Bilingual Teaching in Calculus

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Abstract. In this paper, we describe the necessity and importance of bilingual teaching in the Calculus class in China. First the purpose, meaning and difficulties of the bilingual teaching are discussed. We next compare merits and demerits of classic textbooks in Chinese with the ones in English, which emphasis the importance of choosing the right teaching materials when using the classic English textbook. The new teaching mode in our bilingual teaching is then provided in details. It has produced very good feedback.

Keywords: Calculus · Bilingual Teaching · Multimedia Courseware

1   Introduction

Calculus is one of the most fundamental mathematical courses for undergraduate students major in Science or Engineer. There are quite a lot of developments on teaching skills and methods to improve the teaching quality of the Calculus course in recent years. At the same time, bilingual teaching in Chinese university becomes popular as one of the educational reforms [5–7]. In this paper we first discuss the purpose and difficulties of bilingual teaching. Secondly, the teaching materials and tutorial materials for Calculus in the bilingual teaching are discussed. Thirdly the multimedia courseware, MOOC, and the usage of other online software together with the tutorial sessions will be discussed in details. Finally, we will share the feedback from our students and faculties for bilingual teaching in Calculus in the past six years.

2   Purpose and Difficulties

The bilingual teaching means that the course is taught in a foreign language together with the mother language. In China the corresponding languages usually are English and Chinese. The purpose of the bilingual teaching is to study advanced foreign teaching concepts and educational philosophy, and to improve the comprehensive quality of students. The bilingual teaching usually provides students better chances to pursue master or Ph.D. degree abroad.

On the other hand, most first-year undergraduate students in China do not have excellent abilities to listen and speak in English. So, the progressive teaching is recommended. That is, although all the courseware is in English, one may teach Calculus I in class with

80% Chinese and 20% English in the first term, and teach Calculus II with 40% Chinese and 60% in English in the second term. Furthermore, multimedia courseware and MOOC are really helpful for overcoming the language difficulties.

3 Teaching Materials

Textbook and tutorial materials are important for bilingual teaching. We recommend to choose a classic Calculus textbook in English first. For example, one can choose Thomas' Calculus [1] or Calculus by Stewart [2], which are the most widely-used textbooks in North America. Secondly one should remove some sections which are relatively easy to Chinese students or are already covered in high school mathematics courses in China; e.g., Chap. 1 and part of Chap. 7 in [1]. Then one should add more challenging, supplementary examples to improve the computational skill, and nurture the mentality and the ability to use Calculus to solve problems in other scientific disciplines.

3.1 Merit and Demerit of Textbooks

In most universities in China, Chinese textbooks are used for Calculus (e.g., [3]). These Chinese textbooks usually assume that students already have clear understanding of transcendental functions, such as exponential functions, logarithm functions, inverse trigonometric functions and so on. However, for most first-year undergraduate students, this is not the case. In my class, I like to ask students: $(-1)^{\frac{6}{4}} = \sqrt[4]{(-1)^6}$ or $(\sqrt[4]{-1})^6$? $(-1)^{\pi} = ?$ Very few students are able to give the correct answers. This means that the students do not truly understand these functions. Furthermore, most Chinese textbooks do not emphasis the corresponding physical concepts with mathematical definitions and theorems. Therefore, students do not have a clear understanding of the applications of mathematical theory. These are the demerit of Chinese textbooks.

Classic Calculus textbooks in English [1, 2] are constructed in a different way with Chinese textbooks. For example, the natural logarithm function is defined as $\ln x = \int_1^x \frac{1}{t} dt$. The natural exponential function is then introduced as an inverse function of the natural logarithm functions. The exponential and logarithm functions with other bases are defined afterward. These definitions clearly lead to the conclusion that the domain of the exponential function whose power is an irrational number is $(0, +\infty)$. Therefore, $(-1)^{\pi}$ is not properly defined, and there is no equivalent real number. Furthermore, Calculus textbooks in English include more real-world applications, such as Newton's method for nonlinear algebraic equations. And they put more emphasis on the connection of physical concepts with mathematical theorems.

However, Calculus textbooks in English also have their own demerit [4]. First, the above transcendental functions (logarithm, exponential and inverse trigonometric functions) are derived after the definite integral has been discussed. Therefore, only easy functions can be used for concepts in previous chapters; e.g., limit, continuity and derivatives. Second, unlike the ones in the Chinese textbook, the examples and exercise questions in the English textbooks are usually simple; i.e., not challenging to most Chinese students. Thus, students do not receive enough training for future scientific research if no challenging supplemental example and exercise are provided.

3.2 Difference for the Concepts of Textbooks in Different Languages

We found that occasionally the same concepts have different definitions in textbooks in Chinese and in English. We now give an example.

On page 833 in Thomas' Calculus [1], the definition of "directional derivative" is given by

"The derivative of f at $P_0(x_0, y_0)$ in the direction of the unit vector $\boldsymbol{u} = u_1\boldsymbol{i} + u_2\boldsymbol{j}$ is the number $\lim\limits_{s \to 0} \frac{f(x_0+su_1, y_0+su_2)-f(x_0,y_0)}{s}$."

On the other hand, on page 104 in part II of Chinese Calculus textbook [3], the definition is given using a one-sided limit; i.e.,

" $\lim\limits_{s \to 0+} \frac{f(x_0+su_1, y_0+su_2)-f(x_0,y_0)}{s}$".

Note that all the textbooks in Chinese use the above definition, while almost all the textbooks in English give the same definition as [1]. This difference in the definition may lead to different conclusions in some cases. For example, at the apex of a cone, the directional derivative along any direction exists if the definition in a Chinese textbook is applied; while there is no derivative along any direction if the definition in [1, 2] is applied. The professors should emphasis these difference in bilingual teaching because some of the concepts are frequently tested in the graduate entry examination of China. We should keep in mind that some students may go abroad for advanced study, while others may pursue a graduate degree in China and need to pass the graduate entry examination.

3.3 Supplementary Exercise

Challenging examples and supplementary exercise problems are necessary for the success of bilingual teaching in Calculus. The professors should add more difficult supplementary examples in class lectures, and assign not only the exercise questions in textbook, but also some challenging supplementary questions as homework each week. Which are similar to the supplementary examples. After several years of bilingual teaching, a carefully-written supplementary exercise book has been composed by our Calculus course group last year. As we know, it is the first bilingual exercise book which is designed for Thomas' Calculus [1]. This preprint book has been used by our university for one year. In our experience, it really improves the computational skill of students, and nurture the mentality and the ability to use Calculus to solve problems in other scientific disciplines.

4 Teaching Methods and Skills in Bilingual Teaching

4.1 Progressive Bilingual Teaching Mode

Most first-year undergraduate students in China do not have excellent abilities in listening and speaking in English. Therefore, we tried a progressive approach in the bilingual teaching. First all the courseware is made in English. However, in the first term, the lectures are given using 80% Chinese and 20% English, and the students are allowed to answer the questions in Chinese. After one term practice, the lectures are given with 40%

Chinese and 60% in English in the second term. Furthermore, students are encouraged to answer the questions or discuss with the professors in English.

The assignment questions are given in English, while the questions in the midterm and the final examination are in bilingual languages. And students are allowed to answer those questions in Chinese, although it is encouraged to answer the questions in English.

4.2 Multimedia Courseware

Multimedia courseware is important in bilingual teaching. The courseware must include not only texts and formulas, but also pictures and videos. These help student to attain better understanding of the mathematical concepts and theorems. For example, a video of Klein bottle would stimulate students' enthusiasm for learning. In bilingual teaching, we recommend to construct all the multimedia courseware mainly in English. However, some of the important mathematical concepts should include the corresponding Chinese translation, which will help students for reading some supplementary textbook in Chinese. Furthermore, Calculus usually is taught by a course group in the university. Once the multimedia courseware is constructed, the group members can keep improving the quality of the courseware every year. And it really makes the new group members' job much easier.

On the other hand, we emphasis that, especially for mathematics, professors should not rely on multimedia courseware too heavily. The details of proof and computations in Calculus should be demonstrated in blackboard using chalks step by step. Multimedia courseware can not fully replace the classic teaching mode, for example, language explanation, blackboard derivation, body language, and so on.

4.3 MOOC

Calculus is a relatively difficult course for a lot of undergraduate students. Moreover, the bilingual teaching adds further language difficulties, and slows down the lectures sometimes. The usage of Massive Open Online Course (MOOC) can be very helpful to overcome such difficulties for bilingual teaching in Calculus as well as other courses. Here we recommend the professors to record certain short videos to provide supplementary explanations of some complicated concepts or theorems. Then upload the videos to the internet through certain APP tools (e.g., the Blackboard software system) for the before-class and after-class study by students. In most cases each video is less than 15 min. It is very suitable for fragmentation learning. Students can access the videos easily through smartphones or pads in their fragmentation time. If students prepare lessons before classes, they will attend classes with questions. This will certainly inspire enthusiasm for in-class learning. On the other hand, if students are unable to fully understand certain difficult issues in class, they can also watch the short videos after class. Of course, if the problem is still unsolved, they can ask questions in tutorial sessions or in professors' office hours. As discussed in [8], MOOC serves as a great implementation for the class teaching of Calculus. One can also encourage students to search other MOOC videos for better understanding.

4.4 Tutorial

Tutorial Sessions are crucial to the success of the bilingual teaching. As mentioned before, challenging supplementary exercise problems should be assigned for homework. However, the professors do not have enough time to go through the solutions of those challenging problems. So, in the tutorial sessions, the teaching assistants not only discuss the solutions for the questions on the textbook, but also provide a detailed analysis for the challenging supplementary exercise problems. In our university, the professors provide the materials which have been covered for each tutorial session, and the teaching assistants (mostly graduate students) give lectures in tutorial sessions.

In our experience, well-trained teaching assistants are important for the success of the bilingual teaching in Calculus. First, good teaching assistants for Calculus should have a master of science degree in mathematics. Second, they are also able to communicate with students fluently in English. Third, the before-class preparation is necessary for the teaching assistants. Finally, the assignment questions should be marked properly, and all the mistakes have to be highlighted.

Furthermore, there are four quizzes each term. The quizzes are given also in the tutorial sessions. In our experience, the combination of assignments, quizzes, midterm and final exam provides a good grading system.

4.5 Feedback from Students

Bilingual teaching in Chinese university is still in an exploratory phase. The professors should have more communications with students during and after classes. In our university, each professor has three hours each week as the office hours. The office hours not only serve for answering the questions in Calculus, but also is very useful for obtaining the feedbacks from students. The comments and suggestions from students are very useful for the future improvements in most cases. For example, if a large percentage of students feel that they are unable to follow the lectures because of the language difference, it means that more Chinese should be used in class lectures. During our experience of bilingual teaching, the ideas of progressive bilingual teaching mode and the construction of the MOOC videos were originally from the feedback from students. It works out very well. In summary, the professors should make necessary adjustments for the teaching methods according to the comments and suggestions from students.

5 Conclusions

Bilingual teaching is a long-term and arduous task whose purpose is to study advanced foreign teaching concepts and educational philosophy, and to improve the comprehensive quality of students. The professors should individualize the teaching approach to each person's aptitude, personality and interest. In this paper, we share the experience of our bilingual teaching in Calculus in the past few years. First, we recommend to choose a classic Calculus textbook in English. Then one should add more challenging, supplementary examples to improve the computational skill, and nurture the mentality and the ability to use Calculus to solve problems in other scientific disciplines. Later we discuss

the teaching methods and skills in bilingual teaching from different disciplines, such as progressive bilingual teaching mode, the usage of multimedia courseware, MOOC, and the careful organization of tutorial sessions. Students in our university provided very good feedback in the past few years. Here we sincerely hope that our teaching experience can help others, and we do encourage more professors to join the bilingual teaching in Calculus or other subjects in China.

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