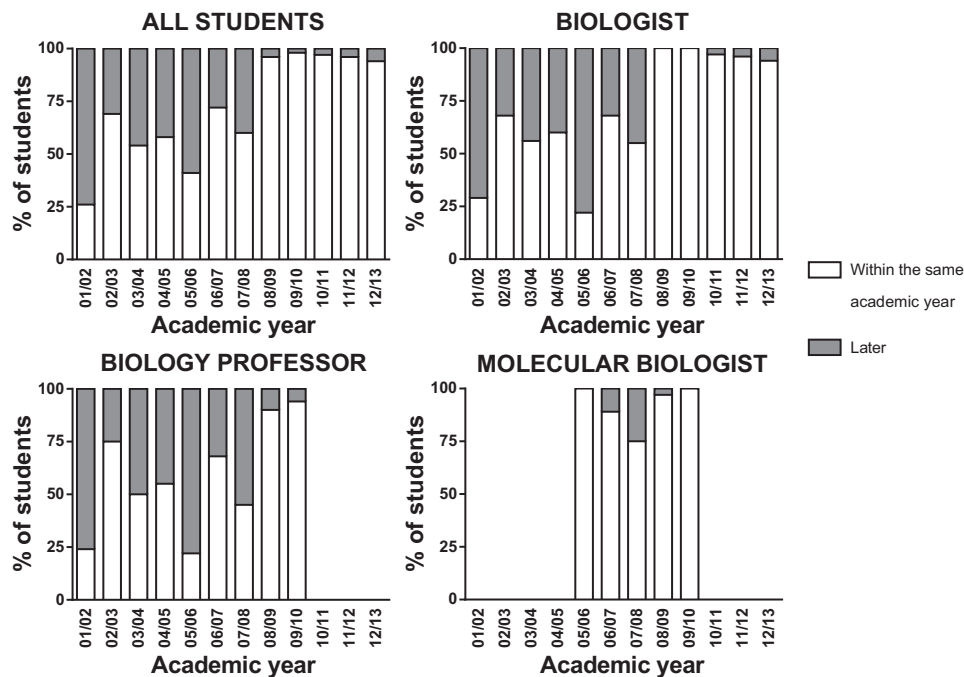


Fig. 4. The percentage of students who completed the practical exam in Animal Physiology within the same academic year or later, for each academic year between 2001/2002 and 2012/2013.

who completed all practical activities within the same academic year, owing to the introduction of mandatory mini-tests at the end of each practical class. In particular, in 2008/2009, the percentage of students who completed the practical exam within the same school year increased from an average of 54% to >95%. This abrupt increase was noted in the results pertaining to all study programs, and the high percentage remained stable over the following years.

The timely completion of practical activities resulted in a greater percentage of students who passed the course within the same academic year (Fig. 5). When analyzing the data set as a

whole, it became apparent that a shift occurred in 2007/2008, when the majority of students passed the course within the same academic year. When student data were analyzed separately for each study profile, the findings revealed that, in 2008/2009, those pursuing Biologist and Biology Professor degrees became more successful in completion of their activities, while Molecular Biology students were efficient throughout the period between 2005/2006–2009/2010. The most drastic increase in student effectiveness was noticed in the Biology Professor study program in 2008/2009, where the number of students who successfully completed the

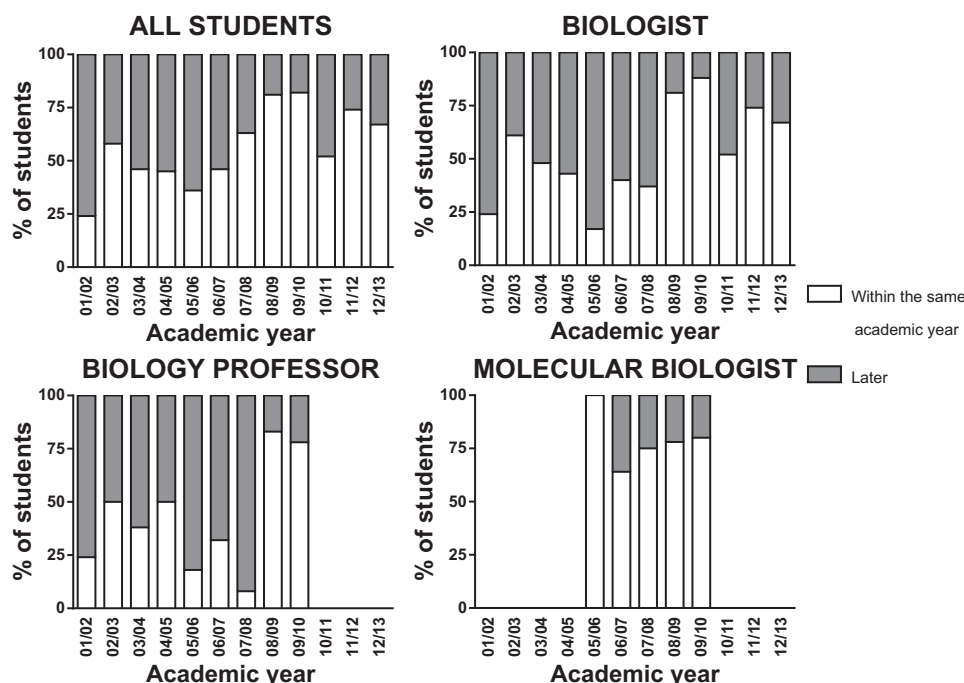


Fig. 5. The percentage of students who completed the Animal Physiology course within the same academic year or later, for each academic year between 2001/2002 and 2012/2013.

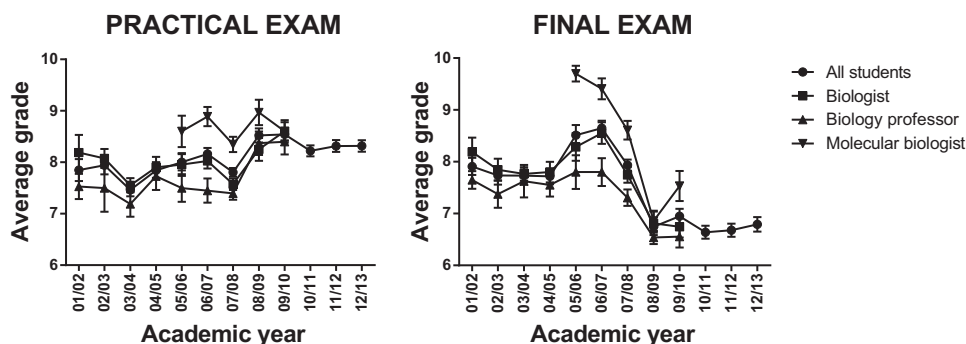


Fig. 6. Average grades at the practical and the final exam in Animal Physiology for each academic year between 2001/2002 and 2012/2013. Values are means \pm SE. Data on the average students' grades at the practical and final exam in different academic years were statistically analyzed by one-way ANOVA, Tukey's multiple-comparison test (Supplemental Tables S1 and S2). Data pertaining to the average grades obtained by students attending different study profiles at the practical and final exam in different academic years were statistically analyzed by nonparametric Mann Whitney U-test (when comparing two study profiles) or one-way ANOVA, Tukey's multiple-comparison test (when comparing three study profiles) (Supplemental Tables S3 and S4).

course within the same academic year increased from an average of 31% to 80%.

Grades obtained for practical activities and the final exam. Student performance in terms of final grades for the practical exam or mini-tests (starting from 2008/2009 when mini-tests were first introduced) and the final exam was also analyzed (Fig. 6; Supplemental Tables S1–S4). In the 2008/2009 academic year, the average grade for all students for the practical exam improved slightly (from 7.8 in 2007/2008 to 8.3 in 2008/2009; $P < 0.0001$) and remained relatively constant thereafter. This increase was particularly noticeable in the Biology Professor study program, where an increase from 7.5 to 8.4 was measured (2007/2008 vs. 2008/2009; $P < 0.05$). It is also noteworthy that Molecular Biology students had the best performance for the practical exam between 2006/2007 and 2007/2008 ($P < 0.01$ or $P < 0.0001$), with an average grade of 8.7.

However, the improvements noted above did not extend to the final exam, where a downward trend was noted, resulting in

a decline in the average final grade from 8.0 to as low as 6.8 in the last 5 yr (significantly different average grades between the years from the period 2008/2009–2012/2013 in comparison to the years from the period 2001/2002–2007/2008; $P < 0.01$ or $P < 0.0001$). Molecular Biology students, on average, performed better at the final exam in all years except 2008/2009 ($P < 0.05$, $P < 0.01$, or $P < 0.0001$) compared with students from other study groups. Nonetheless, their grades also declined rapidly over the years.

Assessment formats chosen by the students. In the 2008/2009 academic year, for the first time, students were given the choice of completing the course by taking only written tests (two semester tests or one final), or proceeding further to the oral exam, with the potential for attaining a higher final grade. The vast majority of students (82–91%) decided not to take the final oral exam (Fig. 7). When the data were analyzed separately by study groups, a slightly different picture emerged, as up to 33% of the Molecular Biology students took the oral exam.

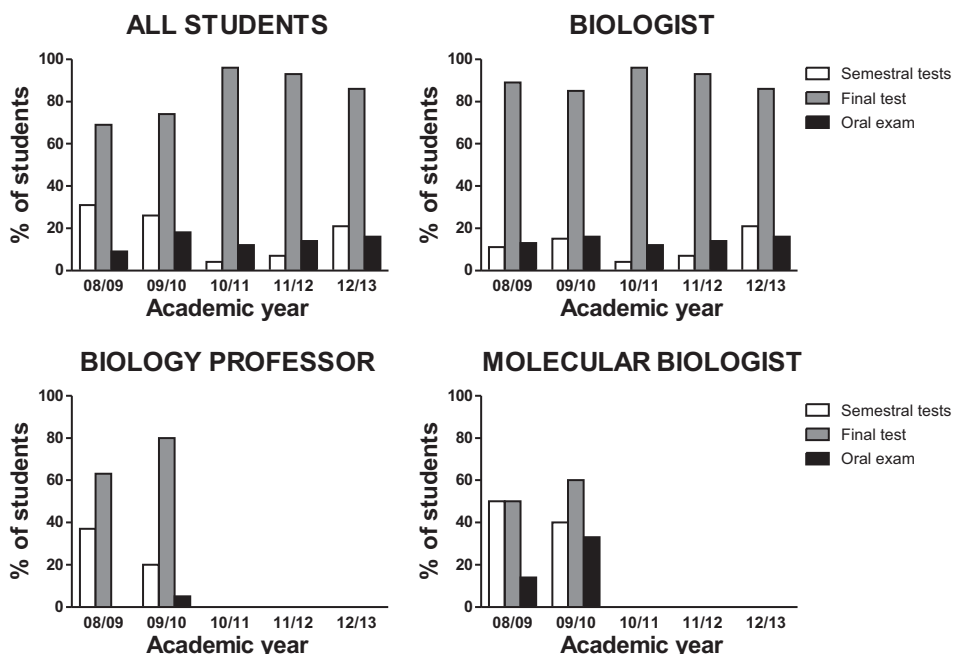


Fig. 7. Assessment formats that students selected for their Animal Physiology exam in each academic year between 2008/2009 and 2012/2013.

DISCUSSION

Recent efforts aimed at improving science education at the university level range from supplementing traditional courses with interactive activities, through the development of more engaging courses that enhance student interest in and appreciation of science, to complete restructuring of courses (17). Initiatives specifically aimed at improving animal physiology teaching include several models for enhancing student learning, such as alternatives to the use of animals (2, 9, 12, 13), interactive computer-assisted learning (14), self-made and graphic imagery models explaining specific physiological processes (18, 19), inquiry-based laboratories (6), and team-based learning in a laboratory course (21), among others.

Despite the decade-long experience of implementation of the Bologna Process, the goal of which is modernization of European higher education, to our knowledge, its outcomes and impacts in the field of animal physiology education have not been previously assessed. On the other hand, extensive research has been conducted on the integration of computer-based alternatives into mainstream teaching and learning, including its efficiency and positive effects on student learning outcomes (8, 12). Our experience has demonstrated that organization of Animal Physiology course at UNSPMF in accordance with Bologna Process recommendations, accompanied by gradual substitution of wet laboratories with alternatives to animal experimentation, have resulted in greater study efficiency. Our findings revealed that a greater percentage of students completed course requirements (both practical and theoretical parts) within the same academic year relative to the period before the introduction of these changes. However, the final goal of improving student learning outcomes has not been fully achieved, since grade improvements were noted for practical activities only.

Although practical laboratory exercises using frogs as an experimental model required development of practical skills as an important learning outcome, stronger emphasis was always placed on understanding physiological processes and the essence of the conducted exercise. Consequently, even though changes in the course structure necessitated a reduction in the share of practical work in laboratory classes and a greater reliance on computer simulations, the main learning outcomes, favoring conceptual over procedural knowledge, remained the same. Both teaching approaches were used to help students develop higher order reasoning, whereby the experimental procedure merely enhanced the students' understanding of the set task. Based on our results, it seems that implementation of alternatives, along with the complete abolishment of harmful animal procedures, was not the main reason for greater student efficiency, or at least not for the first generation of students (2005/2006) to experience this change in experimental teaching methodology. Knight (12) reported that alternatives-based laboratory classes frequently result in enhanced potential for customization and repeatability of learning exercises, increased student confidence and satisfaction, enhanced preparedness for laboratories, and decreased student stress. However, the first generation of students who were taught using the alternative methods tended to exhibit a negative attitude toward computers, as many lacked adequate computer literacy and had poor knowledge of English terminology necessary for understanding the programs. These factors likely contributed to the lower than

anticipated learning efficiency and the suboptimal learning outcomes in this initial cohort. According to study findings reported in 2011 by Kojic and Dewhurst (13), 14 out of 18 schools from 13 Eastern European countries (including Serbia) were still making use of animals, in some instances in quite large numbers, for teaching purposes, with relatively little use of technology-based teaching and learning resources. The authors identified lack of computer software programs in local languages as the major barrier to the introduction of replacement alternatives. However, a more recent study conducted by Zupanec et al. (24) revealed that even biology teachers from elementary schools in Novi Sad exhibited exceptionally positive attitudes toward the application of computer-assisted learning and demonstrated remarkable confidence in the application and contribution of computers to improve biology teaching. These assertions also coincide with results obtained in the present study, where subsequent generations of students exposed to new technologies at a much earlier age exhibited much greater enthusiasm for alternative learning modalities. Thus the problems we observed in 2005/2006 gradually became less pronounced, diminishing with each new student intake. In the present study, we used student efficacy only as a measure of how fast they complete the course and obtain a final grade (within the same academic year or later). However, although this might be an indicator, it is not at the same time a measure of student understanding of animal physiology. In this context, the final grade obtained at the exam is a metric that better assesses student understanding of physiology.

The improvement in student outcomes could also be due to the greater percentage of curriculum time dedicated to practical exercises, which increased from 33% in the period between 2001/2002 and 2004/2005, to 46% and 47% in 2005/2006–2007/2008 and 2008/2009–2012/2013, respectively. However, the greatest increase in student effectiveness and examination results was observed following the introduction of mandatory mini-tests at the end of each laboratory class in 2008/2009. This continuous assessment prompted the students to be more focused on their work and contributed to a more in-depth approach to each exercise and a greater understanding of the procedures involved. Moreover, as mini-tests also incorporated elements of formative assessment, students were provided with relevant feedback on their performance early in the learning process, thereby further supporting their achievement of learning outcomes (16, 20). In particular, we found that following each exercise with a mini-test was constructive for both teachers and students, as the former could identify students in need of further support, while the latter could obtain timely feedback on their performance, enabling both sides to work on their performance and reach the desired level of mutual understanding at an early stage of the course. The downside of this strategy was that many students were overly reliant on their mini-test scores as indicators of course content knowledge. It turned out that these encouraging outcomes from the mini-tests were likely a result of short-term knowledge, since students never managed to reach the same grades during further assessments covering the same topics. It is possible that students, satisfied with such good mini-test results, overestimated their knowledge, and did not invest enough study time to understand the complete course content as a whole. To overcome this problem, and to further encourage students to study continuously throughout the semester, we recently introduced

lecture revisions before each semester test. However, as this is a new initiative, its impacts cannot be presently assessed due to insufficient data. Moreover, in the 2011/2012 academic year, we introduced the Open Source learning management system Moodle (<https://moodle.pmf.uns.ac.rs/>) as a platform for communication with students, as well as an efficient distribution of electronic course materials and information regarding exams, thus facilitating course organization in general. In case this strategy does not prove to be efficient, we are also considering changes in the frequency and/or format of mini-tests that might make them more efficient learning tools. The strategy described by Vujovic (22), relying on students' preparation for class and introductory quizzes that constitute a significant part of the final grade, could contribute to initial understanding of the study material and result in better learning outcomes in general.

A significant issue that has persisted over the years is generally poor student performance on the final exam, as indicated by low final grades. In 2008/2009, when the oral exam became optional, we noted a significant decline in final grades, as the majority of students opted for receiving a final grade (no greater than 8) based on semester activities (mini-tests) and final tests covering the theoretical part of the course, while forgoing the opportunity to increase their grade through the oral exam. Although constantly encouraged by teachers to take the oral exam, and despite their poor performance on final tests (average grade lower than 7), the vast majority of students were satisfied with their lower grade and did not attempt to earn higher marks via the oral exam.

The reasons behind this phenomenon are probably complex and diverse. Although introductory, the Animal Physiology course is comprehensive in scope, and a large proportion of students find the curriculum extremely challenging, which was noticed by other researchers (16). According to Marden et al. (16) large student numbers and a diverse student cohort pose a significant challenge to the teaching staff in terms of motivating and engaging students, providing feedback on performance, and identifying and assisting students in need of remediation. Moreover, given that Animal Physiology is a mandatory course, there is a need to cater to a larger group of students with different levels of prior knowledge, as well as diverse interests, affinities, and strategies for their further professional profiling. Hence, there is a considerable variation in the level of interest in the subject matter and motivation for better performance on exams among the students. In addition, our findings revealed that students enrolled in the Molecular Biologist study profile displayed the greatest understanding of animal physiology, as reflected by their exam results, as well as the higher percentage of those pursuing a higher grade by attempting the oral exam. Since there was no significant difference in prior educational background among students pursuing the study profiles examined in the present investigation, we posit that the discrepancy in performance is directly related to students' interest in the subject, as well as perceived relevance of animal physiology for further academic education and professional career paths. Moreover, the Molecular Biologist study profile traditionally attracted students who attained the best results during high school education and on the entrance exam. Unfortunately, even results from students pursuing this study profile suggest rapid regression in the achievement of learning outcomes over the years. We also noticed that students who

took the oral exam at the end of the course achieved better outcomes in subsequent higher level courses and master studies. Similarly, Luckie et al. (15) reported that attendance at the optional verbal final exam in Introductory Biology correlated with enhanced success in multiple subsequent upper level science courses.

Large class sizes necessitate that student learning be initially assessed via multiple-choice questions that primarily test the ability to recall and recognize the main concepts and terms in physiology. On the other hand, at the oral exam, students are expected to display a much greater level of understanding of physiological phenomena, as well as be able to explain them and place them in a broader context of functional organization of organism. As summarized by Carnegie (5), students often find it difficult to make the transition from answering the multiple-choice questions in written tests, which is essentially a passive activity, to providing eloquent answers that demonstrate their ability to both apply basic scientific principles and link them in a logical manner, which is an active process. Empirical evidence also shows that the strategies used by students when preparing for examinations are driven by the assessment methodology, whereby students prepare for tests based on the multiple-choice questions by adopting only surface strategies such as compilation and memorization of lists of factual information, without analysis, evaluation, and the provision of detailed explanations required for the oral exam. This might explain why a great majority of our students choose not to attend the oral exam and are willing to accept a lower final grade rather than exerting the additional effort required for oral exam preparation. It is, however, likely that such a decline in achievement of learning outcomes stems from the state of the educational system in Serbia as a whole, which affects the quality of students pursuing biology studies and, consequently, results in changes in teachers' attitudes toward students and a revision of examination criteria. While these and other factors are probably involved in the observed effects, their exploration is beyond the scope of the present investigation, as it would require more in-depth analysis by experts from different fields.

Lastly, all of the changes that have taken place in the organization of the Animal Physiology course over a relatively long 12-yr period undoubtedly affected the teachers themselves, in terms of concerns over the suitability of the new course format, and attributing each student success or failure as their own success/failure in transferring knowledge. What helped us during this period is our great ability to adapt and to react promptly in unpredicted situations, critical consideration of problems and obstacles we faced, and decision making based on our previous teaching experience and recognition of students' needs and capacities. We do not spare time and effort to overcome any obstacle on our journey, and, in addition to the reintroduction of mandatory oral exams to overcome student reluctance, we intend to seek solutions for all other problems under our competency.

In conclusion, as a part of an ongoing initiative aimed at better organization of the Animal Physiology course in terms of synchronization with the Bologna Declaration and Law on Higher Education, greater efficiency, frequent assessments, general student satisfaction, and availability of concise and easy-to-understand literature, we have succeeded in increasing the percentage of students who successfully complete the course, albeit at the expense of the quality of knowledge they

attain. We have a difficult task ahead, as we need to reach “old-school” learning outcomes and enhance students’ motivation for better performance while using contemporary teaching methods. This aim can be potentially achieved through reintroduction of a mandatory oral exam, which was implemented in 2013/2014. In the years to come, and with further work on improvements in teaching and assessment methodologies, we hope to find an optimal balance between course completion rates and the knowledge level attained by students, especially in-depth animal physiology understanding, and greater scientific literacy in general.

Our future perspective and general mission is to implement an action plan for the 21st century, as a part of which transformation of undergraduate biology education for all students is proposed (23). As concluded by Vujovic (22), the role of the 21st century lecturer is not merely to transfer information, but rather to facilitate the development of students’ ability to apply basic knowledge and gain higher levels of understanding. Given the extant evidence indicating that course-based undergraduate research experiences (CURE) can make scientific research more inclusive (1), and that high-enrollment CURE improves student conceptions of scientific thinking and ability to interpret data (4), we will aim to learn from the experience of others and incorporate the most effective strategies when making further changes to our curriculum and its mode of delivery and assessment (7, 11). Through the development of the Animal Physiology course, and a number of complementary courses we teach (such as Comparative Animal Physiology, Molecular Cell Physiology, Mechanisms of Cell Communication, etc.), we will strive to improve the educational process, as our ultimate goal is to better equip our students with the necessary knowledge, motivation, and sense of societal responsibility to participate actively in the innovation process. Clearly, it will take years to measure progress toward these ambitious goals, but we have enthusiasm and will make the best use of the Moodle platform established as an E-learning support system at our faculty (<https://moodle.pmf.uns.ac.rs/>) and ERASMUS student exchange programs at our university (<http://www.uns.ac.rs/index.php/en/international-cooperation/internationalization-of-uns/agreement-on-cooperation/e-sporazumi>), as well as all opportunities to learn from the experiences of others (1, 4, 7, 11). We believe that these are powerful tools that, when used optimally, have the potential to shape new generations of young scientists/educators/innovators and thus impact economic governance. We are willing to adopt new tools to transform our ambition of improving student outcomes into reality.

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DISCLOSURES

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AUTHOR CONTRIBUTIONS

S.N.K., S.A.A., and T.S.K. conceived and designed research; S.N.K., S.A.A., and T.S.K. performed experiments; S.N.K., S.A.A., and T.S.K. analyzed data; S.N.K., S.A.A., and T.S.K. interpreted results of experiments; S.N.K. prepared figures; S.N.K. drafted manuscript; S.N.K., S.A.A., and T.S.K. edited and revised manuscript; S.N.K., S.A.A., and T.S.K. approved final version of manuscript.

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