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Teaching Reflectionson "Optimization Theory and Methods" in the Context of Data Science

Huiqin Chen*

School of Artificial Intelligence, Jianghan University, Wuhan, 430056, China
* **Corresponding author:** Huiqin Chen (Email: 1280542695@qq.com)

Abstract: As the main instructor of the course "Optimization Theory and Methods", in response to the recent feedback from students that the course is rather difficult, I have conducted in-depth thinking and reflection, and carried out a reform of this course. I have made a series of adjustments and discussions in terms of teaching content, teaching methods, and assessment. Ultimately, I hope to take students as the main body, Participate in the teaching model driven by both teachers and students, and hope to achieve better results in future teaching.

Keywords: Optimization Theory, Teaching Model Driven by Both Teachers and Students, Learning-programming.

1. Introduction

Since our school transformed the major of Mathematics and Applied Mathematics into Data Science, in order to adapt to the needs of this discipline's development, as the instructor of the course "Optimization Theory and Methods", I have been teaching it for three consecutive years. To deliver this course well, especially for students with a background in data science, I have conducted a series of reflections and preparations.

Our students in this major, in a more science-oriented context, have completed courses such as "Mathematical Analysis" and "Advanced Algebra" as the foundation, and then proceed to study "Optimization Theory and Methods". However, I have noticed that their theoretical knowledge is still insufficient, and they find it somewhat challenging to learn. I actually observed this during the class, but I did not make many adjustments at that time, instead asking them to invest more time.

This year, the course started in February and ended in June. But not long ago, that is, in October, students raised feedback about this course during the teaching symposium, saying that the course was a bit difficult. This prompted me to reconsider and adjust the teaching content of this course, to carry out curriculum reform, and to meet the needs of students. Therefore, under such circumstances, I need to do two things. First, I need to review my previous teaching and think about how to reform it.

Our course is not limited to linear programming and nonlinear programming, but also includes convex optimization and other contents. The teaching objectives generally revolve around the following four aspects: First, professional knowledge[1,2]. We not only need to enable students to understand the classification and knowledge of optimization, such as Hessian matrices, Taylor expansions of multivariate functions, gradients, convex sets, and convex functions, but also to master these concepts. Second, professional knowledge. Students must be clear about the iterative thinking method and form the optimality conditions of optimization problems, including both necessary and sufficient conditions. During the optimization process, the definition of the search interval, as well as the ideas of unconstrained optimization and constrained optimization. Third, professional knowledge. Introduce the gradient descent method, Newton's method, and conjugate gradient method in unconstrained optimization, and explain the connections and differences among these three methods, as well as their convergence speeds. Fourth, professional knowledge. Introduce the Lagrange multiplier method and the selection of penalty functions.

2. Existing Problems

While teaching knowledge, we must also teach them the ability of innovative thinking and practical skills. The course is 48 class hours, all of which are theoretical. However, these algorithms must be calculated by computer. Besides using hands to calculate in homework to strengthen the understanding of concepts and principles, for more complex problems, we use computers to calculate. But this is not included in my class and can only be done by students in their dormitories after class. We use this method to enhance students' ability to solve practical problems and cultivate their hands-on skills, thereby increasing their interest in learning. Because when you learn an algorithm, which may be theoretical or even abstract knowledge, and implement it through a specific example, you will have a sense of achievement. Of course, the prerequisite is that they must take action.

As a class collective, we also need to cultivate their comprehensive quality, that is, their teamwork ability. For example, when we encounter a problem, most students should solve it together. However, one problem we face is that students now like to look at their phones during breaks and rarely chat. So it may be a bit difficult to get them to participate in this learning together. This is also a problem I have to face.

3. Specific Implementation Plan

3.1. Reform of Content

Make some deletions in the content. For example, the simplex method used in this linear programming content is relatively difficult, and the methods it uses do not have strong inheritance with the iterative algorithms we will cover later. Students actually find this section a bit difficult to learn, so it is necessary to delete this content.

At the same time, this course should strengthen the learning of basic knowledge, such as how to calculate the gradient and related proofs of convex set theory. Provide a list of prerequisite knowledge or offer 1-2 review classes. In the past, I wrote on the blackboard quite a lot, and students' practice was relatively less. This is also one of the reasons why they find this course difficult. That is, teachers must cooperate with students, and students must cooperate with teachers. If you find it difficult one day, it is likely that you have not mastered the basic knowledge well.

Strengthen visual teaching to exercise abstract thinking ability. For example, draw the gradient descent, and display convex and non-convex functions with 3D graphs. After each algorithm is taught, immediately show the core Python code for implementation, allowing students to see how mathematical formulas are transformed into executable instructions. Through such a design, this course will no longer be a boring math class, but a dynamic and practical "engine class" that directly points to the core practice of data science. Students will clearly see that each optimization algorithm they learn is a key gear driving the operation of future AI models. A review of the previous teaching content, and then appropriate additions or deletions of content to adapt to the needs of students.

This course is closely related to our major, as we are in the field of big data science. Students need to master knowledge in areas such as machine learning and deep learning, and apply the corresponding algorithms. One of the requirements for this course is to master these basic algorithms and combine them with practical examples. For instance, the gradient descent method is actually applied in the design of neural networks, such as the BP neural network. This enables students to understand that the optimization methods they have learned are closely related to machine learning. Thus, a very clear learning chain is formed.

For example, we will introduce the simulated annealing algorithm and genetic algorithm[3]. Although these algorithms are not very new, we will still provide some explanations. We will also introduce reinforcement learning in deep learning. These explanations will be integrated throughout the teaching process to enhance students' interest in learning and expose them to the latest knowledge and research trends in optimization theory, thereby stimulating their learning interest and spirit of exploration. We can consider establishing models based on engineering background processes and performing calculations using mathematical model[4]s. For instance, we can select some examples. Recently, many students have participated in mathematical modeling competitions, including the national competition and the Central China Cup competition. We can pick out the optimization models from previous calculations and have everyone discuss and study them together.

3.2. Reform of Teaching Methods

I just mentioned a problem regarding teaching methods. In fact, we also want to interact with students, but they were not very active in the past. So this semester, I will ask students about the opinions they have previously raised. This is a very realistic issue. If you don't interact with the teacher, how can the teacher interact with you? Therefore, in the future, both the teacher and the students need to reflect. Our reform approach should definitely be student-centered learning. That is to say, under certain teaching conditions, how can we motivate students' enthusiasm for learning, with them as the main learners. Currently, we cannot conduct small-class teaching, which is actually a very difficult point. In previous teaching reforms, teachers often made changes based on their own requirements. For example, if some students said that this course might be a bit difficult, does it mean that the teaching difficulty must be reduced? Can we not ask students to improve their own learning ability, such as spending more time and being more active in class? It is not impossible for the teacher to lower the difficulty, but the problem is that you may learn less knowledge. If you have less knowledge in this course, even if the teacher lowers the requirements in the next course, you may still not be able to learn well. This is a core contradiction in all education: the "supply side" of teaching and the "demand side" of students. Simply and unilaterally requiring teachers to lower the difficulty is a short-sighted approach that is not beneficial to students' long-term development. A mature and effective teaching reform should not be a unilateral accommodation but a two-way pursuit towards a higher goal by both teachers and students. It is completely correct and necessary to require students to improve their own learning ability.

Especially for core courses like "Optimization for Data Science", the knowledge is structured and has dependencies. Lowering the difficulty of this course means cutting off core content or reducing depth, which will cause a "gap" in students' knowledge system. When they enter more advanced courses such as "Machine Learning" or "Advanced Deep Learning", they will find it even more difficult to learn due to a weak foundation, creating a vicious cycle. If the teaching pace and difficulty only cater to the students who struggle to keep up, it would be unfair to those who are willing to take on challenges and have the ability to digest more advanced content, wasting their potential and time.

3.3. Reform of Teaching Resources and Assessment:

Actually, the teaching resources for this course are quite decent. Since almost every student has their own computer now, the only drawback is that I can't bring my computer to class for demonstrations because our class usually combines two classes. Also, we don't have a large classroom for simultaneous computer-based experiments. Therefore, students may need to spend extra time on their own. To address this, I will adopt a measure of collecting and grading their practical assignments.

Regarding assessment, we don't want to increase the students' burden during exams, so the questions are not too difficult. Some knowledge points are less likely to appear in the exams. For instance, a good algorithm often requires multiple steps to complete, but we generally don't allow students to use electronic devices or even calculators during exams to prevent cheating. As many devices can't be accurately identified as genuine calculators, the assessment methods are quite simple, which means the improvement of their computational skills is limited.

The proposed reform plan is to refer to similar courses from other universities and various literature to see how they arrange and explain the course reasonably. Additionally, we may expand students' horizons by dividing the 48 class hours to focus on some new algorithms, and have students learn from each other in smaller groups. We will also try to upload teaching videos to the platform for students to preview in advance. Of course, we can also introduce more online resources for students to learn from. When some students

didn't understand the class before, they found solutions on Bilibili. Since there is a vast amount of information on these websites, teachers can first review and select suitable online courses for students to study. Because students prefer more diverse learning methods. In summary, through this exploration stage, we hope to truly reform and enhance students' innovation and practical abilities in the next round. Finally, we should always ask about students' situations. For example, the information I received before designing this course prompted me to make a reform. During the teaching process, I will adjust accordingly.

4. Conclusion

As a teacher, it is my responsibility and obligation to teach each course and each class well within the limited time and impart knowledge to students. Of course, the most important issue is to strengthen the construction of the teaching team. Even though I am currently the only one teaching this course, I will still discuss teaching methods with colleagues in various aspects. Always keep in mind that the student is at the center, which means thinking about the students. Because they will eventually look for jobs, so learning knowledge well is a good preparation for them to have confidence in the future. Therefore, we adopt a problem-oriented, student-centered, and teacher-led two-way driven teaching model. We hope to achieve good results in the next teaching.

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