HOW WE TEACH | Classroom and Laboratory Research Projects

Collective and experimental research project for master’s students on the pathophysiology of obesity

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Bourlier V, Conte C, Denis C, Dray C, Guillou P, Belliure M, Lorsignol A, Noël M, Buffin-Meyer B. Collective and experimental research project for master’s students on the pathophysiology of obesity. Adv Physiol Educ 41: 505–513, 2017; doi:10.1152/advan.00147.2016.—We describe here a collective and experimental research project-based learning (ERPBL) for master’s students that can be used to illustrate some basic concepts on glucose/lipid homeostasis and renal function around a topical issue. The primary objective of this ERPBL was to strengthen students’ knowledge and understanding of physiology and pathophysiology. The secondary objectives were to help students to develop technical/practical abilities and acquire transversal skills with real-world connections. Obesity is a worldwide public health problem that increases the risk for developing type 2 diabetes and nephropathies. To study the impact of western dietary habits, students evaluated the effects of a diet enriched with fat and cola [high-fat and cola diet (HFCD)] on metabolism and renal function in mice. Students mainly worked in tandem to prepare and discuss data. Students showed that HFCD-fed mice 1) developed obesity; 2) exhibited glucose homeostasis impairments associated to ectopic fat storage; and 3) displayed reduced glomerular filtration. The educational benefit of the program was estimated using three evaluation metrics: a conventional multicriteria assessment by teachers, a pre-/posttest, and a self-evaluation questionnaire. They showed that the current approach successfully strengthened scientific student knowledge and understanding of physiology/pathophysiology. In addition, it helped students develop new skills, such as technical and transversal skills. We concluded that this ERPBL dealing with the pathophysiology of obesity was strongly beneficial for master’s students, thereby appearing as an efficient and performing educational tool.

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Efficient way to teach, a substantial body of knowledge about cognitive processes and methods of teaching and learning has been collected in recent decades.

Student-centered instructional strategies, rather than traditional teacher-centered learning approach, have been shown to provide a better environment to link theory with practice, to improve communication skills and critical thinking, and to increase intrinsic motivation (7, 11). Project-based learning is an attractive student-centered pedagogy, and studies have proven that this can increase the overall content retention and improve students’ attitudes toward learning (3, 10, 33). Indeed, project-based learning emphasizes complex tasks that involve students in project design, problem solving, decision making, or investigative activities (33). Moreover, it allows students to work relatively autonomously over extended periods of time and culminates in realistic, not schoollike, products or presentations (33). Finally, it also involves both cooperative and collaborative elements that positively influence motivation, social cohesion, cognitive, and developmental processes (31). Altogether, project-based learning both impacts life skills and engages students in real-world tasks (5).

As an experimental scientific discipline, physiology requires experimentations and thereby promotes learning by doing. This teaching method has been shown to deepen understanding of theories, develop practical skills, gain professional experience, and promote the ability to think, analyze, and observe carefully and critically (12, 20). Although alternatives to animal testing must be encouraged (3R principles), animal models are indispensable to elucidate and strengthen the understanding of basic physiological mechanisms and to investigate their dysregulations in diseases (21, 27).

Finally, the relationship between research and teaching is one of the cornerstones of modern higher education (36). Consequently, it appears essential for university students to favor research-based training to explore physiology. Research-based pedagogies have been shown to increase student engagement, responsibility, and confidence in their ability to do and understand science (36). Students also improve their result interpretation skills and begin to apprehend the construction of scientific knowledge and the use of evidence to support assertions (36). Such pedagogy may also influence their future career choices (30).
Based on these perceived benefits, we proposed here a collective and experimental research project-based learning (ERPBL) for master's students to assess metabolism and, more specifically, glucose homeostasis and renal function in the context of diet-induced obesity. The driving question that students and teachers explored and answered through the present project was: what are the long-term effects of a high-fat and cola diet (HFCD) on mouse metabolism and renal function?

**Obesity and Its Associated Complications**

Obesity is a body weight disorder characterized by fat mass excess and is a known risk factor for comorbidities development, such as type 2 diabetes, cardiovascular disorders, or breathing abnormalities (14,32). Type 2 diabetes then contributes to macro- and microvascular complications, including diabetic nephropathy, the most common cause of chronic and end-stage renal disease in the world (28) (Fig. 1). It is known that obesity results from a combination of genetic susceptibility, increased high-energy food intake, and decreased physical activity in modern society (1, 14). Epidemiological data indicate that chronic intake of both fatty diets and fructose contained in sodas, as well as frequent fast food dieting, increase the risk of obesity development (1). The fat and cola enriched-diet was thus taken in our animal study to mimic energy-dense food.

We think that diet-induced obesity and its related complications is a very attractive scientific topic for students for several reasons. First, obesity epidemic is clearly a major public health issue that potentially threatens one’s well-being, including students, their relatives, and close friends. Second, mouse models of obesity are not experimentally hard to develop. Third, this pathology affects numerous organs, such as the liver, skeletal muscles, adipose tissues, pancreas, and kidney, leading to having an integrative point of view. Fourth, the impacts of obesity on energy homeostasis regulation are usually difficult to assess conceptually by the students because of their complexity. Fifth, the effects of a high-fat diet associated with cola on metabolism and kidney function have been poorly studied. Thus testing the complications induced by a combination of HFCD allowed the students to really play an active role in innovative research.

**Learning Objectives**

The primary objective of this ERPBL was to strengthen students’ knowledge and understanding of physiology and pathophysiology. The secondary objectives were to help students to develop technical/practical abilities and acquire transversal skills (i.e., skills that can be used in a wide variety of situations and work settings).

We have identified seven skills that students should acquire after completing this research project program:

A. Manage and monitor a project, select and follow an experimental approach, perform a critical and synthetic analysis of results.

B. Acquire the latest scientific concepts concerning obesity and its associated complications.

C. Set up current techniques for carbohydrate and lipid metabolism analysis in mice in the context of obesity.

D. Set up current techniques for renal function analysis in mice in the context of obesity.

E. Be aware of team working in the context of a scientific project.

F. Communicate a written scientific message.

G. Communicate orally a scientific message.

**Students’ Prerequisite Knowledge and Abilities**

Before undertaking this research project, students should have a basic knowledge of energy homeostasis (including organs, hormones, and regulation of carbohydrate and lipid metabolisms) and kidney anatomy/function. They should also

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Fig. 1. Overview of obesity and its associated complications studied in the current research project. A: obesity, corresponding to an excess of fat mass (i.e., storage of lipids), is usually associated with impaired handling of lipids, leading to deposition of fat in nonadipose tissues, including liver and skeletal muscles. B: this contributes to reduce whole body sensitivity to the actions of insulin (i.e., insulin resistance), which induces increased production of glucose by the liver and reduced glucose uptake by skeletal muscles. In turn, the pancreas compensates for these processes by producing more insulin, thereby leading to hyperinsulinemia. Over time, the pancreatic cells failed, leading to a raised circulating blood glucose concentration (i.e., hyperglycemia), and hence type 2 diabetes. C: obesity and diabetes are major risk factors for kidney disease. The pathogenesis includes the onset of inflammation and fibrosis, which progressively result in significant destruction of normal kidney structure and accompanying functional deterioration.
have some understanding of obesity, type 2 diabetes etiology, and complications, as well as some handling of basic statistical analyses. Laboratory skills that would be helpful include theoretical knowledge of routine cellular and molecular biology techniques (e.g., colorimetric assays, enzyme-linked immunosorbent assay, ribonucleic acid extraction, reverse transcription-polymerase chain reaction), as well as basic pipetting, calculations of dilution, and preparation of solutions.

**Organization of the Course**

**Pedagogical team.** The pedagogical team was composed of six teachers and a technician of the Faculty of Sciences at Paul Sabatier University/Toulouse III in France. Five teachers were physiologists specialized in metabolism/energy homeostasis and renal function, and one teacher was a molecular biologist. They spent in total 120 h in front of the students during the course. The technician was mostly responsible for the well-being of the animals. He also assisted students for animal experiments and helped to prepare the experimental classrooms.

The course took place in the experimental classrooms of the University of Paul Sabatier/Toulouse III, which are well equipped for physiology routine experiments and molecular biology, such as spectrophotometers, balances, pipettes, material for animal handling, or centrifuges. Nevertheless, the project required some additional specialized materials, such as a quantitative PCR instrument, a nanospectrophotometer, a microplate reader, glucometers, metabolic cages, tissue homogenizer, cold plate for modular tissue embedding system, and microtome.

The budget of the course was around 250 euros/student, including animals, food, and biochemical kits.

**Students.** The work was performed with students studying biology at the Faculty of Sciences at Paul Sabatier University/Toulouse III. Students were pursuing a master’s degree in Science, Technology, and Healthcare (specialized in Biology Healthcare). The scientific objectives of the degree program were to enable students to acquire an integrated perspective of physiological and pathological processes in both animals and humans using multidisciplinary approaches.

The first semester of the master was organized into two parts: 1) classroom-based learning, and 2) research-based learning. The classroom-based learning tackled various topics (Fig. 2A) that permitted students to have the prerequisite knowledge listed above. Concerning research-based learning, students had the opportunity to choose the current ERPBL that was presented at the beginning of the scholar year (Fig. 2A). The ERPBL was divided into part- and full-time periods in which both theoretical and experimental works were undertaken (see Fig. 2 for more details).

Three classes (2013–14, 2014–15, and 2015–16) have followed the current experimental teaching program to date. Students were asked to sign a document according the transfer of their rights of property to the pedagogic team.

**General outline/tasks.** At the beginning of the project, students were divided up into seven pairs.

Theoretical work was based on an analysis of reviews (6, 14, 23, 28, 32) and recent research articles on obesity and its complications (9, 15, 16, 19, 22, 26, 29) (Fig. 2B). Each student pair had to prepare two 10-min-long oral presentations, one on a review and the other one on an original article provided by the teachers. In addition, they had to read and prepare questions on the articles given to the other pair of students. Before the beginning of the experimental part of the project, each student also had to orally explain to the group the principle of one technique used in the ERPBL and to write the corresponding experimental protocol. For all of the oral presentations, students were evaluated by two or three teachers on predefined criteria (see below). They received a feedback on both oral presentations and written experimental protocols.

In parallel with theoretical work, students started to learn how to safely manipulate animals with teachers and technician to become autonomous in the follow up and animal handling for experimental work (Fig. 2B). At this stage of the project, the staff raised students’ awareness on animal well-being.

Experimental work was then mainly realized for the next 6 wk of the ERPBL (Fig. 2B). Although experimental work was done by paired students, interactions between the groups occurred very frequently and at different levels. First, scheduling the experiments was a group decision due to constraints imposed by the number of animals or by the limited number of devices. Second, students collectively analyzed the data obtained by each pair, thus allowing statistical power increase. To note, a specific emphasis on abnormal raw data production as a potential index of technical problem occurrence was made by the pedagogical team. The students then had to organize the data as graphs and perform statistical analyses, first together and then under the supervision of teachers. Third, debates were organized by the teachers to compare the obtained results with the expected results. Students had to discuss their results, propose explanations justifying the discrepancies with the literature, and suggest complementary experiments, followed by a critical appraisal of the present project and suggestions for improvement. At this step, teachers made students aware of the importance of ethical considerations for prevention of scientific misconduct.

At the end of the program, each student wrote a scientific report dealing with the research project and gave an oral presentation in front of a jury (Fig. 2B). Specific instructions were given to help them for the writing and to orally communicate their scientific message. In addition, before writing, students first submitted a detailed plan of their manuscript, which was then corrected and discussed with the teachers during individual interviews. After this validation, they began to write their 15-page-long manuscript.

**Mice Data**

All information concerning mice data (material and methods, graphs/table, results, technical and conceptual difficulties, and discussion) can be found in Supplemental Table S1. (The online version of this article contains supplemental data.) To summarize, students observed that HFCD-fed mice displayed significantly increased body weight and fat mass compared with the control diet group, thereby indicating that HFCD led to an obese phenotype. HFCD-induced obesity promoted the onset of type 2 diabetes, since HFCD-fed mice exhibited increased fasting glycemia, impaired glucose tolerance, and hyperinsulinemia. Ectopic fat deposition observed in both liver and skeletal muscle may participate in insulin resistance and thus altered glucose homeostasis. Obesity and type 2 diabetes...
Master Science, Technology and Healthcare
(specialized in Biology-Healthcare)

Semester 1
Semester 2
Semester 3
Semester 4

Classroom-based learning

Research-based learning

Lessons on various topics (7 weeks), including:
- Physiology (energy homeostasis, carbohydrate and lipid metabolism, renal anatomy and function)
- Pathophysiology (obesity, type 2 diabetes and hypertension)
- Cellular and molecular biology techniques
- Statistics

ERPBL (17 weeks):
- Presentation (topics, experimentations, learning objectives and modalities of assessment)
- Theoretical work and manipulation of animals (7 first weeks, 2 half-days/week)
- Experimental work (6 weeks, full-time period)
- Preparation of written and oral reports (upon completion, full-time period)

B

Oral presentation of the techniques to be used

Oral presentation of research articles

Redaction of experimental protocols

Correction of detailed plan of the report

Final oral presentation

Presentation of the research project (by teachers)

Oral presentation of reviews

Redaction of the report

Final discussion

HFCD or Control diet

Analysis of:
- adipose tissue weight
- hepatic lipids
- renal mRNA expression
- liver, muscle, kidney histology
- plasma and urine creatinine

Glycemia
Glucose tolerance test
Insulinemia

Sacrifice

Metabolic cages
had a minor impact on renal function, since only a slight reduction in glomerular filtration rate, without any sign of inflammation or fibrosis, was detected in response to HFCR.

**Educational Benefit**

*Evaluations by the teachers.* At the beginning of the course, students were informed of the criteria used to evaluate their work. Throughout the program, they were assessed on three levels, corresponding to 20% of the final mark: 1) oral presentations: understanding, precision of given information, slide quality, quality of oral expression, ability to analyze and synthesize data, as well as ability to answer questions were evaluated; 2) experimental abilities: technical skills, independence, organization, initiatives, improvement in any of these points, as well as the keeping of an up-to-date laboratory notebook were evaluated; and 3) overall behavior: human relationships, ability to work with coworkers, motivation, participation, as well as quality and quantity of work were evaluated. Each teacher had to return the marks he or she had assigned throughout the project. Those marks were averaged to give each student a single grade.

At the end of the project, each student prepared a manuscript in the form of a scientific article and gave a 10-min-long oral presentation, followed by 10 min of questions, in front of a jury of teachers originating from three distinct disciplines: physiology, cellular and molecular biology, and neurosciences. Skills to communicate written and oral scientific messages, as well as the ability to analyze/critique/synthesize data and understand the concepts and technical approaches related to the study were evaluated, corresponding to 80% of the final mark.

The final marks range between 0 and 20. According to the French grading system, a mark $\geq 10$ gives students 12 European Credit Transfer System (ECTS) credits. The mean score of classical evaluation of the students, performed throughout the program by the teachers for the three classes, was $13.75 \pm 0.27$ out of 20, which is satisfactory for a master’s level teaching unit in the French grading system. All students obtained the 12 ECTS credits, thereby demonstrating that pedagogical objectives were broadly achieved.

To better assess the impact of the ERPBL on students’ scientific knowledge, an anonymous and unexpected test was given twice to the students of the 2015–16 group ($n = 10$), at the beginning (pretest) and at the end of the program (posttest). The test lasted 30 min and included 45 questions about theoretical background relating to the study (i.e., glucose and lipid homeostasis, obesity, insulin resistance, or renal physiology and pathology), experimental design, and practical approaches (Supplemental Table S2). The number of absent or wrong, incomplete, and correct answers was quantified by the teachers. Four sections were defined, and the percentage of absent or wrong, incomplete, and correct answers was calculated for each section. Scores obtained in the posttest were compared with those obtained in the pretest. The ERPBL increased from 15 to 22% and from 27 to 35% for the number of correct answers for theoretical and practical knowledge, respectively (Fig. 3). These results indicate that ERPBL improves students’ knowledge in both theoretical and practical aspects of the topic.

*Students’ perception.* The main purpose of the program was not the acquisition of new theoretical knowledge, since master’s student already had lessons on addressed topics, as mentioned in the students’ prerequisite knowledge and abilities; the goals were rather to expose students to real-life situation to strengthen their scientific knowledge and develop practical and transversal abilities, as mentioned in the learning objectives. To evaluate the students’ perceived benefit of the ERPBL on the seven skills previously defined, we asked them to fill out a multiple choice questionnaire composed of 59 questions corresponding to one or more skills, as indicated in Supplemental Table S3. Each question begins with, “the master’s degree research project allowed you/helped you to.” Students reported the impact of the teaching program, answering “not at all,” “a little,” “moderately,” or “a lot.” Invitations to anonymously complete the questionnaire were sent electronically to students from the three classes after the end of the 2016 teaching period. Twenty-nine students completed the questionnaire. Since no difference was found between the classes (data not shown), data were pooled. For the analysis, we considered that “moderately” or “a lot” meant that students perceived a clear pedagogical benefit of the ERPBL. Thus the answer was classified as positive. Conversely, “not at all” or “a little” indicated that the ERPBL had no impact. We thus considered this answer as negative (Supplemental Table S3).

Except for a few questions (7, 14, 19, 23, 25, or 40) related to different points (e.g., control of stress, use of classical software, or fluency in written report), students perceived a real benefit of the ERPBL since 62–100% of them answered positively to each question (Supplemental Table S3). Strong improvement was reported for questions dealing with theoretical (53–59) and practical (34, 41, 42, or 45) knowledge about the topic, but also oral communication abilities (20–22). These observations were confirmed when questions were clustered into seven skills identified to be meaningful for the benefit of this program (Fig. 4). Indeed, we observed a great increase in the scientific knowledge of obesity and its complications (skill B: 92%), as well as in the current techniques used to assess metabolism and renal function (skill C: 85%; skill D: 86%). ERPBL also helped students to manage and monitor a project and to work in a team (skill A: 82%; skill E: 81%). Finally, while the course improved the students’ ability to orally com-

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**Fig. 2.** Organization of the course. A: during the first semester of the Master in Science, Technology, and Healthcare (specialized in Biology Healthcare), students followed a classroom-based learning and a research-based learning. In this context, the current ERPBL was proposed to students at the beginning of the semester. The ERPBL was composed of three periods of time: 1) a period of part-time work, in parallel with the classroom-based learning, mostly focused on theoretical work as well as manipulation of animals; 2) a period of full-time work dedicated to the experimental part of the ERPBL; and 3) a period of full-time work for preparation of written and oral reports. B: at the beginning of the ERPBL, students performed analyses of reviews or research articles and wrote protocols of techniques to be used. Students also started experimentations. *Body weight, food, and drink intake of C3Heb/HENJ mice fed a control diet (14% kcal of fat) or a high-fat (45% kcal of fat) and cola diet (HFCD) was measured. #Formation to animal experimentation (mouse handling, simulations of intraperitoneal injections) was also realized at that time. Finally, metabolic phenotyping of both groups of animals was realized, as well as analyses of plasma, urine, and tissues. At the end of ERPBL, students wrote a manuscript and gave an oral presentation in front of a jury of teachers. Wc–W18 weeks 0–18.
communicate a scientific message (skill G: 82%), it was a bit less efficient in helping them to communicate a written scientific message (skill F: 74%).

Thus this master research project was effective at various levels in helping students to improve and develop scientific theoretical and practical abilities, as well as personal resources, such as communication, confidence, or organization. Altogether, these results suggest that the presented ERPBL improves conceptual and technical knowledge and allows the acquisition of both practical and transversal skills.

**Discussion**

We described here a collective ERPBL for master’s students that can be used to illustrate some basic concepts on glucose/lipid homeostasis and renal function. In accordance with the extensive literature of the field (20, 31, 33, 36), we hypothesized that the proposed program should facilitate the learning retention of physiological concepts in both normal and pathological situations (primary objective), as well as give technical/practical experience and develop important transversal abilities (secondary objectives). During classical laboratory exercises, teachers prepare a structured laboratory manual, and students blindly follow the step-by-step protocol, as a cookbook, without really understanding the task. In contrast, here the students analyzed scientific reviews and original articles related to the topic to get an overview of the literature and prepared their experimental protocols, thereby becoming true actors in their learning. In addition, data were acquired by compiling results obtained by each student pair, which were then collectively analyzed. Students worked, therefore, as a team, in which each member played an important role. They had to deal with unexpected or contradictory observations, as well as discrepancies with existing literature on the topic, these exercises being important for development of critical-thinking and self-directed learning skills, as previously shown (4). Finally, students played an active role in innovative research by showing that HFCD-fed mice developed obesity, exhibited glucose homeostasis impairments associated with ectopic fat storage in skeletal muscle and liver, and displayed reduced renal function.

The educational benefit of the program was assessed using multiple evaluation metrics. First, students were evaluated on different aspects by the teachers implicated or not in the course. Second, a test was given twice to the students at the beginning and at the end of the program to evaluate the impact...
of the course on students’ theoretical and practical knowledge on metabolism and renal function. Third, a multiple choice questionnaire was prepared to evaluate the students’ perceived benefit derived from the research project.

All of the students obtained the 12 ECTS credits allocated to this research-based learning with a satisfactory score, thereby indicating that globally the objectives of the ERPBL were reached.

Looking more into details, teachers can confirm that the primary objective of the current research project was reached. Indeed, the pre- and posttest evaluation of scientific knowledge confirmed that this course improves theoretical knowledge on the topic. As a reminder, all of students had followed, before the ERPBL, more conventional teaching dealing with metabolism, obesity/type 2 diabetes, and renal function. This increased learning retention was confirmed by the students, since 92% of them considered that the teaching program allowed them to acquire the latest scientific concepts concerning obesity and its associated complications (skill B). Altogether, these results showed that the current approach successfully strengthened students’ scientific knowledge and understanding of some aspects of physiology and pathophysiology. This outcome is in accordance with studies demonstrating that project-based learning applying experimental research improves retention of content, as well as students’ attitudes toward learning (3, 10, 12, 20, 33, 36).

We also concluded that the secondary objective of the program was achieved. Indeed, the pre- and posttests showed an improvement of students’ knowledge in the practical aspects of the study. This high increase of practical knowledge was expected, since students did not have much opportunity to do this large panel of experiments. It was confirmed by the feedback of the students, since 85% of them felt that the course taught them how to set up current techniques for both carbohydrate/lipid metabolism and renal function (skills C and D). We can hypothesized that these improvements in experimental skills may have contributed to reinforce their comprehension of physiology, as it was well established that learning by doing deepens understanding of theories (12, 20). On the other hand, students’ self-evaluation of this research project showed a real benefit for students in terms of transversal skill acquisition. Indeed, skills concerning management of a project (skill A), team working (skill E), and both written and oral communication (skills F and G) seem to be acquired for at least 74% of students, thereby confirming that ERPBL improves students’ personal and professional life-related abilities.

Fig. 4. Acquisition of skills related to the educational benefit of the research teaching project. Students ($n = 29$) completed a multiple choice questionnaire (59 questions) at the end of program (see Supplemental Table S3) to evaluate their perception on the benefit of the current project. Each question begins with, “the master’s degree research project allowed you/helped you to,” and students had to answer with four possible answers to each question: “not at all,” “a little,” “moderately,” and “a lot.” For the analysis, we considered that “moderately” or “a lot” meant that students did perceive a pedagogical benefit of the ERPBL. Thus the answer was classified as positive. Conversely, “not at all” or “a little” indicated that students did not perceive a benefit of the ERPBL. We thus considered these answers as negative. The number of negative or positive answers to questions corresponding to each of the seven defined skills (A–G) was calculated to evaluate whether the skill was acquired or not by students. Graph shows the percentage of positive responses to questions corresponding to each skill.
particular, items such as “assist your coworkers” (question 10), “listen and consider the opinions of your coworkers” (question 8), or “better accept the errors of your coworkers in a collective research project” (question 9) were widely developed by the current program, according to students’ perceptions. Such positive behaviors, which account for interpersonal abilities, will be valuable for students in their future career as far as relationship building and relationship management are high priorities for many employers. In addition, students considered that the project helped them to “better manage your working time and prioritize the tasks to do” (question 48), thereby giving them abilities for more productive and efficient work. Hence, these unspecific competences acquired during the current program give students essential tools for their future career, which are not developed by traditional educational approaches.

To summarize, the global feedback of the students on the educational benefit of the proposed ERPBL was highly positive, since the pedagogical objectives were considered as being acquired by most of them. However, a deeper analysis of the multiple choice questionnaire answers pointed out some points for which the educational benefit of the course could be improved. First, only 74% of the students indicate a beneficial effect of the course on their written communication ability (included in skill F), whereas 82% felt a benefit for oral communication (included in skill G). This could be explained by the fact that, during the ERPBL, numerous oral presentations were performed, while the only written task was a scientific report at the end of the program. We could improve the beneficial effect of the ERPBL on this aspect by asking students to write a synthesis of some published works on obesity and related disorders at the beginning of the program.

Second, evaluating whether the research project helped students to better control their stress (question 19) found a self-reported improvement for only 62% of the students. The origin of stress is multifactorial, and thus management requires methods other than the simple repetition of a task. In addition, stress is not necessarily harmful, and a slightly increased stress level can motivate and increase alertness and energy. Here, although few students did not feel a clear improvement in the management of their stress, we have as teachers perceived a real progress in the oral productions for most of them, thereby suggesting that the stress was rather beneficial. Third, although skill A relating to the management/realization/analysis of a scientific project was acquired for 80% of students, question 7 was related to this skill, and evaluating whether students learned to “take initiatives aiming at facilitating collective research project progress” was badly evaluated (acquired for 62% of students). This means that students need to be given more space and responsibility. To improve this aspect, students could propose experimental procedures for their project as a scientist would do in his or her research laboratory. However, the realization may be difficult to enforce in the context of a course because of the constraints of device/equipment, cost, and time. Instead, we could stimulate students’ initiatives by letting them propose and perform a complementary experiment to those already programmed by the pedagogical team. This complementary experiment would obviously be constrained by a certain budget allocated by the pedagogical team and by the equipment available at the university. We could also propose to the students to be more autonomous in the choice of the publications they have to analyze and present at the beginning of the ERPBL.

In conclusion, with this collective and experimental research project, master’s students strengthened their knowledge and understanding of general and current concepts in the field of physiology/pathophysiology, focusing on metabolism and renal function in the context of obesity. They also improved or developed new skills. Students acquired technical expertise in several areas: experience in animal handling and related ethical principles; expertise on basic science techniques of molecular biology, cell biology, and histology; and specific techniques, such as glucose tolerance test or glomerular filtration rate measurement. In addition, students were trained to manage a project, including experimental design and analysis of the results, to apply critical thinking, and to manage bibliographical resources. They also developed transversal skills, including oral communication, organization, self-management, autonomy, and team work. Finally, students learned a proper scientific approach: asking a question on a topical issue, applying appropriate methods to obtain reliable data, and comparing their results with the literature, as a real researcher would have done.

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DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the authors.

AUTHOR CONTRIBUTIONS


REFERENCES


