

Mathematical Modeling in the People's Republic of China

---Indicators of Participation and Performance on COMAP's modeling contest

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ABSTRACT

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In recent years, Mainland Chinese teams have been the dominant participants in the two COMAP-sponsored mathematical modeling competitions: the Mathematical Contest in Modeling (MCM) and the Interdisciplinary Contest in Modeling (ICM).

This study examines five factors that lead to the Chinese teams' dramatic increase in participation rate and performance in the MCM and ICM: the Chinese government's support, pertinent organizations' efforts, support from initiators of Chinese mathematical modeling education and local resources, Chinese teams' preferences in selecting competition problems to solve, and influence from the Chinese National College Entrance Examination (NCEE).

The data made clear that (1) the policy support provided by the Chinese government laid a solid foundation in popularizing mathematical modeling activities in China, especially in initial stages of the development of mathematical modeling activities. (2) Relevant organizations have been the main driving force behind the development of mathematical modeling activities in China. (3) Initiators of mathematical modeling education were the masterminds of Chinese mathematical modeling development; support from other local resources served as the foundation of mathematical modeling popularity in China. (4) Chinese teams have revealed a preference for discrete over continuous mathematical problems in the Mathematical Contest in Modeling. However, in general, the winning rates of these two problem types have been shown to be inversely related to their popularity-- while discrete problems have traditionally had higher attempt rates, continuous problems enjoyed higher winning rates. (5) The NCEE mathematics

examination seems to include mathematical application problems rather than actual mathematical modeling problems. Although the extent of NCEE influence on students' mathematical modeling ability is unclear, the content coverage suggests that students completing a high school mathematics curriculum should be able to apply what they learned to simplified real-world situations, and pose solutions to the simple models built in these situations. This focus laid a solid mathematics foundation for students' future study and application of mathematics.

TABLE OF CONTENTS

LIST OF TABLES	v
LIST OF FIGURES	vi
CHAPTER I INTRODUCTION.....	1
Need of Study	1
Purpose of the Study	5
Procedures of the study.....	6
CHAPTER II BACKGROUND OF THE STUDY	8
Higher Education and Mathematics Research in China from 1949 to Early 1980s	8
General Education System in China	12
School System.....	12
The role of government.....	13
National College Entrance Examination.....	15
Teacher Education	16
Chapter III LITERATURE REVIEW.....	18
Brief History of Mathematical Modeling Education in China	18
Chinese Scholars' View on Mathematical Modeling	20
Definition of Mathematical Modeling	20
Recognition of Mathematical Modeling.....	21
Mathematical Modeling and College Mathematics Education Reform.....	22
Reasons for Mathematics Education Reform	23
Mathematical Modeling in the College Mathematics Education Reform	25

Mathematical Modeling Related Courses.....	26
Mathematical Modeling Course.....	26
Mathematical Experiments Course.....	27
Relationship between Mathematical Modeling and Mathematical Experiments Courses....	28
Teacher Training.....	28
Mathematical Modeling Activities	30
Mathematical Contest in Modeling (MCM)	30
China Undergraduate Mathematical Contest in Modeling (CUMCM)	33
Summer Camp of Mathematical Modeling.....	34
Influence of Mathematical Modeling Activities	34
Mathematical Modeling and Innovation.....	35
Incorporating the Idea and the Method of Mathematical Modeling into the Main Mathematical Courses in Universities and Colleges	37
Mathematical Modeling and Secondary Education	38
High School Curriculum and Activities.....	39
Teacher Education	39
CHAPTER IV PROCEDURES	41
History of Mathematics Development in China	41
Scholars' Effort in Popularizing Mathematical Modeling Education	42
Initiators' Effort	42
Young Scholars' Effort.....	42
Background of MCM.....	43
Government Influence	44

Organizations' Influence.....	44
Other Resources and Practices.....	45
Chinese Students' Choice of Mathematical Modeling Problems in MCM	45
National College Entrance Examination Mathematical Modeling Problems Identification	46
CHAPTER V RESULTS	47
The Chinese Government's Influence	47
Policy Support.....	47
Initiated Mathematical Modeling Activities	54
Organizations' Implementation and Influence	55
Organizations	55
Mathematical Modeling Activities Organized by the Organizations	58
Other Resources.....	81
Initiators' Effort in Popularizing Mathematical Modeling.....	81
Local Efforts	88
News Media	90
Sponsorship.....	91
Chinese students' preference in choosing problems in the MCM and the winning results.....	92
Mathematics Modeling Questions on NCEE Mathematics Tests.....	96
CHAPTER VI SUMMARY, CONCLUSIONS AND RECOMMENDATIONS	100
Summary.....	100
Conclusions.....	100
Research Question 1	100
Research Question 2	101

Research Question 3	102
Research Question 4	104
Research Question 5	105
Recommendations.....	106
Bibliography	107
Appendix I	119
Appendix II.....	121
Appendix III.....	122
Appendix IV.....	123
Appendix V.....	124
Appendix VI.....	135

LIST OF TABLES

Table 1. PISA 2012 mathematics framework.....	20
Table 2. The winning rate of Chinese teams in problem A and B.....	94
Table 3. The comparison of participation rate and winning rate of Chinese teams from 1990 to 2013.....	95

LIST OF FIGURES

<i>Figure 1.</i> Percentage of Chinese teams in MCM and ICM from 1989 to 2013.	2
<i>Figure 2.</i> Total number of all teams and Chinese teams in MCM/ICM.	3
<i>Figure 3.</i> Percentage of Chinese teams in MCM/ICM.	3
<i>Figure 4.</i> Number of participation in the CUMCM from 1992 to 2013.	64
<i>Figure 5.</i> Number of Chinese teams in the MCM/ICM from 1989 to 2013 and number of Chinese teams in the CUMCM from 1992 to 2013.	68

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DEDICATION

To my family,
who has loved and encouraged me,
to pursue my dream.

CHAPTER I

INTRODUCTION

Need of Study

The Mathematical Contest in Modeling (MCM) and the Interdisciplinary Contest in Modeling (ICM) are mathematical modeling contests initiated and administered by the Consortium for Mathematics and its Application (COMAP), a non-profit organization in the United States. In recent years, teams from Mainland China have shown the dominance in the number of participation and spectacular performances in the two COMAP-sponsored mathematical modeling competitions. This phenomenon has amazed people in mathematics education and sparked interest in the research of Chinese practice in mathematical modeling education.

The MCM, inspired by the William Lowell Putnam Mathematics Competition, was designed as an applied version of the Putnam competition for undergraduate students (Fusaro, 2005). In contrast to the fact that students work independently for six hours (in two sittings) on pure mathematics problems in Putnam competition, students join the MCM in self-formed teams, work collaboratively for three days, and use mathematical modeling to “clarify, analyze and propose solutions” (COMAP, 2013b) to an open-ended but slightly modified real-world problem. Due to the unique nature of the contest, the MCM was very well received since its inception in 1985. There were 211 teams from schools in the United States joined the first MCM in 1985. The number of competing teams in MCM reached to 5,637 in 2013 with participants from all around the world. The MCM has developed from a domestic contest in the United States to an international contest attracting participants from all around the world. Since 1999, the MCM added a third problem in addition to the two problems proposed each year. This newly added

problem is “designed to develop and advance interdisciplinary problem-solving skills as well as competence in written communication” (COMAP, 2013b). Since 2001, the third problem has been judged and awarded separately as the ICM. The ICM has since been established and designated as an extension of the MCM for high school students and college undergraduates. The number of teams participated in the ICM (or the third problem) saw its increase from 60 teams in 1999 to 957 teams in 2013, with a peak of 1,329 teams in 2012.

Chinese teams first participated in the MCM in 1989. Ever since then, the number of Chinese teams has been soaring dramatically. The number of Chinese competing teams in MCM increased from 4 teams in 1989 to 5,195 teams in 2013, which is an increase from 1.9% to 92.16% of all teams in MCM in 1989 and 2013, respectively. ICM also saw an increase of Chinese teams from 25 teams in 1999 to 930 teams in 2013, which is an increase from 41.67% of all ICM teams in 1999 to 97.18% of all ICM teams in 2013. The total number of Chinese teams that participated in the MCM and ICM together rose from 4 teams in 1989 to 6,125 teams in 2013, which is an increase from 1.9% to 92.89% of all teams competing in 1989 and 2013 respectively.

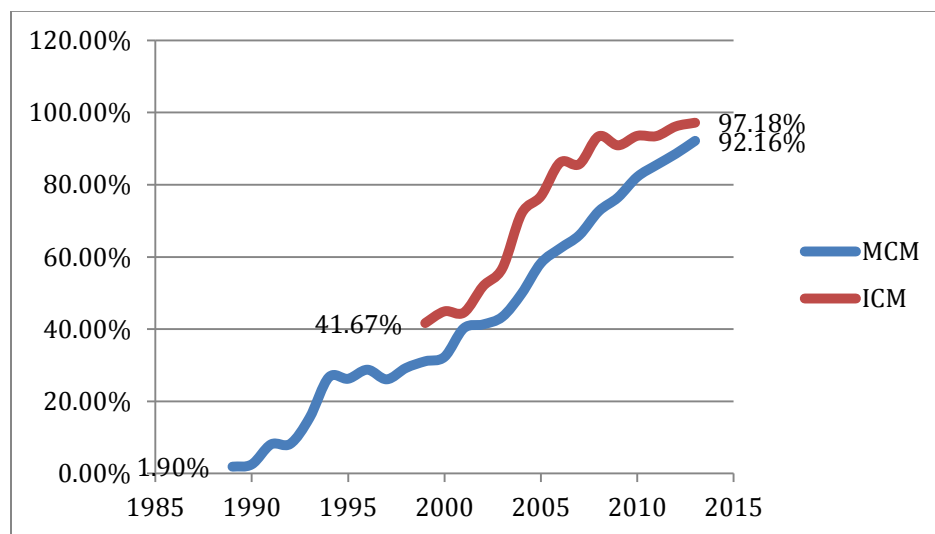


Figure 1. Percentage of Chinese teams in MCM and ICM from 1989 to 2013.

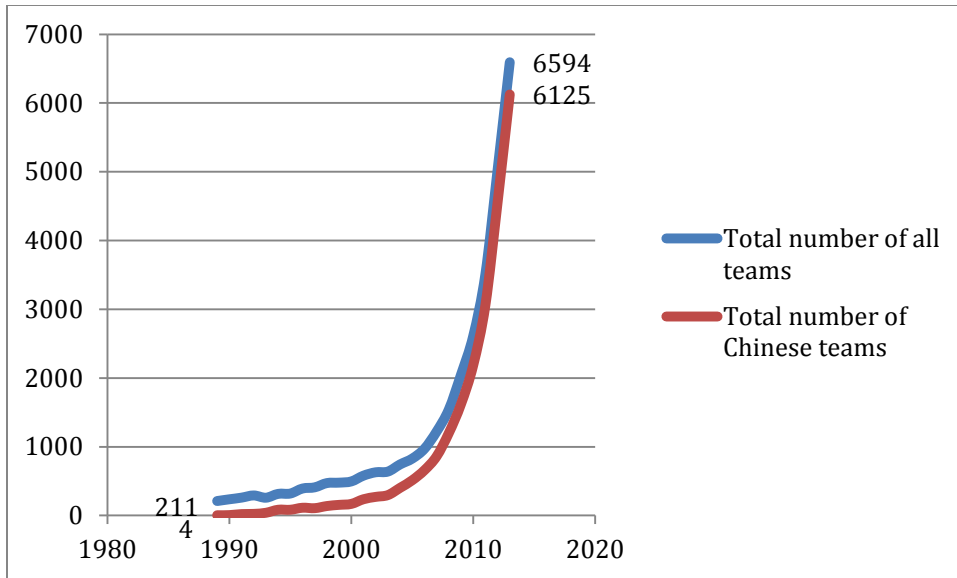


Figure 2. Total number of all teams and Chinese teams in MCM/ICM.

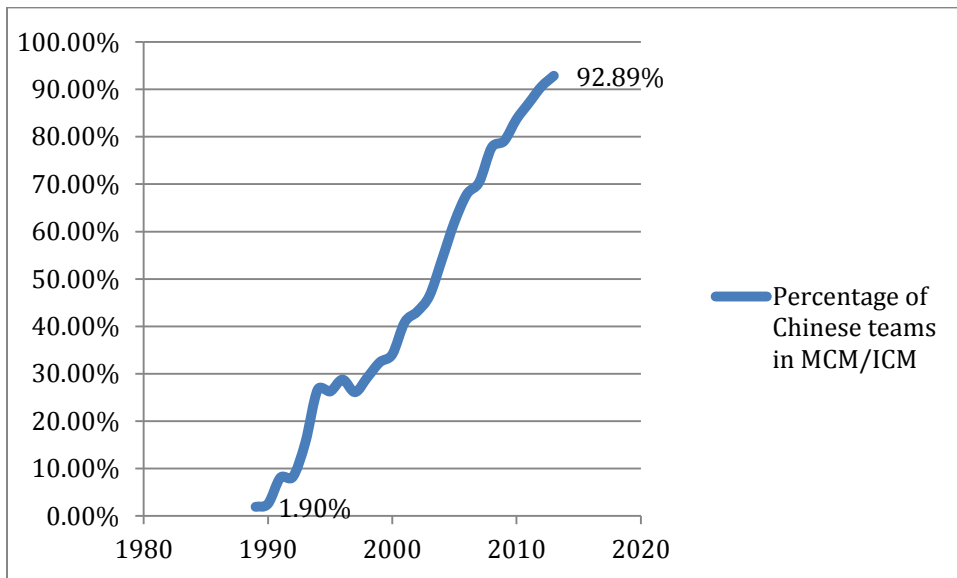


Figure 3. Percentage of Chinese teams in MCM/ICM.

Not only did the percentage of participating teams from China increase dramatically, the number of Chinese winning teams also grew. The participated teams are recognized as Unsuccessful, Successful Participant, Honorable Mention, Meritorious, and Finalist and Outstanding Winner, with the Unsuccessful as the lowest and Outstanding Winner as the highest

award. In 1989, there were only four Chinese teams that participated in the MCM, yielding only one Meritorious award and three Successful Participation awards (D. Li, 2008). In recent years, the Chinese teams' accomplishments in the MCM and ICM have brought an increasing amount of acclaim. For instance, six out of seven ICM outstanding awards in 2012 went to Chinese teams; and eight out of twelve MCM outstanding awards (including one finalist) of 2013 were awarded to Chinese teams (COMAP, 2012).

Despite the indication of Chinese students' performance in the COMAP-sponsored mathematical modeling contests, people from different fields have realized the importance of mathematical modeling in solving real-world problems. In fact, mathematics modeling as a mathematical capability has always been a focus of mathematics educators, applied mathematicians, and scholars working in scientific fields (Davis, 2012)..

Since World War II, mathematics has been valued for its applications in approximating real-world situations (Zhang, 2002). Therefore, the study of mathematical modeling as an academic and research field has greatly increased. As a result, Mathematics underwent a transformation from a set of abstract axioms and theorems to a language that can be used to facilitate people's daily lives. The war enabled mathematicians and scientists alike to realize that mathematics was more than a theoretical tool—its true power could be unlocked when mathematics was applied to life scenarios.

Mathematical Modeling has been incorporated as part of the mathematics curriculum at the undergraduate level in the United States since 1970 (Pollak, 2006). Today, scholars around the world are seeking ways to enhance college students' mathematical modeling ability in solving real-world problems (Engelbrecht, 2010; Perrene & Adan, 2010; Soon, Lioe, & McInnes, 2011; Stillman, Brown, & Galbraith, 2010).

Recently, Mathematical modeling was also designated for inclusion in the Common Core State Standards for Mathematics (NGACBP & CCSSO, 2010) since its inception, further solidifying its importance in academia. The United States Common Core State Standards for Mathematics (NGACBP & CCSSO, 2010) have placed emphasis on the mathematics modeling capability in the teaching and learning of mathematics at the K-12 level (NGACBP & CCSSO, 2010). With the official inclusion of mathematical modeling in the mathematics curriculum, its impact on students must be examined thoroughly. As a result, new challenges also will be presented to educators. The methodology of conferring mathematical modeling knowledge on students will require different techniques and careful examination.

An analysis of the causes and influences on Chinese teams' rapid ascent in mathematical modeling may provide a useful perspective for the future teaching and learning of mathematical modeling.

Purpose of the Study

The purpose of the study is to identify reasons for the Chinese teams' rapid ascent and extraordinary performance in the MCM and ICM. The study sought answers to the following questions:

1. To what extent has the Chinese government influenced the modeling success of the Chinese teams?
2. How do relevant Chinese organizations identify and implement government policy pertaining to mathematical modeling?
3. How have other resources and sponsored activities been assisted the modeling success of the Chinese teams?

4. What is the relationship between Chinese teams' choice of problems in the MCM and the winning results over the years?
5. To what extent has the Chinese National College Entrance Examination (NCEE) influenced the modeling success of the Chinese teams?

Procedures of the study

Chinese government policy relevant to mathematical modeling teaching and learning was analyzed. A documented history of the Chinese organizations that are the initiators and supporters of the mathematical modeling and the success of Chinese teams was explored. Modeling activities sponsored by Chinese organizations, such as Chinese Undergraduate Mathematical Contest in Modeling (CUMCM), Summer Camp of Mathematical Modeling etc. were researched. Chinese universities, websites, companies and agencies that have sponsored mathematical modeling training and learning were identified and examined. Chinese National College Entrance Mathematics Examinations from the year 1953 to 2012 were examined. Chinese teams' choice of problems in the international modeling competition was also analyzed.

In addition to the documented material, mathematicians and mathematics educators who are initiators of the mathematical modeling contests, both from China and United States, were interviewed.

The questions one to five were answered as follows:

In order to answer research question one, the Chinese body responsible for mathematical modeling policy, the Higher Educational Department of the Ministry of Education of the People's Republic of China, and the policy pertaining to the enhancement of Chinese mathematical modeling activities were analyzed. The policy conveyed from both the policy meetings, conferences, and people who are familiar with the matter were studied and interviewed.

In order to answer research question two, the Chinese professional organizations that are related to the initiation of mathematical modeling activities, such as the China Society for Industrial and Applied Mathematics (CSIAM) and Chinese Undergraduate Mathematical Contest in Modeling Committee (CUMCM Committee), were examined. Their roles leading to the Chinese teams' success in international-level mathematical modeling competitions, and their organized modeling activities, such as Chinese Undergraduate Mathematical Contest in Modeling, were determined.

In order to answer research question three, initiators' effort in mathematical modeling education, local organization and institution's effort in training teachers and students in mathematical modeling, regional and local mathematical modeling contests, websites that gather and distribute information about mathematical modeling, companies and agencies that provide intellectual and financial support of the mathematical modeling were examined.

To answer research question four, Chinese teams' choice of problems in MCM, proportionally more discrete or continuous problems, was analyzed and compared to the winning rate for each kind of problems to illustrate the modeling training and teaching emphasis changes over the years in China.

To answer research question five, the Chinese NCEE mathematics examinations from 1953 to 2012 were analyzed with respect to changes and trends pertaining to mathematical modeling. Examination problems that lay the foundation and prepare students to think about mathematical modeling were identified and analyzed year to year.

CHAPTER II

BACKGROUND OF THE STUDY

Higher Education and Mathematics Research in China from 1949 to Early 1980s

Initiators of Chinese mathematical modeling education were college-educated and practiced mathematical modeling during this period. As a result, their mathematical views were formed and influenced by the mathematics education, research, and applications during this time. Therefore, it is helpful to have an understanding of Chinese mathematical research and education of 1949 to the early 1980s.

On September 29, 1949, the Chinese People's Political Consultative Conference (CCPCC), which proclaimed the establishment of the People's Republic of China, adopted the "Common Program" as the basis of the new Chinese government (United States, 1950, p. 1) .

It was under such circumstances that the newly founded China expected a phase of nationwide construction, and sought manpower in order to spearhead the country's economic, national-defense, and cultural improvements. Among the areas the new China sought to strengthen, adjusting and improving higher education according to the Common Program was of great importance ("The speech made by the Minister of Education", 1950, p. 1) .

Articles 46 and 47 of the Common Program stated the method of education, which is "the unity of theory and practice", and placed emphasis on the requirement that education serve the "needs of national construction". China's educational reform at all levels, including higher education, was patterned after the principles set forth in the Common Program (United States, 1950).

Based on the education principles set by the Common Program, China reoriented and reorganized the educational system during 1950 to 1952 (United States, 1951, pp.13-16) .

The Central Ministry of Education accentuated the “combination of theory and practice” in higher education and its curriculum reform, where it was set as a “basic principle”. In the process of realizing the “combination of theory and practice”, the central Ministry of Education aimed to rid its own referendum of the clause “academic for academic per se,” and directed higher education to “strike for the integration of national construction and practice,” while preventing the “narrow-minded utilitarianism or empiricism that refuses theoretical learning” (“The Central Ministry of Education announcement,” 1950, p. 3) .

Following the reorientation and reorganization period came the Soviet-inspired First Five Year Plan (1953-1957) to boost industrial and agricultural growth of the nation, during which, Soviet experts facilitated the national construction and posted strong influence on Chinese higher education. In order to improve the quality of pedagogy and teaching materials, Ma Hsu-lun, the first Minister of Higher Education, called for a systematic study of the Soviet experiences in educational construction. As a result, Russian pedagogical outlines, teaching guides, curriculum materials and textbooks were translated with the assistance of Soviet experts, and put into use in Chinese schools at all levels (Hu & Seifman, 1976b, pp. 41, 45). Therefore, Soviet influence on Chinese education during this period was profound. In terms of mathematics education, the Soviet system emphasizes the importance of learning mathematical theories (Ye, 2011, p. 2).

Following the years of Soviet influence, the Great Leap Forward further evolved Chinese education development during the years spanning 1958 to 1959. “The whole [Chinese Communist] party apparatus, and much of the population, was brought to a frenzy of mass enthusiasm and belief in the impossible” (Snow, 1962, p. 174). Yang Hsiu-feng (1959), the Minister of Education, referred to 1958 as a year of a “great educational revolution” in which “a great leap forward was made in education” (pp. 29, 40). Schools carried out programs that

emphasized a combination of study and production, such as half-farming and half-study programs. Chinese schools' curricula were truly made to reflect the unity of theory and practice (Tung, 1958, pp. 14-22). Two outstanding features of this educational revolution were: (1) the implementation of the policy of "coordinating education with productive labor," and (2) implementation of the "mass line for organizing schools by the entire party and all the people and adoption of the policy of 'walking on two legs'" (H. F. Yang, 1959, p. 40). It was believed that "the students' participation in labor would enable them to gain confirmation of their book knowledge through practice and coordinate theory with actual conditions" (Tung, 1958, pp. 14-22).

Hwa Lo-Keng (1959) stated that research in mathematical fields, such as numerical analysis, partial differential equation, probability and statistics, operation analysis and logic, "have had a more direct connection with the building up of the national economy, and also a weaker theoretical foundation" (p. 726). In addition, "because of the great concern of the party for these fields, our groups in them have grown from small to large" (p. 726). Works in other mathematical fields had also been developed before the Great Leap Forward. However, during the Great Leap Forward, mathematical researchers, almost without exception, directed their work solely towards practical purposes of production (pp. 726-728). Hwa also repeatedly emphasized, "mathematical theory should be integrated with practice, and that priority should be given to rendering service to the socialist reconstruction of the new China".

Unfortunately, "the cumulative effects of the stress placed on productive labor and political activism under the 1958 educational reforms" (Barendsen, 1965, p. 9) and "the emphasis of being 'red', rather than being 'expert'" (Hu & Seifman, 1976a, p. 115) deteriorated the quality of education. Realizing the consequences of Great Leap Forward on education, the

government consequently prioritized additional resources for academic study and research (Hu & Seifman, 1976a, p. 116).

Starting in 1960, as the conflict between China and Soviet Union heated, the withdrawal of Soviet scientific and technical assistance left China with a critical shortage of scientists and technicians. Under the circumstances, China made the decision to train their own scientific and research personnel (Hu & Seifman, 1976a, p. 116).

During the period between 1960 to 1965, research in both pure and applied mathematics in China had been conducted actively (Institute of Mathematics, 2008).

Interestingly, during the period of 1964 to 1965, upon Mao Zedong's criticism of the existing school curriculum, China introduced on a trial basis, the "open-paper" examination in higher education. Students were allowed to consult textbooks, lecture notes, or reference materials while taking the examination in a select number of subjects. A great emphasis was put on students' understanding of knowledge and the ability of applying knowledge they had acquired, rather than rote learning and repeating. The following statement from the head of the welding teaching research group in Shanghai Jiaotong University, a specialized engineering school, described this period well:

We do not regard examinations simply as a method of checking up on how many facts a student has acquired. More importantly, they should help him to grasp the knowledge better and to use it practically. (United States, 1965)

Despite the heavy emphasis on applied mathematics research during the Great Leap Forward and the slogan of "combine theory with practice" throughout the years, pure mathematics had always been a focus taught in school and research. However, during the ten years of the Cultural Revolution from 1966 to 1976, pure mathematics became no longer a concern of Chinese

mathematical research. Like most science in China, mathematics teaching and research had been re-oriented to “serve production” and to “serve society”. Therefore, mathematics was taught and researched from an applied point of view, aiming to solve practical problems (Fitzgerald & Mac Lane, 1977).

After the Cultural Revolution, China implemented the “reform and open” policy and began to focus on social and economic development. Preparing people to better serve this development became a focal point. While education in China was still under Soviet influence, there grew a greater calling and discussion for education reform. From 1977 to 1987, the Chinese government sent 50,000 people to 76 foreign countries for higher education and research (World Education New & Reviews [WENR], 2002); Chinese scholars had more opportunities to collaborate with their counterparts around the world.

General Education System in China

In order to understand China’ educational practice, one must understand the education system in which Chinese implement all the educational policies and activities. Particularly, the following two comments should be kept in mind: (1) Chinese people believe in the importance of education, and that it is effort, instead of inherited intelligence, that is the key to educational success. (2) “China is a country that is extremely pragmatic, and makes a practice of experimenting carefully and then rapidly spreading what works through the entire nation”(Center on International Education Benchmarking, 2013b).

School System

The educational system in China encompasses preschool, six years of primary school, six years of secondary school (middle school and high school), higher education institution (university and college), and graduate school. Students usually begin primary school education at

the age of six. The promulgation of the “Compulsory Education Law of the People’s Republic of China” since 1986 stipulates the nine-year compulsory education (National People’s Congress, 1986), including primary and middle school. At the end of the middle school, students take a locally administered high school entrance examination. Based on the performance of the examination, students may elect to attend a three-year regular academic high school or vocational high school, three to five years of vocational school, or simply end their formal education (Center on International Education Benchmarking, 2013a; CHINA.ORG.CN, 2006).

Higher education is offered by a variety of institutions, including universities, colleges, institutes and vocational colleges (CHINA.ORG.CN, 2006). There are 2,442 regular higher education institutions in China, among which 1145 institutions offer four-year bachelor degree programs and 1,297 institutions offer two or three-year vocational programs (Ministry of Education of the People's Republic of China, 2013d). 23,913,155 students are enrolled in regular higher education institutions, which counts for approximately 24% of the population of tertiary age (Ministry of Education of the People's Republic of China, 2013e; UNESCO Institute for Statistics, 2011). The degree system in China was introduced in 1980, with the first bachelor’s degree awarded in early 1982. People who were educated before that were only awarded certificates or diplomas (WENR, 2002).

The role of government

The Chinese education system is mainly government-oriented (Ministry of Education of the People's Republic of China, 2010). Zhao (2003) provided a description of the features of government-oriented education, which depicts the role of government in China’s education system: firstly, governments determines the kind of education should be provided, the manner in which schools should be run, and the purpose in running the schools. Secondly, governments

have a definite production function for educational development. Thirdly, the information for education operation is transmitted from upper-level to lower-level governments. Fourthly, the transmission of information is based on the connections among various levels of governments. Fifthly, the incentives for teachers and students are instituted within the administrative framework and institutions. Lastly, the reward criterion depends on the extent that educational development plans have been fulfilled.

Ministry of Education of the People's Republic of China (2013f) is in charge of all the education related overall planning, coordination, and management. Some of its responsibilities include “lay down requirements and basic documents for teaching; take charge of the overall management of the educational funds; administer teachers’ work; manage the entrance examination for academic credentials for higher education”, etc.

Basic and higher education are separately governed. Within the Ministry of Education, Departments of Basic Education I and II take charge of K-12 educational matters, whereas, the Department of Higher Education is in charge of higher educational affairs (Ministry of Education of the People's Republic of China, 2013a, 2013b, 2013c) In terms of education policy implementation and quality control supervision, the local government takes the main responsibility in monitoring reform and development of primary and secondary education. The central government, provincial governments, as well as some central government directed municipalities supervise higher education (United Nations Educational, 2011; M. Yang, 2009a).

In terms of funding sources, the Chinese government serves as a major financial resource for public education, supplemented by funds raised through other means. Private education is relatively small in scale compared to public education, and is funded by various sources (M. Yang, 2009b).

Beijing and Shanghai are two cities that enjoy the governmental status of provinces. They have their own right to make decisions in education policy and practice, when other cities and provinces have to follow the policies set by the central government in Beijing (Center on International Education Benchmarking, 2013b). Many education initiatives and reforms were first experimented and conducted in these two cities.

National College Entrance Examination

The National Education Examinations Authority (NEEA) is an affiliated organization to China's Ministry of Education. The NEEA's responsibilities include, but are not limited to, design, evaluation, and analysis of all kinds of national examinations. The National College Entrance Examination (NCEE) is one of the most important tests supervised by the NEEA in China.

The NCEE is a large-scale high-stakes test, and is held once a year on June 6, 7 and 8. The majority of high school graduates across China rely on their performance on the test to be admitted to Chinese higher education institutions. "For many Chinese, access to higher education is synonymous with access to success in life" (Center on International Education Benchmarking, 2013b). Because of the criticality of the NCEE, the test often reflects the focus of the curriculum. The change of the curriculum emphasis is normally reflected through the NCEE. During the three-day examination, students are tested in Chinese, mathematics, and a foreign language; with English being the most popular foreign language taught in school. In addition, students are required to take a comprehensive test either in the liberal arts or science, depending on the student's high school track of study. Chinese students put an enormous effort into preparing for NCEE, in particular, into the study of mathematics (Center on International Education Benchmarking, 2013b). The NCEE had been a unified test in China before the Cultural

Revolution from 1951 to 1965. During the Cultural Revolution from 1966 to 1976, the NCEE was abolished. Then the NCEE was reestablished in 1977, but was designed and administered by provinces. The NCEE became a unified examination designed and administrated by Ministry of Education since 1978. Shanghai employed its independent examinations from 1985. The privilege of adopting customized tests has been given to more provinces and municipalities ever since then (Center on International Education Benchmarking, 2013a). By 2012, 13 provinces and 4 municipalities design their own NCEE. The other 14 provinces still use NCEE designed by NEEA.

Based on their NCEE scores, students are admitted to four levels of higher education institutions. The most desired universities are national key universities, followed by provincial universities, local universities and the least desirable two or three year colleges (Yu & Suen, 2005).

Teacher Education

Teaching is a highly respected career in China. The government attracts top candidates by offering priority admissions in higher education institutions to prospective teachers (Center on International Education Benchmarking, 2013c; United Nations Educational, 2011).

The goal of the teacher education program in China is to cultivate K-12 teachers. Normal schools, teacher colleges, normal universities and teacher preparation programs in non-normal comprehensive universities are the main sources of teacher training (Zhu & Han, 2006). Students graduating from these programs are awarded teaching certificates, which is a prerequisite for a teaching career (Center on International Education Benchmarking, 2013c; UNESCO, 2011).

Normal schools admit graduates from middle school and usually hold a five-year program that awards students with an Associate's degree. Graduates from normal schools may work in kindergartens or primary schools. However, with China's recent economic growth and educational development, schools have since required teachers to be equipped with additional credentials and training aside from the bare minimum requirements.

Based on their NCEE scores, high school graduates may choose to attend teacher colleges, normal universities, and teacher preparation programs in non-normal comprehensive universities for a four-year study on a subject. The major requirement of the subject courses for prospective teachers is very similar to students majoring in the subject but in a non-teacher-training program. In addition to the content study, students in perspective teacher programs are required to take educational courses, such as pedagogy, psychology, and education law. Nowadays, normal universities and teacher preparation programs in non-normal comprehensive universities are “reshaping their focus from preparing teachers to educate students for all occupations and professions”; “some normal universities pursue the aim of being research-oriented universities” (Zhu & Han, 2006). That being said, normal universities offer majors that are unrelated to teacher training as well. Due to their non-restrictive education goals, students from teacher preparation programs may enjoy career paths that are not limited to teaching.

Chapter III

LITERATURE REVIEW

Mathematical modeling was first introduced to college students in China in early 1980s. Ever since then, mathematical modeling courses and activities have been developed significantly. In this literature review chapter, the following aspects will be examined: the brief history of mathematical modeling education in China, Chinese scholars' view on mathematical modeling, mathematical modeling and college mathematics education reform, mathematical modeling related courses, teacher training, mathematical modeling activities, mathematical modeling and innovation, incorporating the idea and the method of mathematical modeling into the main mathematical courses in universities and colleges, and mathematical modeling and secondary education.

Brief History of Mathematical Modeling Education in China

It is widely recognized by Chinese scholars that the development of mathematical modeling in China can be divided into three stages (Jiang & Xie, 2011; Tan, 2010a). The following is the brief summarization by the scholars in China.

The first stage is in 1980s. As it was documented in the 1983 North American Delegation trip to China report, “ Undergraduate Mathematics Education in the People’s Republic of China,” the mathematics faculty in Chinese universities had already expressed a “consistent interest in applied mathematics courses.” More specifically, this interest lied in “mathematical modeling courses designed for mathematics majors” (Steen, 1984, p. 29). Pioneers in mathematical modeling education offered mathematical modeling courses in only a few universities. Students who took the courses were mainly mathematics majors. The initiators also started nation-wide teacher training seminars to train teachers in mathematics modeling. Approximately 20 to 30

textbooks on mathematical modeling were published by the end of the 1980s. In 1989, Chinese students from several universities began to participate in the MCM. This period laid the foundation for later popularization of mathematical modeling in China (Jiang & Xie, 2011; Tan, 2010a).

The second stage is in 1990s. Nation-wide mathematical contest modeling, China Undergraduate Mathematical Contest in Modeling (CUMCM) has been organized and popularized. Due to the effect of the contest, mathematical modeling courses were developed rapidly. Students of all majors began to take the courses. By the end of 1990s, approximately 300 to 400 schools offer mathematical modeling courses. Related textbooks have reached to approximately 40 (Jiang & Xie, 2011; Tan, 2010a).

The third stage is in 2000s until now. In addition to the national mathematical modeling contest, school-wide and regional mathematical modeling contests are prevalent. Students are holding their own mathematical modeling groups and organizing relevant activities. Mathematical modeling courses are not only offered in four-year colleges, but also in associate colleges. Approximately 1,200 schools across China offer mathematical modeling courses of all levels to students. Besides, mathematical experiments course was introduced to colleges and universities, and has been developed rapidly in this period (Jiang, 2001; Tan, 2010a, p. 20; Xie, 2010). Related textbooks have reached 110 (Jiang & Xie, 2011). According to Tan (2010a), if counting textbooks and other publications related to mathematical modeling, the total publication could reach to 200. New course development and research related to mathematical modeling are conducted among teachers and researchers (Jiang & Xie, 2011). Besides, the project “merging the idea and the method of mathematical modeling into the main mathematical course in

universities and colleges” has been initiated and developing across the country (Tan, 2010a; Xie, 2010; Ye, 2007).

Chinese Scholars’ View on Mathematical Modeling

Definition of Mathematical Modeling

Jiang and Xie (2011) regard mathematical modeling as the following three steps: firstly, convert a real-world problem to a mathematical problem; secondly, analyze, compute and solve the mathematical problem; thirdly, check whether the solved mathematical result can successfully answer the real-world problem it modeled. If the mathematical result cannot effectively explain the real-world situation in terms of its qualitative or quantitative features, then the mathematical model needs to be modified until the satisfying result is achieved. (p. 79)

The organization for Economic Co-operation and Development (OECD) published the following PISA 2012 mathematics framework (OECD, 2003):

Table 1. PISA 2012 mathematics framework

	P1 Formulating situations mathematically	P2 Employing mathematical concepts, facts, procedures, and reasoning	P3 Interpreting, applying and evaluating mathematical outcomes
devising strategies for solving problems	P1.1 Select or devise a plan or strategy to mathematically reframe contextualized problems	P2.1 Activate effective and sustained control mechanisms across a multi-step procedure leading to a mathematical solution, conclusion, or generalization	P3.1 Devise and implement a strategy in order to interpret, evaluate, and validate a mathematical solution to a contextualized problem
Using symbolic, formal and technical language and	P1.2 Use appropriate variables, symbols, diagrams, and standard models in order to represent a	P2.2 Understand and utilize formal constructs based on definitions, rules, and formal systems as	P3.2 Understand the relationship between the context of the problem and representation of the mathematical

operations	real-world problem using symbolic/formal language	well as employing algorithms	solution. Use this understanding to help interpret the solution in the context and gauge the feasibility and possible limitations of the solution
Using mathematical tools	P1.3 Use mathematical tools in order to recognize mathematical structures or to portray mathematical relationships	P2.3 Know about and be able to make appropriate use of various tools that may assist in implementing processes and procedures for determining mathematical solutions	P3.3 Use mathematical tools to ascertain the reasonableness of a mathematical solution and any limits and constraints on that solution, given the context of the problem

In this framework, “formulating situations mathematically”, “Employing mathematical concepts, facts, procedures, and reasoning”, and “interpreting, applying and evaluating mathematical outcomes” gave the same idea as what Xie described for mathematical modeling above.

Recognition of Mathematical Modeling

Mathematical modeling is a bridge between the real world and mathematical science, and that mathematical modeling is a necessity for mathematics to be applied to the real world (Jiang & Xie, 2011, p. 79). Jiang and Xie (2011) state that solving practical problems by mathematical methods requires building a bridge between the problems and mathematics. The process of building the bridge is the process of mathematical modeling above.

It is widely agreed by Chinese scholars that mathematical modeling is not a new idea. Jiang and Xie (2011) pointed out that even though mathematical modeling seems a new term, it has a long history just as mathematics itself. Examples, such as Euclidean geometry, law of

gravitation, and many important formulae in hydrodynamics, electrodynamics, and quantum mechanics are all the results of mathematical modeling.

Though mathematical modeling has always been existent and used, it only became a people's concern in late 20th century (Jiang & Xie, 2011). The following reasons are widely recognized by Chinese scholars (Jiang, 1996; Jiang, Xie, & Ye, 2011; D. Li, 1989; Xie, 2009): (1) the invention and development of computer technology provides a powerful tool for the application of mathematical modeling. Many mathematical models in engineering existed hundreds years ago, but they could not be solved due to the lack of powerful computing tools back then. The development and popularization of computer technology make the application of mathematical modeling possible. (2) In areas of high technology, mathematical modeling and scientific computing is indispensable. High-technology fields, such as aerospace engineering, telecommunications, etc., all rely on computer supported mathematical modeling. (3) Mathematical modeling is used in fields that never employed mathematics before. Approximately one century ago, areas such as economics, biology, medicine, etc., were still reliant on qualitative analysis. With the development of modern technological society, mathematics has been applied to these areas. Therefore, mathematical modeling has been applied into new fields as the merits of this specialized field of applied mathematics became more evident.

Mathematical Modeling and College Mathematics Education Reform

In retrospective, introducing mathematical modeling at the college level is considered to be “the largest and most successful practice in mathematics education reform” (Jiang & Xie, 2011, p. 80).

Reasons for Mathematics Education Reform

There are three reasons that initiated and propelled this college mathematics education reform.

The first reason is to better adapt to social and technological needs in a fast changing world, where mathematical modeling is increasingly important. Having recognized the importance of mathematical modeling in the 20th century, Chinese scholars believe that higher education must reflect and adapt to the development of technology and social advancement (Jiang & Xie, 2011).

The second reason is the disadvantage of teaching and learning mathematics under the old mathematics education focus. Ye (2011) stated that Mathematics education in China was under the influence of the former Soviet Union's system since 1952. The emphasis of college mathematics education was to lay a solid foundation in pure mathematical theories (Jiang & Xie, 2011; Ye, 2011). Ye (2011) believes that even though it is an effective way to learn mathematics, it is not the only way. Scholars pointed out issues in learning mathematics under this education method. Xie (2010) noted that "students' ability of using mathematics to solve real-world problems was highly neglected" and that "students were weary of university mathematics as it was tedious and uninteresting". Jiang and Xie (2011) stated that teachers found teaching mathematics ineffective and many students found learning very exhausting. Those who could score well in exams found it hard to apply mathematical knowledge to practical problems. Teachers were anxious to find an effective way to teach mathematics and students were desperately in need of vivid mathematical knowledge (Jiang & Xie, 2011).

The last reason is Chinese mathematicians and mathematics educators' experience and vision in studying and using mathematics. Ye (2011) stated that many mathematicians and

mathematics educators had experience in applying mathematical knowledge in solving practical problems during the Great Leap Forward and Cultural Revolution; they appreciated the beauty of mathematical applications and realized the setbacks in mathematics education in the old manner. Therefore, these mathematicians and educators wanted to reform the mathematics education by adding the usefulness of mathematics they experienced into the mathematics education. In addition, Mathematicians and mathematics educators kept learning from good mathematical modeling education practices in other countries (D. Li, 1989; Ye, 1989, 2011). Thus, they had a sharp vision on what could benefit students and mathematics education. Since China implemented the reform and opening-up policy in 1978, scholars were more exposed to the ideas and knowledge from foreign countries and foreign educational systems (Xie, 2010). Chinese scholars have been very attentive to broader international opinions on the importance of mathematics and reforms of mathematics education, worldwide. Viewpoints from U. S. publications such as the following reports, *Renewing U.S. Mathematics: Critical Resources for the Future* that “when we entered the era of high technology, we entered the era of mathematical technology” (The Ad Hoc Committee on Resources for the Mathematical Sciences, 1984, p. 2), and from *Mathematical Sciences, Technology and Economic Competitiveness* that “the mathematical sciences are vital to economic competitiveness; they are a critical, generic, enabling technology” (Board on Mathematical Sciences, Commission on Physical Sciences, & National Research Council, 1991), are widely accepted by Chinese scholars (Jiang & Xie, 2011; Xie, 2009).

Mathematical Modeling in the College Mathematics Education Reform

Having recognized the importance of mathematical modeling and the need to reform mathematics education, Chinese mathematicians and mathematics educators were introducing mathematical modeling to teachers and students through various ways.

Ye (1997) pointed out that the mathematical modeling activities, such as CUMCM, are actually a non-interfering and large-scale college mathematics education reform experiment. He gave two reasons for the statement: firstly, students voluntarily participate in the activities so that it doesn't affect the existing teaching activity; secondly, the mathematical modeling activities, to some extent, provides evidence of students' competency in the mathematics learned, which helps discovering possible problems in teaching. In addition, he also listed the positive effect of mathematical modeling activities on the teaching and learning in college mathematics. For example, mathematical modeling courses are required courses for mathematics majors in almost all universities and colleges; mathematical modeling courses are offered to many non-mathematics majors as elective courses; many teachers began to incorporate the idea of mathematical modeling into regular mathematical courses they teach, etc.

Many scholars have emphasized the importance of mathematical application in the mathematics education reform. To properly reflect the function of mathematics in society, mathematics education at the college level should properly increase the content of basic knowledge, strengthen mathematical modeling ability, and embody mathematics culture (Xiao, Tan, Cao, & Zhu, 2000). In the Report of Research in the Strategy of Mathematics Major Development (2005), researchers in the teaching of mathematics and statistics pointed out the importance of mathematical modeling in cultivating students with "mathematical application consciousness". Thus, the research group suggested that schools emphasize on the teaching of

mathematical modeling, mathematical experiments in addition to the traditional mathematics courses.

D. Li (2010) emphasized that college mathematics curricula not only need to avoid deviating from practice and application, but also need to make certain to maintain the rigor and integrity of mathematics.

Mathematical Modeling Related Courses

Mathematical Modeling Course

In 1982, professor Wenci Yu of Fudan University offered a mathematical modeling course to students in the department of mathematics (Ye, 2011, p. 2). In the same year, Zhejiang University also offered an undergraduate mathematical modeling course. These are the first and earliest mathematical modeling courses offered in China that can be found in the literature (Q. Yang, 2011; Ye, Tan, & Jiang, 2011). About the same time, only several colleges and universities began to offer mathematical modeling courses to students (Jiang & Xie, 2011, p. 79). These schools included, but were not limited to, Fudan University, Zhejiang University, Tsinghua University, and Tianjin University, etc. Teachers, who were initiators of mathematical modeling teaching in their respective schools, later shared their experience (Bian, 2011; Jiang, 2011; Ou, 2011; Q. Yang, 2011). The stories of initiators and pioneers of mathematical modeling are later narrated by their students and coworkers (Bian & Jiang, 2011; Ye et al., 2011). By the end of 1980s, approximately 20 to 30 schools in China offered courses in mathematical modeling. Students who took the course were mainly those in departments of mathematics (Jiang & Xie, 2011; Ye, 2011).

In the 1990s, due to the popularity of mathematical contests in modeling—both MCM and CUMCM, mathematical modeling courses were offered in more than 300 universities and

colleges. Students who took the courses were not only mathematics majors, but also those who majored in engineering, economics, and agriculture, etc. (Jiang & Xie, 2011).

In the 21st century, mathematical modeling courses are being offered not only in four-year colleges but also in two- and three-year colleges. Approximately 1200 schools in China have offered mathematical modeling courses. Mathematical modeling courses now are designed to suit the needs of students with different backgrounds and mathematics achievement levels (Jiang & Xie, 2011; Xie, 2010).

Mathematical Experiments Course

Under the influence of mathematical modeling competitions and the existing mathematical modeling courses (Jiang & Xie, 2011, p. 82), mathematical modeling education scholars in China were introducing a new course — Mathematical Experiments to teachers and students in the late 1990s and early 2000s. According to Jiang (2001), such a mathematical experiments course introduces methods to analyze and solve practical problems using students' existing mathematical knowledge and computer software (p. 614). Mathematical experiments along with calculus, linear algebra and geometry, and scholastic mathematics have been established as the four core courses in college mathematics education for non-mathematics majors (Xiao, Tan, Cao, & Zhu, 2001).

Jiang (2001) recalled the initiation of the mathematical experiments course in Tsinghua University, including the process of publishing related textbooks and holding teacher training seminars, and he provided some insightful reflections as noted in the following narrative. As an expert in mathematical modeling education, he stated his opinion in an article on the mathematical experiments course's guiding idea, content design, textbook design, and practice

and reflection. His introduction provides a detailed perspective and reference to educators who want to teach the course (pp. 613-617).

Relationship between Mathematical Modeling and Mathematical Experiments Courses

Both Jiang (2001) and Tan (2010a) compared and contrasted mathematical modeling and mathematical experiments courses.

It is commonly recognized that the two courses possess the same goal, which is the ability to use mathematics to solve practical problems (Jiang, 2001; Tan, 2010a). Since both courses are driven by problem solving, Tan (2010a) believes they changed people's impression about mathematics, making people realize the effect of mathematics in economics, technology and the social advancement; promoted the reform of mathematics teaching; and aroused students' capacity in problem-solving and creativity. Jiang (2001) believes that the mathematical experiments course satisfies the need of both mathematics and non-mathematics major students.

However, Jiang (2001) further believes that the content of both courses are very different. He stated that a mathematical modeling course focuses on the modeling process of practical problems and moreover explores the model's explanation and application. Less emphasis is on the solving of mathematical models. Mathematical experiments, supplementing mathematical modeling, also focuses on several important aspects such as the model solving, and concentrates on the methods of solving mathematical models with the help of computer and mathematical software (p. 616).

Teacher Training

In spring 1983, professor Shutie Xiao of Tsinghua University began to teach a mathematical modeling course to undergraduate students in the Department of Applied Mathematics (Bian & Jiang, 2011, p. 139; Ye, 2011, p. 2). Bian (2011) recalled that schools in

the collaboration group of 12 engineering schools directed by the Department of Education can send teachers to Tsinghua University to take the course (p. 160). Many teachers who took the course were among the first to be exposed to mathematical modeling and later dedicated their research and teaching to mathematical modeling (Bian, 2011; Gan, 2011; Jiang, 2011; Ou, 2011; Ren, 2011).

National mathematical modeling teaching and teacher training seminars started to be held in 1983 (CUMCM, 2011, p. 11; Jiang & Xie, 2011). The China Conference on the Teaching of Mathematical Modeling and Application (CCTMMA) has been convened in every two or three years since 1986 (Xie, 2010). These conferences and seminars, along with the course offered by professor Xiao, cultivated the first generations of mathematical modeling teachers, and laid a foundation for later mathematical modeling activities (Jiang & Xie, 2011). In 1990, China Society for Industrial and Applied Mathematics (CSIAM) was founded. CSIAM, and especially its sub-society of mathematical modeling, played a major role in promoting mathematical modeling education and activities in China (CUMCM Committee, 2011; Xie, 2010).

In 1990s, national teacher training seminars were still the main sources for teacher training (CUMCM, 2011), while regional seminars were active (Ye, 1994). Ye (1994) reported that teachers in the seminars shared experience in effective teaching methods for mathematical modeling courses, reported their research outcomes, learned mathematical modeling software, and discussed national and international mathematical modeling articles.

In the first decade of the twenty-first century, in addition to national teacher training seminars, provinces also organized training seminars to teachers across the nation (CUMCM, 2013a).

Mathematical Modeling Activities

Mathematical Contest in Modeling (MCM)

Dr. Henry Pollak was president of the Mathematical Association of America (MAA) from 1975 to 1976. During his tenure, he wondered whether the Putnam family would be interested in supporting a Mathematical Modeling in addition to the pure mathematics competition the family was already well known for, the William Lowell Putnam Mathematical Competition. Dr. Pollak asked Professor Andrew Gleason, mathematics professor at Harvard University and MAA representative of the Putnam family at the time, to present his idea of an additional mathematics competition before the Putnam family. Unfortunately, the Putnam family lacked interest. With the prospects of the mathematical modeling competition in question, the idea was held in abeyance. It was only until the early 1980s when COMAP finally initiated and implemented an official modeling competition.

Fusaro (2005), in an informative article, introduced the background and the history of the MCM. Mathematical Contest in Modeling that was inaugurated in 1985 by Dr. Bernard (Ben) A. Fusaro. The genesis of the contest was due to several factors including: (1) the university where Dr. Fusaro worked at —Salisbury University had a high percentage of first-generation college students who were practical-minded; (2) “there was scarcely any appreciable applied or constructive mathematics presence” (p. 3); (3) applied mathematics as well as other branches of mathematics are as important as pure mathematics; and (4) the importance of computers should be addressed.

The goals and purposes of the MCM as summarized by (Fusaro, 2005) are:

The purpose of this competition is to involve students and faculty in clarifying, analyzing, and proposing solutions to open-ended problems. We propose a structure, which will encourage widespread participation and emphasize the entire modeling process. Major features include:

- The selection of realistic open-ended problems chosen with the advice of working mathematicians in industry and government.
- An extended period of time for teams to prepare solution papers within a clearly defined format
- The ability of participants to draw on outside resources including computers and texts.
- An emphasis on clarity of exposition in determining final awards with the best papers published in professional mathematics journals. (p. 3)
-

“As the contest becomes established in the mathematics community, new courses, workshops, and seminars will be developed to help students and faculty gain increased experience with mathematical modeling” (Fusaro, 2005, p. 3). This goal has been fully realized as the mathematical modeling competitions became popularized in China.

MCM is sponsored by COMAP and usually held in January or February each year. The contest includes three problems. Problem A focuses on continuous mathematics, Problem B emphasizes discrete mathematics, and Problem C is an interdisciplinary problem. Problem C appeared in 1999, began to be used in 2001, and subsequently it was separated into another competition ICM. According to the Contest rules (COMAP, 2013a), “to participate in a contest, each team may consist of a maximum of three students and must be sponsored by a faculty member from its institution”. Teams have four days to solve one of the three problems “with any inanimate source of data or materials” but “may not seek help from or discuss the problem with their advisor or anyone else, except other members of the same team”. Based on the quality of the paper, teams will be awarded from high to low, namely: Outstanding, Meritorious, Honorable Mention, and Successful Participant. In addition, COMAP (2013a) recognizes outstanding contestants with the following awards:

- The Institute for Operations Research and the Management Sciences (INFORMS) will designate an Outstanding team from each of the three problems as an INFORMS winner.

- The Society for Industrial and Applied Mathematics (SIAM) will designate one Outstanding team from each problem as a SIAM winner.
- The Mathematical Association of America (MAA) will designate one Outstanding team from each problem for the MCM as a MAA winner.
- The Ben Fusaro Award, Typically, among the final MCM papers from which the Outstanding ones are selected is a paper that is especially creative but contains a flaw that prevents it from attaining the Outstanding designation. In accord with Ben's wishes, the award will recognize such teams.
- The Mathematical Contest in Modeling's Frank R. Giordano Award began in 2012. It honors Brig. Gen. (ret) Frank Giordano who directed the MCM for 20 years. This award goes to a paper that demonstrates true excellence in the execution of the modeling process.

Changes have been made to the contests as they developed over time. Initially, the COMAP stipulated that the amount of teams from the same institution in any year cannot exceed seven, with up to four teams competing for MCM and three teams competing for ICM. In addition, the number of teams that an advisor can advise was limited to three. These limits were abolished in 2009 and 2014. That being said, students now can form as many teams as they want to join the contests, and advisors can advise as many teams as they will. With almost 30 years of development, MCM attracts students and faculty from over 50 institutions around the world. Nowadays, over 90% of the participants are from China.

Ye (1989) introduced MCM and gave some thoughts about the event to scholars in China. In his 1989 article, he introduced the William Lowell Putnam Mathematical Competition, and compared it to the Putnam Competition, including the advantages and even the necessity of MCM from some American mathematicians' viewpoints. Ye (1989) believes that the reason that there was a higher than 30% increase in the number of participants, and concurrently an increasing recognition from renowned schools worldwide, means that the MCM conformed to the emerging awareness of, and progressive developments in, mathematics education of the time (p. 138). Combined with similar practices in other countries, he also suggested that Chinese

scholars should think how contests, such as MCM, could be used to cultivate students' mathematical interests and proficiencies in China (p. 145).

Ye (1996) reported that Chinese students began to participate in the MCM in 1989. Subsequently, up to the 1995 MCM, more than one fourth of all the teams were from China. Even under the condition of inadequacy of teachers, low level of familiarity with the contest, lack of training time, and the inconvenience of using computers, students still attained good outcomes from the contest, which indicated the competitiveness of Chinese students (p. 90).

China Undergraduate Mathematical Contest in Modeling (CUMCM)

According to Ye (2007), mathematical modeling competitions in China started from regional contests. Starting in 1990, regional mathematical modeling competitions began to appear. Shanghai was the first city in China that held its regional mathematical contest in modeling in 1990 and 1991. Xi'an held its regional competition in 1992. Then, the national level mathematical contest in modeling was organized in 1992 and 1993. Eventually the national competition CUMCM was organized. A summary of the history of the development of the national competitions can also be found in Xie's (2010) article.

CUMCM has developed rapidly. School-wide and regional mathematical modeling competitions are prevalent (Jiang & Xie, 2011). Xie (2010) mentioned that "because of the very challenging nature of the contest, it attracts the most competitive students in China in an ever-increasing manner" and "currently, CUMCM has become the most widespread extra-curriculum scientific activity for undergraduates in China" (p. 602).

Follow-up research on the competition problems is regarded to be a very important stage of the CUMCM. Students contacted relevant organizations to validate the mathematical models. Many research outcomes have received positive feedback from field practitioners. Some of their

models have already been put into practice to better serve the applicants' organizations (Jiang & Xie, 2011).

Summer Camp of Mathematical Modeling

According to Tian and Xie (2013), to further students' experience in mathematical modeling, mathematical modeling educators designed a Summer Camp for mathematical modeling in 2006, and later made it an annual event since 2011. Students have more than three months to research a real-world project using mathematical modeling techniques as well as obtaining help from researchers and practitioners in the fields. This experience is an extension of mathematical modeling activities for CUMCM. Due to the large scale of resources, students could get access to relevant resources, and a more practical time frame for researching a project, and students could "obtain an in-depth experience of tasting the authentic, real-world problem solving process" (p. 39).

Influence of Mathematical Modeling Activities

Mathematical modeling activities, especially CUMCM, have promoted the reform of mathematical teaching methods and content; and advanced the growth of relevant research and teachers' careers (Jiang & Xie, 2011; Xie, 2009).

In the 1980s, only a few books were published. By contrast, in the 1990s under the influence of the contests, approximately 40 textbooks were published. In the early 2000s, more than 110 textbooks, with different specialties and serving needs of different student ability levels, have been published since 2001 (Jiang & Xie, 2011). According to Tan (2010a), if textbooks and other publications related to mathematical modeling were counted, the total publications could reach 200.

In addition, students are the greatest beneficiaries from the contests. For example, some commented poignantly on the importance of their experience with one sentence “Once participated, benefit for life long” (Xie, 2009, 2010; Ye, 2011). Through the pre-contest preparation, hard work during the contest, and further research after the contest, students’ enthusiasm for learning, creativity and overall capabilities are advanced (Xie, 2010). Specifically, Jiang and Xie (2011) stated that,

- (1) students are more capable of solving practical problems using knowledge comprehensively from mathematics, computer technology and other subjects;
- (2) students are more attentive to country and social development as the problems of the contest are from hot sought-after problems in society;
- (3) students’ imagination, intuition, creativity, and the ability to conduct research independently towards complicated subjects are advanced;
- (4) students’ ability to clearly express themselves in writing is advanced;
- (5) students’ teamwork spirits and collaboration ability are advanced;
- (6) students’ belief in honesty and self-discipline are advanced. (pp. 81-82)

Xie (2010) and Ye (2011) also pointed out the increasing recognition of mathematical modeling activities by scientific and industrial communities. Companies began to sponsor the CUMCM; some regional governmental organizations have given substantial support to the Summer Camp of Mathematical Modeling; graduate schools and industry began to show their preference for recruiting students with modeling experience to further their study or to be employed, respectively.

Mathematical Modeling and Innovation

The significance of integrating mathematical modeling into the mathematics education

will be understood more fully if the following comment by Tucker (2005) is carefully considered.

[...] So we ended up with something of a paradox. The Chinese may well be producing the most mathematically adept population in the world, and therefore have the potential for producing the world's most capable workforce anywhere in the vital fields of science, mathematics and engineering. But, at the same time, they have a culture and an education system that may make it singularly difficult for them to cultivate the creative, innovative and entrepreneurial abilities that may prove most important to economic success in high wage societies in the future. The Chinese are very aware of this paradox and determined to do something about it. (p. 19)

The survey cosponsored by the Ministry of Education of China and the China Youth League examined Chinese students' creative thinking abilities among 19,000 students in 31 provinces (Ban, 2001). The findings from the survey showed that most students in China lack innovation consciousness. According to Tucker (Tucker, 2005), the Ministry has acknowledged the problem and has been trying to solve it. The practice includes "putting an end to rote learning and promote problem solving and critical thinking" (p. 19). What they are striving is for "students to be more independent, to be able to apply what they have learned to real world problems, and to be more creative" (p. 19).

Dan and Xie (2011) pointed out that since China has recognized the cruciality of innovation for sustainable development, cultivating a spirit of innovation and practical ability are the primary concerns for the mathematics education reform; mathematical modeling courses and pertinent activities, as the breakthrough of reform in Chinese mathematical education, are "gradually becoming the best bonding point to enhance students' mathematical knowledge and application ability".

In a study conducted by Dan and Xie (2011), data are presented showing that undergraduate student's mathematical modeling skills and creative thinking levels were strongly positively correlated. Yang and Tan (2011) reported the impact of mathematical modeling activities on the enhancement of students' innovation spirit. S. Li (2003) discussed his

exploration of cultivating students' innovation ability through mathematical modeling and mathematical experiments. He believes that having students using their existing knowledge, or learning new knowledge, during the process of problem solving is the best way to cultivate students' innovative ability and spirit of creativity. In terms of college level basic mathematical courses, such as Calculus and Linear Algebra, S. Li recommends that we should be very careful when reforming such courses due to their already long-established and mature knowledge system. However, he proposed that those courses can be taught using the problem-driven method, which makes students try to solve the posed problems, and thus gradually realize the importance and practical merits of learning the mathematical knowledge and techniques introduced in the basic courses. Therefore, students can experience the process of solving problems while enhancing their innovative ability.

Incorporating the Idea and the Method of Mathematical Modeling into the Main Mathematical Courses in Universities and Colleges

Having recognized the benefits of mathematical modeling competitions and courses, mathematical modeling educators have been enlarging the scale of beneficiaries to a broader size. Thus, the project "Incorporating the Idea and the Method of Mathematical Modeling into the Main Mathematical Courses in Universities and Colleges" was initiated and established from 2002 to 2005 (Ye, 2013). The main mathematical courses in Chinese universities and colleges are calculus, linear algebra, and elements of probability and statistics (Jiang, Xie, & Ye, 2007).

The emphasis of the project is on "designing and writing feasible modules on mathematical modeling, which includes the explanation of the whole mathematical modeling process from real-world problems, and they can be embedded or effectively used for the teaching of existing courses"; most importantly, the project requires that "the use of the modules doesn't

disturb instructor's regular teaching" (Jiang et al., 2007). Scholars have also given examples and principles in writing modules in calculus, which provided a guideline for designing modules for other subjects (Jiang et al., 2007; Ye, 2006, 2013). D. Li (2006), project leader, emphasized that the crucial point of this project is to incorporate the ideas into the main courses, instead of taking over the main courses completely by mathematical modeling. D. Li (2002) also believes that mathematical modeling education is a form of mathematics application competency education.

Later in 2000s, as the idea of the project popularized among educators, scholars have tried to further incorporate the idea of mathematical modeling into general education courses, thus, enabling liberal arts students to be exposed to the ideas of mathematical modeling and to appreciate them more fully (Cai, Cao, & Tan, 2013; Tan, 2009).

Mathematical Modeling and Secondary Education

Ye (1997) once predicted that the reform in college mathematics education definitely would have an impact on secondary mathematics education; and, to some extent as documented below, his prescient view has been confirmed.

National College Entrance Examination

Yan (1994) pointed out that the kind of mathematics knowledge students learned in secondary education had very little connection with their experience from daily life. As a result, learning mathematics for the National College Entrance Examination, as then constituted, was their major primary goal, and they had little consciousness of the practicality of mathematics knowledge. Due to the critical evaluation role of the National College Entrance Examination, it became a very important constraint to the reform of secondary education. Many scholars realized the importance of reform of the National College Entrance Examination, including incorporating mathematics application problems in the National College Entrance Examination, and believed

that it would have a positive influence and pose a stimulus to improve secondary mathematics teaching and learning (The Beijing Discussion Group of "Application", 1994; Yan, Zhang, & Su, 1993).

High School Curriculum and Activities

The Ministry of Education in China has prioritized the secondary curriculum reform nationwide in the past 20 years, resulting in the issue of three national high school mathematics curriculums in 1996, 2000 and 2003. The most recent High School Mathematics Curriculum Standards promulgated in 2003 “strives to create a curriculum that motivates interest and creativity, fosters basic knowledge and applicable skills. This is in contrast to previous curriculum geared almost exclusively to knowledge acquisition” (WENR, 2012). In the mathematics section, the Standards include mathematical modeling as part of the high school mathematics curriculum. Ma (2007) noted that this is a milestone for the development of secondary education in the aspect of mathematical modeling and application, and that it marked the official inclusion of mathematical modeling into the high school mathematics education.

In addition, the high school mathematical knowledge application contests in Shanghai and Beijing since 1991 have provided good demonstrations of mathematical modeling activities (Ye, 1997, p. 95).

Teacher Education

Among the important issues brought up in the late 1990s was the importance of emphasizing an ability of applying mathematics in teacher education (Yan, 1998). In the beginning of 2000s, due to the economic benefits brought by mathematics directly in the information age, it has become widely recognized by scholars in China that mathematical modeling and mathematical experiments should be listed in the required mathematics courses for

teachers in teacher education. Many top research normal universities in China have already proved the benefits of adding these two courses in the curriculum (Zhang & Wang, 2001).

Moreover, Zhang and Wang (2001) noted that topics, which are new to the secondary mathematics education curriculum, such as data analysis and mathematical modeling, are introduced in the secondary mathematics education curriculum. It is widely recognized that the establishment of “Nine-Year Compulsory Education Mathematics Curriculum Standards” and “High School Mathematics Curriculum Standards” would have a “far-reaching impact on the mathematics curriculum in teacher education”.

CHAPTER IV

PROCEDURES

The study was initiated when the fast-growing number of annual Chinese MCM participants demonstrated exceptional performance when participating in the contest. Interest has been aroused as to how mathematical modeling has achieved such immense recognition and an outburst in popularity among Chinese students.

This study has been completed with the help of many individuals who have been promoting, or have experienced, mathematical modeling education both in the United States and China, and is in part, a reflection of their important legacy in the field. In addition, analysis of pertinent published literature, data from COMAP, and the mathematics portion of the National College Entrance Examination were examined in order to piece together the history of mathematical modeling education development in China.

History of Mathematics Development in China

In order to understand the recent phenomenon of mathematical modeling success in China, it is necessary for readers to be familiar with China's contemporary history of mathematics development, especially its attitude towards learning, research, and using mathematics. Dr. Henry Pollak, member of the 1976 American Pure and Applied Mathematics Delegation to China, provided a seminal report (Fitzgerald & Mac Lane, 1977) of the trip. In addition, he provided the 1977 report of the National Council of Teachers of Mathematics (NCTM)-sponsored Study Visit to China (Becker, 1980). These two reports, along with resources from Hwa (1959), Kolata (1980) and Hu and Seifman (1976c), provide a vision of the mathematics development in China from the foundation of China in 1949 to the end of the Cultural Revolution in 1976. Besides, Dr. Pollak also provided the 1983 report of the North

American Delegation trip to China (Steen, 1984). Dr. Warren Page, leader of the 1987 People to People International Undergraduate Mathematics Education Delegation to China, provided the report of the trip. These two reports gave an insight to mathematics education in China in the 1980s.

Scholars' Effort in Popularizing Mathematical Modeling Education

Chinese scholars' vision and persistent effort over 30 years in popularizing mathematical modeling education is one of the most critical reasons behind Chinese students' success, as demonstrated by their performance in the MCM.

Initiators' Effort

In order to learn “why” and “how” the initiators have been so devoted to mathematical modeling education, the author of this study interviewed some of the early initiators of Chinese mathematical modeling education, such as Professor Shutie Xiao, Professor Qixiao Ye, Professor Qiyuan Jiang, Professor Yongji Tan, Professor Daqian Li, Professor Fuping Bian and Professor Laifu Liu. They shared their experiences in mathematics and mathematical modeling education. The information provided by the professors, along with information documented in two books *China Undergraduate Mathematical Contest in Modeling* (D. Li, 2011), *China Undergraduate Mathematical Modeling: Chronicles of 20 years* (CUMCM, 2011), and in related articles revealed some of the initiators' efforts in developing mathematical modeling education since 1982.

Young Scholars' Effort

During the past 10 years or so, young scholars, such as Dr. Jinxing Xie and Dr. Zhijie Cai, have taken over the responsibility of organizing mathematical modeling activities and improving mathematical modeling education. The interviews with these two scholars, along with analyses

of published articles, revealed current practices of general mathematical modeling education in China. The interviews with Dr. Jingxing Xie and Dr. Zhijie Cai, including additional ones with Dr. Yingdong Liu, Dr. Xiaofeng Gao and Professor Yi Fu, provided an understanding of the current practice of mathematical modeling education in Chinese undergraduate colleges and universities.

Background of MCM

The author of this study contacted the initiator of MCM, Dr. Bernard (Ben) Fusaro, to learn how Chinese students first began to participate in the contest. Dr. Fusaro provided letters of correspondence from December 1986 to November 1994 between him and his Chinese counterparts, revealing how Chinese teams initially participated in the MCM. Professor Qixiao Ye, initiator of the conversation between Chinese professors and Dr. Fusaro, communicated with some of his contemporaries in those early days, and expressed his interests in learning more about the contest and having Chinese students participate in the contest. These communications between Dr. Fusaro and Professor Ye were particularly valuable in documenting the process whereby Chinese teams participated early in the MCM. Professor Qixiao Ye, who first introduced the idea of the MCM to the general public in China in a journal article “Mathematical Contest in Modeling and some thoughts” (Ye, 1989), also documented the process of Chinese students’ initial participations in the article “Unforgettable years— A retrospective of birth, maturity and development of China Undergraduate Mathematical Contest in Modeling” (Ye, 2011). Other Chinese scholars’ letters of correspondence with Dr. Fusaro illustrated the early registration process of Chinese teams and scholars’ interests in learning mathematical modeling activities outside of China.

In addition, Dr. Fusaro provided resources illuminating the history of the MCM, including its founding goals and purpose, which eventually became a precedent of the CUMCM.

Government Influence

Government documents supporting mathematical modeling activities were extracted and organized for analysis from the information available in books: *National Undergraduate Mathematical Contest in Modeling, Chronicles of 20 years* (CUMCM Committee, 2011) and *China Undergraduate Mathematical Contest in Modeling* (Li, D. (Ed.), 2011a). The government documents were analyzed to elucidate the government's attitude on mathematical modeling education. The interviews with Professor Qixiao Ye and Dr. Jinxing Xie also revealed government attitudes towards mathematical modeling education. The Summer Camp of Mathematical Modeling held in Shenzhen was examined because it exemplifies local government support and its role in mathematical modeling activities.

Organizations' Influence

Chinese organizations' effort in promoting mathematical modeling activities and education is mainly reflected by the work of the mathematical modeling committee of the China Society of Industrial and Applied Mathematics (CSIAM) and China Undergraduate Mathematical Contest in Modeling Committee (CUMCM Committee). Their work was extracted and organized for analysis from the information available in the book *National Undergraduate Mathematical Contest in Modeling, Chronicles of 20 years* (CUMCM Committee, 2011) and through various interviews arranged with individuals who has been involved in the work and development of the two organizations. The author of this study also attended the China Conference on the Teaching of Mathematical Modeling and Application (CCTMMA), one of the

mathematical modeling conferences in August 2013, and gathered detailed information about mathematical modeling teaching and academic exchange.

Other Resources and Practices

Regional mathematical modeling activities are critical to the development of mathematical modeling education in China. Regional and school-wise mathematical modeling activities, regional teacher training sessions, colleges' effort in integrating mathematical modeling into the major mathematics curriculum, information sharing websites, industry sponsorships were all analyzed to exemplify the support and recognitions of mathematical modeling activities from everyday experiences and participation in Chinese society.

Chinese Students' Choice of Mathematical Modeling Problems in MCM

Chinese teams' choices of MCM problems, continuous problem (problem A) or discrete problem (problem B), were analyzed from COMAP's data from 1990 to 2013.

The number of Chinese teams that chose problem A was compared to the number of Chinese teams that chose problem B. The comparative results illustrated some of the Chinese teams' preferences in choosing problems.

Winning the MCM is defined as a team obtaining an Outstanding, Meritorious, or Honorable Mention award—all above that of Successful Participant. The percentage of Chinese teams in all winning teams is defined as the winning rate of Chinese teams. The winning rate of Chinese teams in problem A was compared to that in problem B, which illustrated whether a problem had a higher or lower winning rate for Chinese teams.

The participation rate of the Chinese teams in certain problems is defined as the percentage of Chinese teams among all teams who chose that problem.

National College Entrance Examination Mathematical Modeling Problems Identification

The author of the study examined mathematics examinations in the National College Entrance Examination from 1951 to 2013 to find mathematical modeling problems. The mathematical modeling problems were identified as problems that contain the full process of mathematical modeling. The full process of mathematical modeling is defined in the Literature Review chapter, but the following essential aspects are included as part of the methodology.

In this thesis, mathematical application problems are defined as mathematics problems containing only the first two steps of the mathematical modeling process, which are “formulating situations mathematically, and “employing mathematical concepts, facts, procedures, and reasoning.” However, mathematical application differs from mathematical modeling in this thesis, in that the last step of the mathematical modeling process, “evaluating and improving the mathematical outcomes,” is not required.

Mathematical modeling problems, if any, were analyzed via the number of problems appearing on the test as well as the context in which the problems used over the years. The analysis was conducted in order to illustrate the trend of mathematical modeling education in China at the secondary level.

CHAPTER V

RESULTS

Ever since Chinese teams first participated in the MCM in 1989, the attendance of Chinese teams has dramatically increased. The total number of Chinese teams that participated in the MCM/ICM rose from 4 teams in 1989 to 6,125 teams in 2013, marking an increase from 1.9% to 92.89% of all teams competing in 1989 and 2013, respectively. The MCM, which consists of one continuous mathematical problem and one discrete mathematical problem each year, attracts the majority of competing teams. The number of Chinese competing teams in solely MCM increased from 4 teams in 1989 to 5,195 teams in 2013, which is an increase from 1.9% to 92.16% of all MCM teams. The ICM, which appeared as the third problem since 1999 and was officially separately awarded from MCM since 2001, saw an increase of Chinese teams from 41.67% of all teams in 1999 to 97.18% in 2013. The reasons resulting in the significant changes are complicated. In this chapter, results will be presented regarding the support provided to encourage mathematical modeling activities by various influential sources including: the Chinese government, Chinese organizations, and a variety of other resources—including efforts made by experts dedicated to mathematical modeling education. In addition, students' preferences of problems in the MCM, and influence from the National College Entrance Examination are also analyzed in order to reveal the connection to this significant increase.

The Chinese Government's Influence

Policy Support

The Chinese government's interest in the mathematical applications may be traced long prior to its support of mathematical modeling activities. In fact, the 1983 report by North

American Delegation documented the Chinese Ministry of Education's desire to "see more attention given to the applications of mathematics"(Steen, 1984, p. 26).

The Department of Higher Education of the Ministry of Education in China played an indispensable role in arousing the awareness and recognition of mathematical modeling activities across China, including increased interest by potential participants, especially in the early stages of the development of the CUMCM. The Department of Higher Education showed its support by issuing multiple policy documents pertaining to the development of the CUMCM.

In 1993, 1994 and 1995, the Department of Higher Education issued three notices to all levels of governmental departments and organizations calling for preparation to organize the national mathematical contest in modeling and other contests (Li, D. (Ed.), 2011c, pp. 7-10).

Notice #178 in 1993 was the initial notice calling for suggestions and plans for holding national contests in electrical design, mechanical design, structural design and mathematical modeling. This notice only targeted pertinent ministries in the central government and the CSIAM. In notice #178 distributed by the Department of Higher Education, it was announced that the mathematical modeling contest would be held by both the Department of Higher Education and the CSIAM; and that the CSIAM would be the one that organized the actual contest process. This announcement officially established the leadership role of the CSIAM in the CUMCM.

Notice #76 in 1994 announced the decision of hosting three national contests in the same year, including contests in mathematical modeling, mechanical design and electronic design. The Department of Higher Education asked the governments at all levels to facilitate the work of the CSIAM in organizing the CUMCM, and other pertinent departments in organizing the contests in mechanical design and electronic design. This notice targeted wider government levels,

including all the provinces, autonomies, municipalities, local departments of higher education, and departments of education subordinate to Ministry of Electronics and Ministry of Mechanics in the central government. The issue of the notice officially marked the CUMCM as one of the activities administrated by the Department of Higher Education (CUMCM Committee, 2011, p. 141).

It is worth noting that among all the three national contests held in 1994, the CUMCM was the only contest that accepted participation from all higher education institutions across the country. In contrast, the contest in mechanical design was experimented only in higher education institutions affiliated to the Ministry of Mechanics, and the contest in electrical design was experimented only in Beijing, Sichuan and Shaanxi Provinces.

Notice #45 in 1995 was specifically dedicated to the CUMCM. The notice recognized the benefits of the CUMCM in cultivating students' practical problem solving ability and innovation consciousness, as well as in accelerating the reform of mathematical content and curriculum structure. The notice also announced the decision of continuing the CUMCM once a year from then on, and confirmed the actual organizer to be the CUMCM Committee.

The difference in the scale of promoting the contests nationally in 1994 was not baseless. Please keep in mind that China is a pragmatic country that makes a practice of experimenting carefully and then spreads what works through the entire nation (Center on International Education Benchmarking, 2013b). Compared to the contests in mechanical design and electrical design, the mathematical modeling contest had already gained extensive and successful holding experience on both regional and national levels before it was promoted as CUMCM in 1994. At regional level, Shanghai and Shaanxi province already had successful experience in holding three regional-level mathematical modeling contests, respectively, in late 1990 (in Shanghai),

mid 1991 (in Shanghai), and early 1992 (in Shaanxi). Furthermore, at the national level, successful experience had been obtained from two national mathematical modeling contests held by the CSIAM, a mid-scale national level mathematical modeling contest including only major cities in late 1992, and a large-scale national mathematical modeling contest that was successfully held in 1993. All the experience gained from the previous contests laid the foundation for officially promoting the mathematical modeling contest nationally as the CUMCM (Ye, 2011, p. 5). The CUMCM reached the national stage only when it was deemed mature.

In a country where the education system consists more of a centralized administration as compared to the United States, the education administration of the Chinese government bears greater authority in promoting and advocating education practice. Apparently, Chinese education administrators were very well aware of this power. They maintained the credentials and authority of the education administration by supporting carefully experimented, well substantiated and well received education practices. It is worth noticing that the decision makers in the Department of Higher Education were very careful when it came to promoting the mathematical modeling activities and practices nationally in the name of the Department of Higher Education. Before the CUMCM had the Department of Higher Education as one of its hosts, decision makers in the Department of Higher Education were quite attentive to the development of the contest. Professor Kaixuan Zhu, then director of the Ministry of Education, expressed his interest in, and commitment to, the mathematical modeling contest. Professor Yuanqing Zhou, then director of the Department of Higher Education, also visited the contest site and attended the 1993 awards ceremony of the national mathematical contest in modeling. In addition, other officials in the Ministry of Education, such as the chief and vice chief of the department of engineering

education, Zhipeng Liu and Zhihong Li, all immediately recognized the significance of the contest. It is very necessary to have support from relevant officials before the activities are held in large scale (Qixiao Ye, personal communication, August 2013). Due to their understanding of the contest and mathematics as a subject, the contest received immense policy support from the government (Liu & Li, 2011; Ye, 2011, p. 7).

It is important to note that in all the three notices, cultivating student ability in practical problem solving, innovation consciousness, and promoting reform in the mathematics curriculum was a governmental concern and goal. Zhipeng Liu and Zhihong Li also recalled that professor Qixiao Ye and professor Qiyuan Jiang sought support for the CUMCM on behalf of the CSIAM from the Department of Higher Education in 1993. At that time, the Ministry of Education was encouraging the reform of the models for cultivating talent as well as teaching content and pedagogy. The practices that the mathematical modeling contest proposed, such as the ability in practical problem solving, innovation and cooperation consciousness, and teaching and learning reform, fully complied with the goals of the government reform (Liu & Li, 2011).

As the term of service of the first CUMCM Committee expired, the Department of Higher Education issued two notices in 1997 and 2002 confirming the formations of the second and third CUMCM Committees and granting them full authority within their terms of service. It was specified in both notices that the appointments of the CUMCM Committee were decisions that were discussed and agreed by both Department of Higher Education and the CSIAM. The two notices advised all provinces, autonomies, municipalities, education administrations, and higher education institutions to work with the CUMCM Committee in organizing the CUMCM within its term of service (Li, D. (Ed.), 2011c, pp. 10, 12).

As the development of CUMCM prospered, the Department of Higher Education gradually reduced its participation in the administration activities that are related to the CUMCM and its Committee designations (Jinxing Xie, personal communication, August 2013). By 2001, the CUMCM had already become the largest undergraduate extracurricular activity in China (Li, D. (Ed.), 2011c, p. 12). In 2001, the Department of Higher Education announced that the CUMCM Committee would be fully in charge of the organization of the CUMCM from then on, and the Department of Higher Education would no longer issue any additional notices on the matter (Li, D. (Ed.), 2011c, p. 11). From then on, the CSIAM became the primary decision maker for the designation of the CUMCM Committees. Even though the Department of Higher Education no longer participates in the decision making process, the decisions related to the designation of the CUMCM Committees, are still reported to the Department of Higher Education for record (CUMCM Committee, 2014b; Li, D. (Ed.), 2011c, pp. 16-19).

In addition to the policy support in promoting the CUMCM at the initial stage of the contest, the Department of Higher Education also demonstrated its encouragement in mathematical modeling activities through other influences.

For the CUMCM held in the 1990s, the Ministry of Education showed support through national teacher training in mathematical modeling. Gradually, schools dedicated more effort in support of teacher training. Therefore, a greater amount of education funds was allocated to the mathematical modeling activities. As a result, teachers in most schools were fully reimbursed for their participation in training activities (Yongji Tan, personal communication, August 2013).

In 2002, the Department of Higher Education granted permission to initiate the project “Incorporating the Idea and the Method of Mathematical Modeling into the Main Mathematical courses in Universities and Colleges”. The two-year project was integrated into the Ministry of

Education's initiative "Undergraduate Education Reform in the Higher Education Reform of the New Century". The principal investigating organization of the project was the CUMCM Committee, and the principal investigator was professor Daqian Li (Li, D. (Ed.), 2011c, pp. 13-14).

In 2003, the Department of Higher Education issued a notice addressed to all higher education institutions that teachers' work in advising undergraduate students' participation in activities, such as the CUMCM, should be encouraged and effectively rewarded (Li, D. (Ed.), 2011c, p. 14). In the 2003 notice, the Department of Higher Education confirmed the beneficial effects of mathematical modeling activities, such as the CUMCM, that had already been proven in past years. Yet, the Department of Higher Education also brought up problems that had arisen during the development of mathematical modeling activities. For instance, the workload of teachers who had advised students in mathematical modeling activities were not fully recognized in some schools, which not only affected teachers' enthusiasm in the work, but also consequently inhibited the future development of those activities. As a result, the authority asked higher education institutions to recognize teachers' workload in the activities such as the CUMCM, and recommended that an effective incentive system fitting the needs of each local environment be established in order to encourage more teachers to be involved in advising students in activities such as the CUMCM (Li, D. (Ed.), 2011c, p. 14).

In 2007, the Department of Higher Education issued a notice regarding the Ministry of Education and Ministry of Finance's Approval to financially support undergraduate contests for the year 2007. The CUMCM was among the nine contests that the two Ministries financially supported that year (Li, D. (Ed.), 2011c, p. 15).

Initiated Mathematical Modeling Activities

In addition to the policy support, the Department of Higher Education of the Ministry of Education also entrusted organizations and institutions to hold multiple national teacher training seminars in mathematical modeling. The support in mathematical modeling from the Department of Higher Education broadened and deepened the recognition of mathematical modeling activities in higher education institutions, and also increased the importance of teacher preparation in mathematical modeling throughout China.

From August 15 to 25, 1994, the Department of Higher Education of the Ministry of Education entrusted Tsinghua University to hold a national mathematical modeling seminar. Experts in mathematical modeling education, including professors Wenci Yu, Qixiao Ye, Qiyuan Jiang, and Yongji Tan, were invited to share their thoughts on mathematical modeling. Approximately 160 teachers from over 100 higher education institutions came to the seminar (CUMCM Committee, 2011, p. 15).

In August 1997, the Department of Higher Education entrusted Tsinghua University, the mathematical modeling committee of the CISAM, and Chengde Petroleum College to hold a teacher-training seminar on the use of mathematical software in mathematical modeling. Over 180 teachers from more than 130 higher education institutions participated in the seminar. This seminar served as a major impetus to promote mathematical modeling activities, especially through the use of mathematical software (CUMCM Committee, 2011, p. 17).

Under the influence of increasingly popularized mathematical modeling contests and relevant mathematical modeling course offerings in universities and colleges, a new course called “Mathematical Experiment” was gradually introduced in higher education institutions. In August 1999, the Department of Higher Education entrusted Tsinghua University to hold

seminars on the course “Mathematical Experiment”. Five experts in the field, including professors Qiyuan Jiang and Yongji Tan, were invited to the seminar to give talks on the new course. The seminar played a leading role in promoting the course nationally amongst teachers and students (CUMCM Committee, 2011, p. 20).

In May 2002, the Department of Higher Education entrusted the CUMCM Committee to hold the national training seminar on mathematical modeling for key teachers. One hundred fifty-eight teachers from 140 higher education institutions participated in the training (CUMCM Committee, 2011, p. 24).

In August 2003, the Department of Higher Education entrusted the PLA Dalian Naval Academy to hold a teacher-training seminar for key teachers in two-or-three-year programs in colleges and occupational schools. Over 140 teachers participated in the training (CUMCM Committee, 2011, p. 26). Considering that the CUMCM added two problems each year specifically for students at two-or-three-year colleges since 1999, the teacher training specially dedicated to teachers working in these kinds of colleges was no doubt very helpful for their future advisement of their students and popularizing mathematical modeling activities in their respective schools.

Organizations’ Implementation and Influence

Organizations

The China Society for Industrial and Applied Mathematics (CSIAM) and the China Undergraduate Mathematical Contest in Modeling Committee (CUMCM Committee) are the two leading organizations that promote and implement national mathematical modeling activities.

China Society for Industrial and Applied Mathematics. China Society for Industrial and Applied Mathematics (CSIAM) was founded on November 1st 1990 (Ye, 2011, p. 5). Prior

to that, some local SIAMs had already been established, such as the ones in Shanghai, Shaanxi province. Subsequently after the establishment of the CSIAM, more provinces began to form their own SIAMs. The formation of all levels of SIAMs marked a new stage in the development of applied mathematics in China (Ye, 2011, p. 5).

The goal of the CSIAM is to establish a connection between the mathematical community and industry, promote close collaboration among mathematicians, engineers, technicians and industry managers, solve various mathematical problems derived from economic development and technological advancements, and promote research and education of applied mathematics (CSIAM, 2014). Collaborating with the Department of Higher Education of the Ministry of Education, the CSIAM lists the following objectives as part of its major operations: organizing teaching, research and communication of industrial and applied mathematics; organizing national mathematical modeling competitions and activities (CSIAM, 1992).

There are eight specialized committees subordinate to the CSIAM: mathematics in system and control, mathematical modeling, gymnastic mathematics, medicinal mathematics, climate and environment mathematics, geometric design and computation, numerical methods for oil and water resource, and signal and information processing (CSIAM, 2014). Among which, the mathematical modeling committee was established in November 1991. Since its establishment, the mathematical modeling committee of the CSIAM has been leading the development of mathematical modeling activities in China (CUMCM, 2011, p. 14).

CUMCM Committee. The CUMCM Committee decides and executes on all matters pertaining to the CUMCM, which includes but are not limited to issuing contest announcements, coordinating registration processes, finalizing contest problems, organizing grading processes,

and arranging awarding events, etc. The CUMCM Committee, collaborating with the CSIAM, played a major role in popularizing and promoting the mathematical modeling activities in China.

The first CUMCM Committee was established in March 1994 (Ye, 2011, p. 7). Each term of its service spans four years. As of 2014, the sixth term of the Committee is in service from 2014 to 2017. The Committee was jointly appointed by the Department of Higher Education of the Ministry of Education and the CSIAM for the first three terms. Starting with the fourth term, Committee members must be approved beforehand by the CSIAM, and submitted to the Department of Higher Education of the Ministry of Education for recordkeeping (Li, D. (Ed.), 2011c). Committee formation announcements were made by the Department of Higher Education for the first three terms, and have since been processed through the Committee itself starting with the fourth term.

The Committee consists of advisors, a director, vice directors, counselors, a secretary general, and secretaries. Starting with the fourth term, an affiliated expert panel has been set up with each term of the Committee (CUMCM Committee, 2010a, 2010b, 2010c, 2014b). The individuals appointed to the Committee and the expert panel, are prominent researchers and professors. The advisors of the Committee are usually people who are directors or vice directors from higher education management and research organizations, such as the Department of Higher Education of the Ministry of Education, and China Association of Higher Education. Professor Shutie Xiao of Tsinghua University, one of the initiators and pioneers of Chinese mathematical modeling education, served as one of the advisors from second term to fifth term of the Committee. The rest of the committee is comprised of renowned professors in mathematics and sciences at top research universities, researchers in distinguished research

institutions such as Chinese Academy of Sciences, and chief editors from Higher Education Press, etc.

Local CUMCM Committees have been set up by provinces and regions to facilitate the job of the CUMCM Committee since 1994.

Mathematical Modeling Activities Organized by the Organizations

The mathematical modeling committee of the CSIAM was the main organizer of mathematical modeling activities before 1994. Since the establishment of the CUMCM Committee in 1994, the mathematical modeling committee of CSIAM and CUMCM Committee have been working collaboratively in holding mathematical modeling related events. Results are presented in the center of activities they have held together, as well as separately—specifically during the CUMCM, Summer Camp, conferences and teacher training sessions.

Prior to the CUMCM. The mathematical modeling committee of the CSIAM was the main organizer of mathematical modeling activities prior to the establishment of the CUMCM Committee in 1994. The mathematical modeling activities held by the mathematical modeling committee of the CSIAM mainly included the 1992 and 1993 national level mathematical modeling contests.

On November 27-29, 1992, “The First National Undergraduate Mathematical Contest in Modeling” made its appearance. Nine major Chinese cities participated in the contest, constituting nine contest divisions, including Beijing, Xi’An, Guangzhou, Shanghai, Wuhan, Dalian, Chengdu, Chongqing, and a joint Shanghai division. Three hundred fourteen teams from 74 schools participated in the contest (Li, D. (Ed.), 2011b, p. 132). The designation of awards was granted within each contest division, considering that this was the first large-scale national mathematical modeling contest organized within a short period of time and without much prior

experience (Ye, 2011, p. 6). The successful holding of this contest laid the foundation for the holding of later national level mathematical modeling contests.

Having had the experience of holding a national contest involving major cities in 1992, the CSIAM expanded the national mathematical modeling contest to students in all Chinese higher education institutions in 1993. Four hundred twenty-nine teams from 16 provinces and 101 higher education institutions participated in the 1993 national contest (CUMCM Committee, 2011, p. 15).

Despite the formats of the 1992 and 1993 contests being identical to the CUMCM, the mathematical modeling contests were not officially named the CUMCM until 1994.

CUMCM. The China Undergraduate Mathematical Contest in Modeling, briefed as the CUMCM, is an annual mathematical modeling contest cohosted by the Department of Higher Education of the Ministry of Education and the CSIAM since 1994.

The CUMCM Committee was established in March 1994. It has since been the main organizer of the CUMCM and its pertaining events (CUMCM Committee, 2011, p. 16). Local CUMCM committees that set up by provinces and regions facilitate the work of the CUMCM Committee. Thirty of the total 34 provinces and regions have established their own local CUMCM Committees, so far. Usually, each province or region is regarded as a contest district. Currently, there are 31 contest districts across China. Provinces that have not constituted their own contest district become a joint contest district. Teams from outside of China become a contest district. All together, there are 33 contest districts for CUMCM (CUMCM Committee, 2014a).

The Constitution of the CUMCM, which was enacted in 1994 when the CUMCM Committee was established, specified the CUMCM in terms of its purpose, content, format and

rules, organizing structure, judging and awarding procedures, and financial support resources (Li, D. (Ed.), 2011c). The Constitution of the CUMCM has been amended twice since its initial publication in 1994 to reflect the changes of the contest. The two amendments were issued in 1997 and 2008, respectively.

The purpose of the CUMCM is to provide students with an opportunity to experience the mathematical modeling process; improve students' understanding of mathematics, especially mathematical modeling; arouse students interests in learning mathematics; and improve students' competency in creativity and innovation, collaboration, and applying mathematics to the real world (Xie, 2013). The contest is also to be considered as an important aspect of the college mathematical teaching reform (Li, D. (Ed.), 2011c).

The problems on the CUMCM are simplified real world problems from engineering, management, and other fields. Students need to apply the mathematical modeling process to develop and modify models in order to solve the given problems. No prior knowledge background pertaining to the contest problems is required. A good command and competency of the mathematical knowledge at college level is recommended.

The basic rule of the CUMCM is very similar to that of the MCM/ICM in the U.S. In fact, mathematical modeling educators in China recognized the benefits of the MCM in the 1980s, and established the Chinese version of the MCM in 1992, which eventually turned out to be the CUMCM today (Xie, 2013). Undergraduate students participate in the CUMCM in teams, with each team consisting of up to three members from the same institution. Prior to the contest, teams register for the contest and obtain contest information on the CUMCM website. Upon the start of the contest, teams can access problems through the website and download given data, if needed. The CUMCM usually starts at 8:00 a.m. on the second or the third Friday in September

and ends at 8:00 a.m. the following Monday. During the contest's three-day period, teams have to choose one of the problems and write their solutions as research papers. Students are allowed to have discussions within their teams, and consult with non-human resources, such as the Internet and library materials. However, it is prohibited for any team to have any discussion or advisement from human resources outside of the team during the contest. It is highly emphasized that appropriate credit must be attributed to sources. Failure to do so may result in disqualification. Advisors or advising groups that formed by teachers are recommended for teams to consult before the contest. However, it required that advisors and advising groups have no communication of any kind with the competing teams during the contest. Graduate students are not allowed to compete in the CUMCM (Li, D. (Ed.), 2011c).

Teams register and obtain contest information and material from the CUMCM website. At the end of the contest, each team should submit a solution paper to the local CUMCM committee. The Local CUMCM Committees then performs the first round of judging. Strong papers selected by the local CUMCM will be submitted to the CUMCM Committee for the final judging. The amount of papers entered in the national judging level is approximately 10% of the total papers submitted. Based on the quality of the submissions, the prize structure awards teams the Higher Education Press Cup, first prize, and second prize at the national level. Furthermore, the top two teams are awarded the Higher Education Press Cup. Only 1% of teams are awarded first prize, and approximately 6% of the of all teams are awarded second prize. Each year, about 15 outstanding papers are published in the journal "Engineering Mathematics", which is one of the official publications of the CSIAM. Since the contest problems are open questions without absolute correct or incorrect answers, the judging of the quality of the papers is based primarily on four criteria, namely "the reasonability of the model assumptions, the creativity/innovation of

the model, the correctness of the solutions, and the readability of the presentation” (Xie, 2013, p. 439).

There have been some changes to the CUMCM over the years. Before 1999, the CUMCM consisted with a total of two problems each year. Undergraduate students from higher education institutions competed and were awarded based on the performance on the two problems of the given year. Starting from 1999, the CUMCM began taking into account the mathematical ability at two-or-three-year colleges, and created two additional problems each year specifically for students enrolled in two-or-three-year colleges. Since 1999, the CUMCM was divided into two competing and awarding levels, four-year undergraduate program level and two-or-three-year undergraduate program level. Teams from two-or-three-year colleges may elect to attempt both problems at their level and as well as those designated for four-year institutions teams. The teams from four-year institutions, however, may only attempt problems at the four-year level (Li, D. (Ed.), 2011c, p. 6). The problems at the two levels have differed in most of the years since the implementation of the new rules. However, there were years when the same context was used for a single problem at both levels. Details of the previous problems in English may be found on the official CUMCM website <http://en.mcm.edu.cn>.

The CUMCM has been the most widespread undergraduate extracurricular activity in China since 2001 (Li, D. (Ed.), 2011c, p. 12). As early as 1992, 314 teams from 74 higher education institutions participated in the national mathematical modeling contest — which was not officially named as CUMCM at that time. The popularity of the CUMCM in China has skyrocketed over the past 20 years. In 2013, there were 23,339 teams from 1,326 higher education institutions participated in the CUMCM. Considering that there are 2,442 higher education institutions in China, the number of participating institutions accounts for more than

half of all participating institutions — among which, the most prominent higher education institutions have all been represented. It is worth noting that “more than 80% of participants are from engineering, economics, management, and even humanities majors, other than mathematics majors one might expect” (Xie, 2013, p. 438). It is also interesting to note that based on the research by Professor Qiyuan Jiang and Dr. Jinxing Xie, the ratio of participation majors and their awarding ratio is relatively the identical; mathematics majors possess no inherent advantage in terms of performance shown in the CUMCM; engineering majors, however, have shown the strongest performance in the CUMCM among all participated majors (Jiang & Xie, 2011, p. 81). This phenomenon was actually shown when the mathematical modeling contest was first initiated in China. Professor Yongji Tan recalled that when the first China mathematical modeling contest was held in Shanghai in 1990, it was deemed exclusively for mathematics majors. At that time, many engineering-major students were eager to participate in the contest. In the end, the organizing committee of the contest agreed to let two teams of engineering students join the contest. To everyone’s surprise, the two teams were among the best performing teams in the contest (Yongji Tan, personal communication, August 2013).

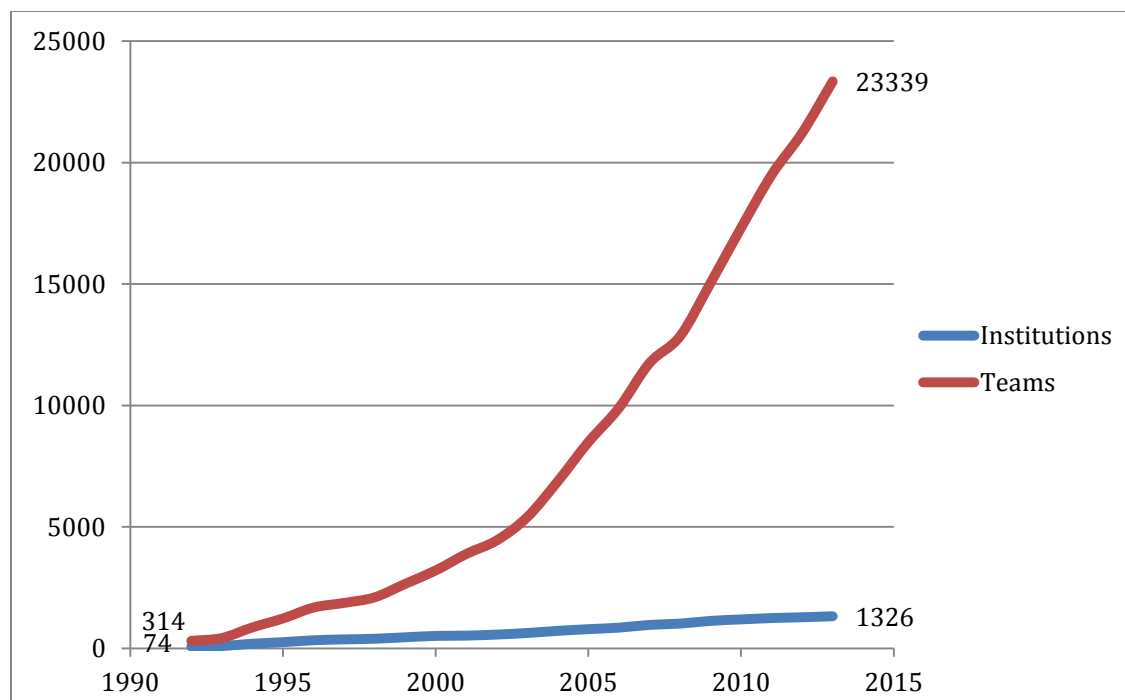


Figure 4. Number of participation in the CUMCM from 1992 to 2013.

Why has the CUMCM been popular and attractive to students in China? Dr. Jinxing Xie (2013), Professors Qixiao Ye and Yongji Tan mentioned the following reasons to answer the question.

(1) The contest is a real challenge to students while also providing unique experience in applying the mathematics knowledge learned. Through the contest, students can get access to the real problems from industry and research, which most students normally don't have the opportunity to if the contest were not held. In order to have a good performance in the contest, students need to find their teammates wisely, have a thorough understanding for college mathematical knowledge and possibly other skills, such as computer programming, and work collaboratively in the contest, which provides students an experience that's closer to the work environment, and that is quite different from the experience they would normally have in school (Jinxing Xie, personal communication, August 2013).

(2) The increasing recognition of mathematical modeling by industry, academia and other parts of society has provided students with mathematical modeling experience with a greater chance to further their careers, which may lead to a bright future of their lives. For instance, in the IBM China Research Lab's hiring notice for its research positions in 2009, it listed in its job description that "an award in a well-known mathematical modeling contests is a plus" (Xie, 2013, p. 441), which indicated a strong interests for IBM's in hiring students with mathematical modeling experience. Furthermore, many advisors in graduate program admissions have showed strong interests in students with mathematical modeling experience as well. These factors continue to serve as incentives for students to learn mathematics modeling. The intriguing nature of the contest combined with the unique experience it affords to participating students, the popularity of the CUMCM is understandable and befitting of the CUMCM's official slogan: "once participated, lifelong benefits"(Qixiao Ye, Yongji Tan, Jinxing Xie, personal communication, August 2013).

When asked about students' motivation in participating the CUMCM or MCM/ICM, scholars gave the following reasons:

(1) Some students participate in the contests seeking for potential good awards to facilitate their future career enhancement, such as finding a good job, entering a good graduate school, etc. Many experts in mathematical modeling education that have been promoting the CUMCM and mathematical modeling education for a long time, agreed that students with that motive indeed exist but only account for a small fraction of the participant body. With the very selective awarding percentage (1% for the national first prize and less than 6% for the national second prize in the CUMCM), only those who are really good at mathematical modeling may excel in the contest. An excellent performance in the CUMCM cannot be attained within a short

time. Competing at a high level requires a good master of college level mathematics, a solid understanding of the connection between mathematics and the real world, and good writing skills in expressing the mathematical ideas clearly and effectively. Most importantly, the aforementioned competencies must be carried out by a team rather than on an individual basis. Therefore, the ability for one to work collaboratively is also a critical required skill.

(2) Students participate in the modeling contests because of their curiosity. The format of the mathematical modeling contest, which students have to compete collaboratively for three days in a row, is quite intriguing to students. Students who have participated in the contests would tell those who haven't how unique the experience was, and that they would never have known it without participating it (Qixiao Ye, personal communication, August 2013).

All of the Chinese mathematical modeling education experts the author interviewed unanimously agreed that so long as students participate in the CUMCM, they would benefit from the experience, regardless of their motives in attending the competition. (Qixiao Ye, Qiyuan Jiang, Yongji Tan, personal communication, 2013).

Prior to the CUMCM, Chinese college mathematics education focused primarily on the introduction of mathematical theories and their proofs, with little emphasis on mathematical application. After going through required mathematics courses, most students did not understand how to apply what they learned into practice. Therefore, many of them lost interest in mathematics. Teachers, on the other hand, continued searching for effective ways to pass on mathematical knowledge to students, but did not attain much success (Jiang & Xie, 2011). Besides, there was an ongoing debate about the content of the mathematics curriculum — specifically whether certain portions of the knowledge should be removed or not. However, the

matter was eventually left undecided (Ye, 2011). The success of the CUMCM has provided people with some thoughts on enhancing mathematics education in China.

The popularity of the CUMCM has posed numerous positive influences on the undergraduate education in China. Its accomplishments include successfully introducing mathematical modeling in the undergraduate education, which makes it the most successful experiment in the undergraduate mathematical teaching reform to date. The popularity of CUMCM has also promoted national recognition of mathematical modeling; from which, students have recognized the value of mathematics in the real world in addition to its theoretical importance. Thus, students' interest in learning mathematics has been aroused. Teachers deem mathematical modeling a good tool in introducing mathematical ideas. In addition, it successfully promoted the mathematical modeling courses in China. Before the CUMCM, there were only 30 or so schools that offered mathematical modeling related courses, and those courses were mainly for mathematics majors. Due to the influence of the CUMCM, more than 1,200 schools in China offer mathematical modeling related courses in their curricula nowadays, and they are open to students of all majors. It has also promoted mathematical modeling activities of all kinds and of all scales. Mathematical modeling textbooks and related materials that target students at different levels have been published. Many regions have already held their own regional mathematical modeling contest. Students have voluntarily formed all kinds of mathematical modeling clubs in their schools (Jiang & Xie, 2011).

With the CUMCM's popularity and influences in mind, it's not hard to understand the phenomenon of increasing numbers of Chinese participants in the MCM/ICM. Students who have experienced the fun of mathematical modeling will seek more in the similar events, such as MCM/ICM.

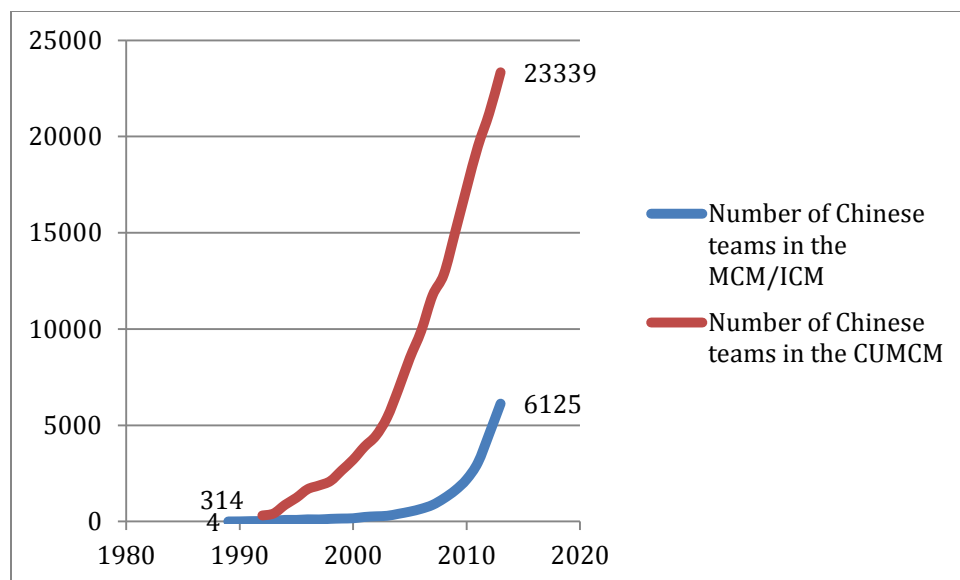


Figure 5. Number of Chinese teams in the MCM/ICM from 1989 to 2013 and number of Chinese teams in the CUMCM from 1992 to 2013.

However, compared to the number of Chinese teams in CUMCM, the number of Chinese teams participating in the MCM/ICM accounts for only a small fraction of total CUMCM participation. If it were not for the following possible reasons, the number of Chinese participants in the MCM/ICM could have been even greater. Here are major reasons considered by the author:

(1) Language barrier. The language used in CUMCM is Chinese (English papers are also accepted for foreign participants), the native language for all Chinese participants, whereas, solutions in English are the only judging proof in MCM/ICM. Although several judges in the MCM/ICM have noticed the significant enhancement in Chinese teams' English writing competency (William Fox, Chris Arney, personal communication, May 2013), developing a mathematical modeling idea and fully expressing it using a non-native language is challenging for the majority of students.

In addition to the enhancement of students' ability in expressing ideas in English, judges also found that

[...]the Chinese teams appear to read the commentaries and many teams provide the MCM paper in the format and style the judges desire as well as THEY appear to be using more “real” modeling rather than just throwing tons of theory at the problem without resolution to a solution. (William Fox, personal communication, May 2013)

Xiaofeng Gao, who was a two-time CUMCM and once MCM contestant when she was a student, is an engineering professor at Shanghai Jiaotong University, one of the top engineering schools in China. She concluded Chinese teams’ increasing good performance to the fact of Chinese teachers’ ever-increasing level of knowledge and horizon. An increasing amount of Chinese teachers working at university levels obtained their doctoral degrees abroad. Due to their education experience, more and more teachers are familiar with ways that enables more effective communication at an international level (Xiaofeng Gao, personal communication, August 2013).

(2) Furthermore, the limit of team numbers from the same institution mandated by MCM/ICM before 2009 posed an additional restriction. Prior to 2009, MCM/ICM limited the number of teams from each institution to seven, in order to avoid dominance of larger schools over smaller ones (Sol Garfunkel, personal communication, April 2014). Chinese Teams wishing to compete in the MCM/ICM often had to compete against each other for the limited number of MCM/ICM entrance tickets. Since the CUMCM is held in September and the MCM/ICM in February, oftentimes, schools took teams’ performance in the CUMCM into consideration and issue priority eligibility to the MCM/ICM teams with strong performance for subsequent years (Zhijie Cai, personal communication, August 2013). As the limit was removed in 2009, the number of teams participating in MCM/ICM per year has increased from 1,621 in 2009 to 6,125 in 2013. The CUMCM, on the other hand, has never restricted the number of teams from the same institution.

High quality mathematical modeling problems are critical for the continued success of the CUMCM. Every year, the CUMCM Committee calls for problems from people in different fields, including professors, engineers, and managers, etc. Those problems often stem from their real research and work projects. Approximately 40 problems can be collected per year. The CUMCM Committee then holds a conference gathering all of the experts in order to choose the most suitable candidates as competition problems for that year. Problem proposers are invited to the conference and give talks about their problems. The remaining problems become recycled into the problem pool for potential future use. Oftentimes, in order to be deemed competition worthy, problems must be modified (Zhijie Cai, personal communication, August 2013). There exist two standards that the CUMCM Committee refers to when choosing contest problems: (1) the problems should be challenging and attractive to the students, while having no solution available anywhere that can be found; (2) the problems should not require overly complicated knowledge and skills in mathematics, considering that the majority of the participants are not mathematics majors (Xie, 2013). The CUMCM Committee also awards outstanding problem proposers every year in the CUMCM awarding ceremony for their contributions (CUMCM Committee, 2011, p. 31).

Compared with problems in MCM/ICM, many Chinese students who had experience in both the CUMCM and the MCM/ICM think problems in the CUMCM were not as open as those in the MCM/ICM. Often times, two research papers with completely opposite conclusions can both obtain outstanding awards in the MCM/ICM if both of the papers showed an outstanding reasoning and modeling process. However, a similar phenomenon is relatively rare in the CUMCM. Many Chinese experts who were involved in the contest problem proposing process

agreed with the difference. However, it is also a trend for the CUMCM to achieve the similar flexibility and openness as in the MCM/ICM (Jinxing Xie, Zhijie Cai, August 2013).

In order to make sure that the CUMCM is held successfully every year, the CUMCM Committee also holds news conferences to publicize the contest to the general public before the CUMCM, and holds a conference for managers for local CUMCM committees, informing them about the contest plan for the next year. Furthermore, to strengthen the communication with the local CUMCM committees, participating schools, students and teachers, the CUMCM Committee published the CUMCM Newsletter since January 2000, which serves as a platform for people who are interested in mathematical modeling and its activities to communicate with each other (CUMCM Committee, 2011). Most importantly, the official website of the CUMCM <http://en.mcm.edu.cn> (English version) provides all the information on CUMCM, Summer Camp of Mathematical Modeling, and relevant mathematical modeling activities.

In recent years, the CUMCM has attracted students outside of Mainland China as well. For example, Hong Kong students first participated in the CUMCM in 2000; Macau first participated in 2009; Singapore and Australia first participated in 2010.

Summer Camp of Mathematical Modeling. The Summer Camp of Mathematical Modeling is a recently created mathematical modeling activity. It was initiated and organized by the CUMCM Committee, aiming to provide students with an in-depth exposure to mathematical modeling in addition to the CUMCM. The Summer Camp of Mathematical Modeling can be seen as a further practice of mathematical modeling for the mathematical modeling enthusiasts after the CUMCM took place.

The Summer Camp of Mathematical Modeling is a week-long (five-day) mathematical modeling activity that is held in late August, providing students with an opportunity to present

their research results to posed problems, communicate with other mathematical modeling enthusiasts, and exchange ideas from experts and mathematical modeling practitioners in different fields. In order to participate in the Summer Camp, students must go through the following process.

In around mid-April of each year, the CUMCM Committee posts four real-world problems that are generally regarded as “mathematical modeling tasks” on the CUMCM’s official website. Each year, the problems presented in the Summer Camp reflect the hot issues at regional and national levels. For example, “Garbage Classification and Disposal” was the 2011 topic, the “Prediction of the Relationship on Population and Medical Demand” in Shenzhen in 2012, and “Investigation of Natural Disaster Insurances” in 2013. A full list of problems from the Summer Camp of Mathematical Modeling may be found in the Appendix III. Interested students may partner with at most two other students from the same school and attempt to come up with solutions to one of the four tasks designated for that year. There is no restriction in terms of the student body to which the team members belong. Undergraduate students, graduate students, or a mix of both may form a team together, as long as they are from the same school. Teams have two months, until late June, to provide solutions for the chosen problems. During the two months, students may consult any sources, including teachers in schools, and experts in relevant fields, etc. This consulting and collaboration process is strongly encouraged by the CUMCM Committee, because the goal of the Summer Camp is to have students experience the process of using mathematical modeling to solve manageable real-world problems, rather than to be a formal competition. Therefore, the process of applying mathematical modeling to solve problems is set up in order to simulate as much of a real-world problem-solving scenario as possible. At the end of the research period, teams must submit research papers to the Camp’s

provincial organizers, presenting their submissions of solving the chosen problems through mathematical modeling.

The Camp's provincial organizers perform the preliminary selection of the papers in order to decide on one outstanding paper for each problem. Then, each provincial organizer submits four outstanding papers to the CUMCM Committee for the final assessment.

Approximately 20 of all the papers that enter the final judging stage are selected for the Summer Camp of Mathematical Modeling. Teams that are authors of the selected papers are invited to the Summer Camp to present and defend their problem-solving approaches. Experts and mathematical modeling practitioners are invited to the Summer Camp to communicate ideas with teams as well.

On the first day of the Summer Camp, experts usually give talks on their views or experience in mathematical modeling to all participating Summer Camp teams. During the following three days, teams that choose the same problems are placed into academic exchange sessions. A chair, usually one of the experts in mathematical modeling, moderates each session. During the academic exchange sessions, each team has 30 minutes to present their mathematical modeling solution to the chosen problem, and 30 minutes for a discussion with the audience. Interested audience members raise challenging questions to the presenting teams, and teams defend their approaches and methods. The discussion is then concluded by the chair with a summarization of the strengths and weaknesses of the presenting team's mathematical modeling approach. Both presenters and audience significantly benefit from the process. The last day of the Summer Camp is usually assigned for industry field trips. Students in the Summer Camp are guided to technology-intensive companies or research organizations and observe how mathematical modeling is used outside of academia (Tian & Xie, 2013)..

The necessity of the Summer Camp of Mathematical Modeling derived from the constraints shown by the CUMCM. The benefits that the CUMCM has brought to students are undeniable. However, CUMCM rules do not necessarily apply to real-world mathematical modeling processes. Due to the format of a contest, the CUMCM does reveal its limits in providing students with the mathematical modeling experience in a contest form. For example, the time constraint in the CUMCM limits the complexity and the authenticity of the contest problems. The CUMCM only lasts for three days. Therefore, problems in the contest are usually modified versions of original research questions, so that it is possible for students to achieve satisfying results within the given time frame. As a result, problem proposers have to take the complexity of the problems into consideration, which, to some extent, lose the authenticity of the original problems. Secondly, the CUMCM's rules stipulate that students may only obtain information from inanimate sources, such as books, the Internet, and libraries. Discussions are restricted to be within the team. In contrast, in the real world, the problem solving process with mathematical modeling requires experts from cross-disciplinary fields to work together (Tian & Xie, 2013). Despite all the constraints, the CUMCM has done an outstanding job enhancing students' awareness, appreciation, and competency in mathematical modeling.

The initiation of the Summer Camp of Mathematical Modeling dates back to 2001. As the CUMCM welcomed its 10-year anniversary in 2011, education officials and experts were brainstorming activities that enable students to be exposed to a more thorough real-world problem solving process, deepening students' mathematical modeling experience. The Director of Higher Education in the Department of Education of Hubei Province, Haiying Du, along with the experts on the CUMCM committee, brought up an idea of holding a summer camp of mathematical modeling in the awarding conference of the 2000 CUMCM. This suggestion

received unanimous approval from experts and representatives in the conference. As a result, the first Summer Camp of Mathematical Modeling was held in 2001 as part of a series of events celebrating the CUMCM's 10-year anniversary. Similarly, the second Summer Camp of Mathematical Modeling was held in 2006 as a part of the celebration events for the CUMCM's 15-year anniversary. Beginning in 2011, the Summer Camp of Mathematical Modeling is held as an annual event (Tian & Xie, 2013).

Conferences and Teacher Training. The CUMCM Committee and the mathematical modeling committee of the CSIAM have always understood the criticalness of teacher preparation for mathematical modeling education. In addition, the two organizations have been dedicated in order to provide opportunities for teachers and experts to exchange ideas on teaching and research of mathematical modeling. In this section, conferences and teacher training sessions held by the CUMCM Committee and the CSIAM will be introduced.

The China Conference on the Teaching of Mathematical Modeling and Application (CCTMMA) has served as a major communication platform for teachers and researchers interested in mathematical modeling in China. The first two conferences were held in 1985 and 1988, respectively, long before the CSIAM and the CUMCM Committee were established. Therefore, the CSIAM and the CUMCM Committee have also been the organizers for later conferences.

Teachers, researchers, and industry practitioners of mathematical modeling gather in the CCTMMA to share their work in teaching and applying mathematical modeling. The conferences mainly focus on two aspects: (1) sharing the experience in mathematical modeling teaching and applications; (2) sharing the experience in organizing and advising students on the mathematical modeling contests. The CCTMMA is usually held in August, when teachers and

experts are on their summer vacation. Prior to 2000, the conference was held irregularly on every two or three years. Since 2000, the conference has been held every two years. The most recent one was held in 2013, which was the 12th conference of the CCTMMA. The CCTMMA has seen its growing influence as a major stage for mathematical modeling communication. The number of participants grew from 20 representatives from 10 schools in the first CCTMMA in 1985 to over 600 participants in the 12th CCTMMA in 2013.

The author of this work participated in the 12th CCTMMA in the summer of 2013. In the following discourse, the introduction of this CCTMMA will be based on the experience the author had while participating in the conference and the documented previous conference history.

The 12th CCTMMA was held in Xi'An from August 12th to 15th 2013. Xi'An Jiaotong University, a key university in China, and the local CUMCM Committee in Shaanxi province were the two partners of the CUMCM Committee and the mathematical modeling committee of the CSIAM in holding this conference.

The topics of the 12th conference were as follows: (1) incorporating the idea of mathematical modeling into mathematics teaching and reform; (2) developing courses of mathematical modeling, mathematical experiments, and building mathematical experiment labs so that the CUMCM and related mathematical modeling contests may enjoy further development; (3) applied mathematics research on mathematical modeling and problem-driven research; (4) practice in mathematical modeling and cultivating undergraduate students' competency in research (CUMCM Committee, 2013b). Over 600 teachers across the country participated in the conference.

The conference started with two plenary one-hour lectures. One lecture was given by Dr. Zongben Xu, an academican of the Chinese Academy of Sciences, professor of mathematics and

computer science, and vice president of Xi'An Jiaotong University. He described his work regarding the theory and methodology of sparse modeling. The other lecture was given by Dr. Solomon Garfunkel, executive director of the COMAP, on developing materials that present mathematics through applications and modeling. Since the number of Chinese participants has been drastically increasing in the COMAP sponsored MCM/ICM, the collaboration between the COMAP and the CUMCM Committee in mathematical modeling activities has become more frequent and closer in occurrence. As a result, Dr. Garfunkel was invited to give a talk about COMAP's history and work to the Chinese educators and researchers in mathematical modeling. Participants of the conference thus had opportunities to ask Dr. Garfunkel questions directly.

Following the two lectures, there were six panel presentation and discussion sessions. Five of the panel presentation and discussion sessions were dedicated to the four topics of this conference. Each session had four to five presenters to share their work on the selected topic. Participants were able to join any session they were interested in and communicate with presenters. The other panel session was "A Talk with Dr. Solomon A. Garfunkel". Members of the CUMCM Committee, along with interested educator and researchers, gathered in the session and raised questions to Dr. Garfunkel. It was an opportunity for both parties, Dr. Garfunkel and the participants, to communicate with each other, both on mathematical modeling itself and on matters relevant to the MCM/ICM.

It is worth noting that Math Works and IBM, two of the sponsors for the CUMCM, also hosted their own presentation and discussion panels. During the two panel discussions, many examples of industrial mathematical modeling applications were provided, with illustrations of solving the problems with mathematical and statistical software of the two companies, such as MATLAB and SPSS.

Six plenary lectures were scheduled on the next day. Presenters of the plenary lectures were experts of the mathematical modeling education in China. Different topics were covered, including mathematical teaching and research methodologies, international mathematical modeling dynamics, as well as suggestions and advice to Chinese students in the participation of the MCM/ICM.

The description of the 12th CCTMMA is merely an example of a scenario of the effort made by the CUMCM Committee and the mathematical modeling committee of the CSIAM in promoting communication and exchanging ideas of mathematical modeling among educators, researchers and people in industry.

Previous CCTMMAs were devoted to exchanging ideas in mathematical modeling teaching and research. In addition, the conference publishes selected papers submitted by the participants to the *Engineering Mathematics*, one of the official journals of the CSIAM.

Some of the decisions made in the conferences have propelled the development of the CUMCM and other modeling activities. For example, in August 1991, CSIAM entrusted two schools in Hunan province to hold a National Mathematical Models Conference, which was later named The Third China Conference on Mathematical Modeling Teaching and Application. Forty-five representatives from 30 higher education institutions joined the conference. People at the conference fully discussed the possibility of organizing mathematical modeling contests in 1992 and 1993. Taking into account the experience gained from Shanghai's regional mathematical modeling contests in 1990 and 1991, the representatives at the conference all agreed that it was time to expand the mathematical modeling contests to the national level. It was also suggested at the conference that a national mathematical modeling contest only including major cities first be held in 1992. The discussion that ensued at the conference laid the

foundation for the successful organization of later national mathematical modeling contests (CUMCM Committee, 2011, p. 15). Upon the formation of the mathematical modeling committee by the CSIAM on November 23-24, 1991, the general council of the CSIAM asked Professor Wenci Yu, the director of the mathematical modeling committee of CSIAM, to organize the mathematical contest in modeling that involved major cities across China in 1992 (Ye, 2011).

In addition to the CCTMMA, there has been a recently created mathematical modeling conference that is specifically dedicated to the mathematical modeling contest training methodology and research, which is called the National Conference on Mathematical Modeling Training and Application (NCMMTA). The NCMMTA operates every two years. The past two conferences were held in 2010 and 2012 respectively. The NCMMTA focuses on the training and advising methodology for teachers to use when preparing students for mathematical modeling contests. This includes both the CUMCM and MCM/ICM.

Taking the 2012 NCMMTA as an example, the outline of the conference topics was as follows: (1) seminar on the content, methodologies and skills used in mathematical modeling contest training; (2) analysis of the classical problems in mathematical modeling contests; (3) examples of mathematical modeling research and analysis; (4) the trends of current mathematical modeling contests and the ways to prepare for them; (5) academic exchange on mathematical modeling teaching and contests preparation; (6) introduction to commonly used mathematical software in mathematical modeling.

As indicated in the outline of the conference, the NCMMTA specifically focuses on the research and preparation of the mathematical modeling contests, whereas, the CCTMMA places greater emphasizes on teaching mathematical modeling. In the NCMMTA, people who have

previously served as problem proposers, mathematical modeling contest judges, or researchers in mathematical modeling education are invited to the conference to give talks about their understanding of the mathematical modeling contests.

In December every year since 2010, after the judging and awarding of CUMCM is completed, the CUMCM Committee and the mathematical modeling committee of the CSIAM will organize an annual seminar about the CUMCM. The seminar will announce the CUMCM's participation and awarding information of that year. Most importantly, problem proposers of the year, as well as mathematical modeling education experts will be invited to the seminar to give talks about their analysis on the CUMCM problems.

The above three national conferences and seminars provide educators and researchers of mathematical modeling with plenty of opportunities to communicate with each other and stay abreast of the current mathematical modeling teaching and research. In addition, the mathematical modeling committee of the CSIAM and the CUMCM Committee have been creating additional opportunities for teachers to keep updated about the mathematical modeling teaching, curriculum and research.

For example, the mathematical modeling committee of the CSIAM hosted two national teacher-training seminars in 1992 and 1993, in which they collaborated with the Beijing Mathematics Society, Beijing Mathematics Society College Board, Beijing Higher Education Mathematics Research Committee, China Mathematics Education Committee, and Department of Applied Mathematics of Beijing Institute of Technology (Ye, 2011, p. 6). In May 2002, the CUMCM, entrusted by the Department of Higher Education of Ministry of Education, hosted a national mathematical modeling training for key teachers. In July 2003, a teacher training conference was held to train key teachers for the two major mathematical modeling courses:

Mathematical Modeling and Mathematical Experiments. In May 2008, the CUMCM Committee and the mathematical modeling committee of the CSIAM collaboratively held a seminar on the reform of mathematical modeling teaching and mathematical experiments in Shanghai. More than 30 teachers participated in the seminar. In July 2008, a teacher-training seminar that is specifically for teachers working in two-or-three year colleges was held. More than 130 teachers participated in the seminar. In June 2010, the China Seminar on Mathematical Modeling Contest Training and Application was held in Shanghai. More than 600 teachers participated in the seminar (CUMCM Committee, 2011).

Other Resources

Initiators' Effort in Popularizing Mathematical Modeling

The current recognition and popularization of mathematical modeling in China cannot be achieved without scholars' years of effort in promoting mathematical modeling education. In this section, the efforts made by initiators and pioneers of mathematical modeling education in China will be provided through the information obtained from their interviews and the written materials. The detail of the interviews can be found in the Appendix VI. It is worth noting that all of the scholars have dedicated themselves to mathematical modeling research and education, and were extremely well trained mathematicians prior to devoting themselves to mathematical modeling education.

Pioneers of mathematical modeling education in China began introducing mathematical modeling to undergraduate education in the early 1980s. Professor Wenci Yu of Fudan University and Professor Shutie Xiao of Tsinghua University were pioneers of China's mathematical modeling education. In the 1982 meeting of 12 engineering schools that were directly directed by the Ministry of Education, Professor Shutie Xiao advocated that engineering

schools should offer mathematical modeling courses, and that cultivating mathematical modeling teachers was a must (Bian, 2011). In 1982, Professor Wenci Yu offered a mathematical modeling course to the mathematics majors at Fudan University. The topics given in the course were presented with real-world examples illustrated with their applied mathematical significance (Shutie Xiao, personal communication, September, 2013). In the same year, Zhejiang University also offered undergraduate mathematical modeling courses (Q. Yang, 2011). In 1983, professor Shutie Xiao offered a mathematical modeling course to students majoring in applied mathematics at Tsinghua University. In the course, mathematical modeling was not only presented with topics' individual real-world mathematical applicability, but also in a more concrete and systematic manner (Shutie Xiao, personal communication, September 1, 2013). Those were the earliest mathematical modeling courses offered in China. In addition, Professor Shutie Xiao also started to train teachers in mathematical modeling in around the early 1980s. Initially, he invited mathematics instructors interested in the mathematical modeling at other top universities to join his mathematical modeling class at Tsinghua University. Many of these instructors first learned mathematical modeling in professor Xiao's class and became mathematical modeling educators and researchers from then on. Subsequently, they went back to their own schools and began offering mathematical modeling courses (Bian, 2011). These instructors comprised the first generation of China's mathematical modeling educators. Many of them have also been instrumental in the development of the national mathematical modeling activities, such as the mathematical modeling contest and teacher training. Professors Qixiao Ye, Qiyuan Jiang, Fuping Bian, etc, were all the students of Professor Shutie Xiao.

When asked for his initial thoughts and reasons for introducing mathematical modeling to undergraduate education, professor Xiao mentioned two points: (1) Many students obtaining

doctoral degrees in mathematics abroad only focused on problems and areas that they studied with their doctoral advisor. When they came back to China, they continued to do the research solely on these problems and areas. In this case, mathematical research cannot be fully developed.

(2) In early 1980s, China was in the midst of mass construction and development in order to rebuild itself from the damage caused by the Cultural Revolution. Therefore, applications of all subjects, including mathematics, were badly needed. At that time, it was a necessity to popularize mathematics that had the practical ability of solving real-world problems. Since engineers played a key role in building the country, enhancing engineers' mathematical ability was critical. Reciprocally, the enhancement of engineers' mathematical competency provided problems for mathematicians in research (Shutie Xiao, personal communication, September 2013).

In addition to popularizing mathematical modeling in schools, professor Xiao, along with other researchers, also produced the Report on the Reform of Mathematics Curriculum for Non-Mathematics Majors in 1996. The report is also regarded as the "white book", in which he mentioned the significance of including mathematical modeling in undergraduate education.

Professor Qixiao Ye of Beijing Institute of Technology was one of the initiators of the mathematical modeling education in China. He was the first person that introduced the MCM to China. When he learned about the MCM in 1986, he contacted Dr. Benard Fusaro, initiator of the MCM, for more information. Professor Ye and Dr. Fusaro maintained correspondence through mail dating from December 1986 to April 1993. In one of the letters from professor Ye, he stated the two problems he most faced as a mathematics professor at the university, which were the fact that (1) not every student enjoys pure mathematics; (2) most students do not understand the importance of mathematics (Qixiao Ye, personal communication, August 2013). Those problems

echoed the ones Dr. Fusaro initiated when he conceived the idea of creating the MCM. After professor Ye read the MCM materials from Dr. Fusaro, he realized that the activity would be a good way to attract additional students to study mathematics, and eventually came to the understanding that it was a positive step in the development of mathematics (Qixiao Ye, personal communication, August 2013). In January to May 1988, professor Ye was a visiting professor at Brown University, during which he visited the university that Dr. Fusaro worked at in order to observe how teacher training was conducted for the mathematical modeling contests. Once he returned to China from the U.S. at the end of his visiting period, he introduced the MCM to professor Longan Ying at Beijing University and professor Qiyuan Jiang at Tsinghua University. The three professors decided to form teams from their own schools and participate in the MCM in 1989. As a result, four teams from China participated in the MCM for the first time in 1989.

Professor Qixiao Ye recalled his experience in preparing the 1989 MCM. He asked four teachers from the mathematics department and three students to form a mathematical modeling seminar. Students in the seminar were to study outstanding papers from the previous MCM, and to report their understandings to the rest of the members in the seminar. Teachers in the seminar challenged students with questions on these papers, and answered questions from students. As the result of it being the very first time that Chinese teams participated in the contest, the preparation was very serious. Professor Ye also asked officials in the university to grant permission to students' access to the computer lab, library and dorm outside of normal operation hours. The other two schools also provided students participating in the competition with similar support.

After the 1989 MCM, he wrote an article introducing the MCM to the general public, which is titled "Some Thoughts about the MCM in the U.S." in the journal, *Applied Mathematics*:

A Journal of Chinese Universities. He mentioned the benefits of the MCM and the possibilities of holding a similar mathematical modeling contest in China. What exceeded his expectation was that a national mathematical modeling contest was held as soon as in 1992, only three years after the Chinese teams' initial MCM participation (Ye, 2011).

Over the years, mathematical modeling initiators, such as Professors Qixiao Ye, Qiyuan Jiang, Yongji Tan, Laifu Liu, Fuping Bian, and Daqian Li have dedicated themselves to the development of mathematical modeling education and its related activities. They are the founding members of the mathematical modeling committee of the CSIAM as well as the CUMCM Committee. They began organizing mathematical modeling activities at an early stage. For example, professor Wenci Yu, Yongji Tan of Fudan University along with renowned mathematician Su Buqing and CAS academician Li Daqian organized “Shanghai Undergraduate (Mathematics Major) Mathematical Contest in Modeling on December 7-9, 1990, and “Shanghai Undergraduate (Non-Mathematics Major) Mathematical Contest in Modeling on June 7-9 1991”. Those were the very first modeling contests held in China. In addition, they organized and participated in numerous teacher-training sessions and mathematical modeling conferences in order to train teachers in the early stage of the development of mathematical modeling activities in China. For example, professor Qixiao Ye initiated and organized the Beijing mathematical modeling teaching and learning seminar from 1992 to 1997, with the support from many organizations and associations of mathematics. Experts in mathematical software and mathematical modeling were invited to the seminar to share their knowledge to the participants. They wrote mathematical modeling books for teachers and students to consult and study (Qixiao Ye, personal communication, August 2013). The book *Mathematical Modeling* authored by professor Qiyuan Jiang is the most widely used mathematical modeling book in China. The

professors also offered mathematical modeling courses in their schools, cultivated students and advised new instructors. They obtained very little or no compensation for the additional work of mathematical modeling they dedicated themselves to, especially in the beginning of the development of mathematical modeling education. However, they have been persistently contributed to the mathematical modeling education and its activities at college level for more than 30 years. Even today, they continue contributing to the field.

The persistence and enthusiasm for mathematical modeling exhibited by the initiators of the Chinese mathematical modeling education may trace their roots to their experiences:

(1) Education experiences. The social and political transformations and turbulence had posed heavy influences on education since the foundation of China in 1949. During the early stage of the modern foundation of China, the country fully adopted Russian's mathematics education pedagogy, which placed heavy emphasis on pure mathematics and little on applications. However, the Great Leap Forward from 1957 to 1959 transformed China's education concept to the opposite direction, placing focus on applications. As with other academic subjects at the time, there was much ongoing debate on the mathematics curriculum and its applications as well. The questions, such as should certain portions of mathematical content be omitted or retained, or should mathematics and non-mathematics majors use the same curriculum, were heatedly discussed and debated. Many initiators of the mathematical modeling education in China were mathematics majors in college in the late 1950s and early 1960s, when the then-ongoing discussions also provoked their thoughts on the issue. The advent of the MCM made professor Ye and other scholars realize that it was a good activity for people weighing in on both sides of the debate to see that the system of mathematical knowledge formed as a whole,

that no portions should be omitted because when used or applied to the real-world problems, they are all useful (Qixiao Ye, personal communication, August 2013).

(2) Work experiences. In the interview, Professor Qixiao Ye shared his experience in applying mathematics knowledge to solve real-world problems. Having had done three national projects using mathematical modeling during the Cultural Revolution, he realized that mathematics is quite useful and can make tangible contributions to the real world. At the same time, he gained a mastery of the entire process of mathematical modeling through participating in the projects. In addition, the solutions to the projects he presented from mathematics perspectives also surprised engineers working on the same subject matter. The engineers did not expect a pure mathematician to be able to solve problems in engineering. More importantly, he realized that the competency of mathematical modeling could not be achieved without people actually practicing modeling. He also discovered that a certain amount of project-based training and practice was necessary. Therefore, the MCM caught professor Ye's attention soon after its advent, as it was a good way for students to experience the entire process of mathematical modeling. At the same time, he also further realized the importance of pure mathematics. Therefore, in addition to promoting mathematical modeling activities, he has been enormously dedicated in carrying out research and projects such as teaching college foundation mathematics courses, such as calculus. The project "Incorporating the idea of mathematical modeling into college calculus teaching and learning" is a good example (Qixiao Ye, personal communication, August 2013).

Professor Yongji Tan also mentioned his experience in using mathematics to solve real world problems before, during and after the Cultural Revolution. He recalled that he had been using mathematics to solve real-world problems when he was a college student in 1960s. During

the Cultural Revolution, he worked with Hwa Lo-Keng on several application problems along with other scholars (Tan, 2010b). Professor Daqian Li was one. In addition, right after he and other professors learned that mathematical modeling courses were offered in other countries, they designed and offered their own course in 1982 (Yongji Tan, personal communication, August 2013).

(3) The responsibility of cultivating talents for the country. With the experience they obtained through political movements and from studying abroad, scholars of that generation knew the difference of China and countries with advanced development. They also realize that people with strong mathematics background can succeed in many scientific fields. Therefore, they want to cultivate talents who are competent in mathematics for China. Considering their expertise in mathematics, when good activities, such as MCM, were available, they were soon dedicated to developing versions of their own and benefiting students from them (Qixiao Ye, personal communication, August 2013).

Local Efforts

Local CSIAM. Before mathematical modeling activities were recognized by the central government and national organizations, such as the CSIAM, local SIAMs that were established prior to the CSIAM had already begun to sponsor and organize mathematical modeling contests. Shanghai SIAM, for example, supported the Shanghai Undergraduate (Mathematics Major) Mathematical Contest in Modeling on December 7-9, 1990. This was the first mathematical modeling contest held in China (CUMCM Committee, 2011, p. 14). In the following year, on June 7-9, the Shanghai SIAM organized a similar undergraduate mathematical modeling contest for non-mathematics majors called the Shanghai Undergraduate (Non-Mathematics Major) Mathematical Contest in Modeling. Then, Shaanxi SIAM organized its Xi'An Undergraduate

(Mathematics Major) Mathematical Contest in Modeling on April 3-6, 1992. The experience from hosting the local mathematical contests in modeling laid the foundation for holding the CUMCM and other later national level mathematical modeling activities later on (Ye, 2011).

Teacher Training. In addition to the teacher training seminars and conferences held by the CSIAM and the CUMCM, local government, schools and organizations also organize their own training seminars. For example, locally initiated training sessions were held as early as before the First National Undergraduate Mathematical Contest in Modeling in 1992 (Ye, 2011, p. 6).

Recently, an increasing number of the CUMCM provincial organizers have been the hosts of national teacher training conferences and seminars, which, in the past, were held mainly by the CSIAM and the CUMCM Committee. For example, Sichuan and Shandong provinces held two national teacher-training seminars in April and July 2011 respectively. Henan and Guangxi provinces held their own mathematical modeling teaching and research conferences in 2012, which both targeted teachers of their own provinces. Although the targeting audience was mainly within their own provinces, teachers from outside of their regions were also welcomed to the conferences. Similarly, in May 17-19 2013, five provinces held a collaborative research and teaching conference in mathematical modeling (CUMCM Committee, 2013a).

In addition to the traditional content existed in the mathematical modeling teacher-training seminars, such as methods and skills for constructing mathematical models, the mathematical modeling training seminars began to emphasize on the training of using mathematical software, which becomes a necessity in building, testing and solving mathematical models nowadays.

Other Mathematical Modeling Contests. In addition to the CUMCM being the largest undergraduate mathematical contest in modeling in China, other regional mathematical modeling contests of relatively smaller scales compared to the CUMCM are currently popular among students as well. For example, East China Mathematical Modeling Competition, Subei Mathematical Contest in Modeling, Mathematical Contest in Modeling for the Three Provinces in Northeast China, and Central China Mathematical Contest in Modeling, etc.

Communication Platforms. Currently, about 20 websites featuring mathematical modeling serve as platforms for people to share ideas about mathematical modeling. Most of these websites were founded by universities and colleges, which were intended to set up online platforms for students to share ideas in mathematical modeling. After years of development, many of these websites have accrued numerous resources for students to learn mathematical modeling independently, and many precious experiences from students who have participated in mathematical modeling contests. Lists of resources can be found from the CUMCM's official website.

News Media

The Chinese news media recognized the significance of mathematical contest in modeling immediately after the first national contest was held. On November 28, 1992, the second day of the contest, the China National Radio (CNR), one of the most important and influential media channels in China with a domestic listenership exceeding 700 million, broadcasted "Briefing on Undergraduate Mathematical Contest in Modeling" authored by Professor Qixiao Ye during a half hour programme at noon (CNR, 2014; Ye, 2011).

China Central Television (CCTV) broadcasted the news of 1993 CUMCM awarding ceremony in the most widely watched evening news program on December 4th 1993.

As the development of new media and the mathematical modeling activities, the news of mathematical modeling can be found everywhere in newspapers and on websites.

Sponsorship

Companies began to sponsor CUMCM since 1999. The Skyworth (full name Hong Kong Skyworth Digital Holdings Co. Ltd.), a Chinese company that mainly designs, manufactures, and sells televisions and audio-visual products, was the first company that sponsored CUMCM in 1999. NetEase, a well-known Chinese Internet company, sponsored the CUMCM in 2000. Higher Education Press obtained the sole sponsorship since 2002, and the name of the CUMCM was modified into “Higher Education Press Cup” CUMCM (Liu & Li, 2011).

In addition, software companies have been sponsors to the CUMCM in recent years. For example, the MathWorks began to sponsor the CUMCM since 2009. The CUCMC Committee set up a Matlab innovation award to teams showing outstanding performances. Similarly, the IBM (China) began to sponsor the CUMCM since 2013. The CUMCM Committee set up an IBM SPSS innovation award to teams that perform outstandingly in the CUMCM.

The Department of Education in Hubei Province and China Three Gorges Dam Engineering Company partnered with the CUMCM Committee in hosting the first Summer Camp in 2001 (Tian & Xie, 2013). The Higher Education Press also partnered with the CUMCM Committee in holding the Summer Camp of Mathematical Modeling in 2006. Since 2011, the Science and Technology Association of Shenzhen began to sponsor the Summer Camp of Mathematical Modeling. The Association provides full financial support for participants in the Summer Camp, including the cost of room and board and other activities costs from the Summer Camp.

Chinese students' preference in choosing problems in the MCM and the winning results

There are two problems in MCM each year. Problem A is a continuous mathematics problem; problem B is a discrete mathematics problem. The data of Chinese teams' preference in choosing problems have been analyzed from 1990 to 2013.

- (1) Chinese teams' preference in discrete problem (problem B) is stronger than in continuous problem (problem A). Only in three years, which are 1997, 2006 and 2009, that the number of Chinese teams that chose problem A is higher than teams that chose problem B.

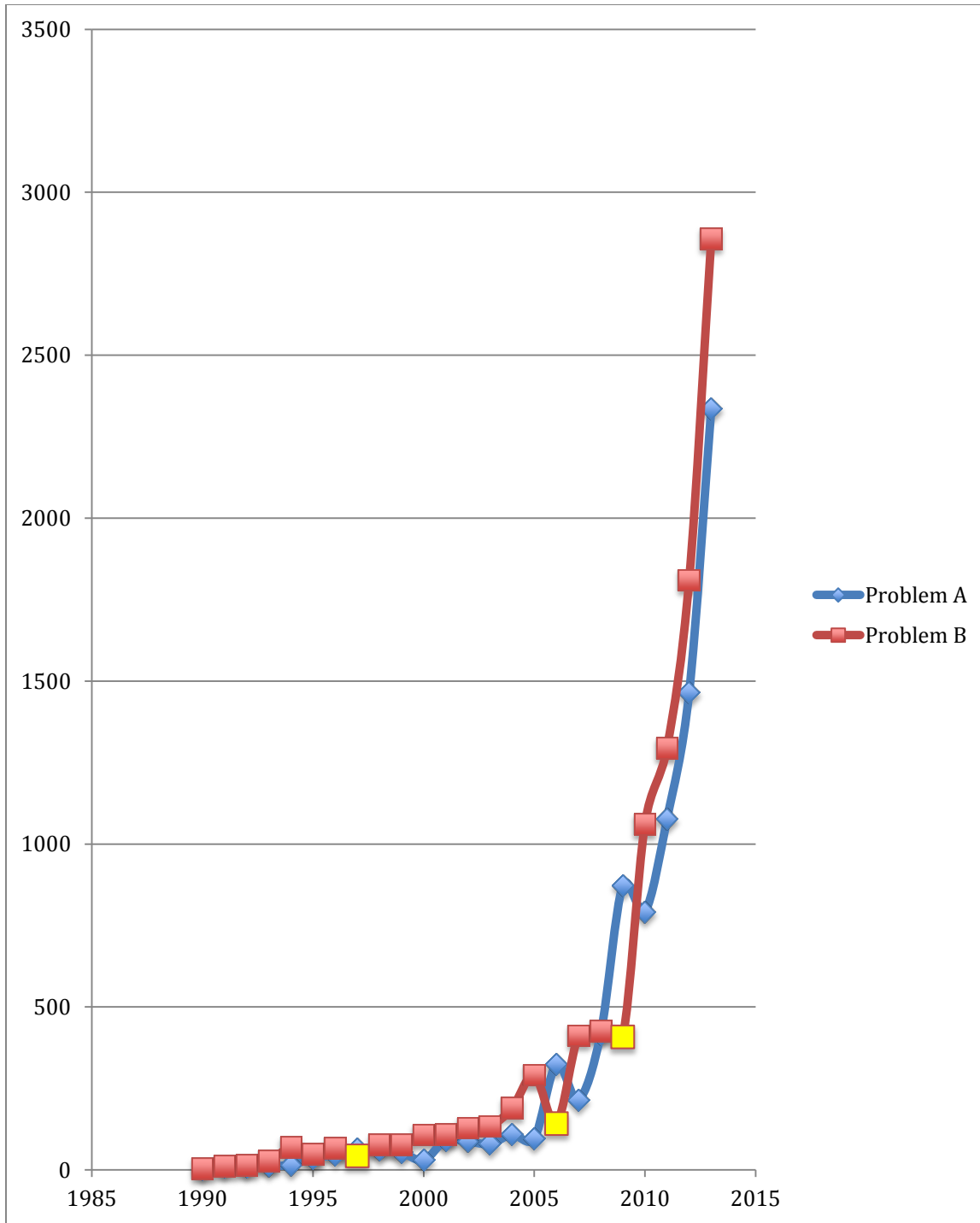


Figure 6. The number of Chinese teams that chose problem A and problem B from 1990 to 2013. Yellow dots are the years when the number of teams chose B is fewer than that choosing A.

- (2) The winning rate of Chinese team in problem A is higher than that in problem B in 15 out of the 24 years from 1990 to 2013.

Table 2. The winning rate of Chinese teams in problem A and B.

Chinese teams' winning rate in problem A	Chinese teams' winning rate in problem B	Comparison
3.23%	5.80%	A<B
9.62%	7.55%	A>B
13.64%	7.79%	A>B
19.05%	17.14%	A>B
28.57%	27.18%	A>B
25.00%	32.39%	A<B
49.12%	11.67%	A>B
41.00%	34.72%	A>B
39.76%	27.50%	A>B
37.00%	33.91%	A>B
30.56%	48.33%	A<B
43.82%	31.58%	A>B
39.82%	46.67%	A<B
16.55%	51.58%	A<B
46.75%	43.71%	A>B
51.28%	54.25%	A<B
39.91%	59.18%	A<B
62.42%	61.16%	A>B
59.76%	66.25%	A<B
73.41%	71.67%	A>B
82.84%	81.26%	A>B
89.57%	80.45%	A>B
95.14%	82.50%	A>B
93.51%	96.23%	A<B

- (3) For problem A, the participation rate of the Chinese teams is lower than the winning rate of the Chinese teams in 17 out of the 24 years. For problem B, the participation rate of the Chinese teams is higher than the winning rate of the Chinese teams in 16 out of 24 years.

Table 3. The comparison of participation rate and winning rate of Chinese teams from 1990 to 2013.

Year	Participation rate of Chinese teams in problem A	Winning rate of Chinese teams in problem A	Participation rate of Chinese teams in problem B	Winning rate of Chinese teams in problem B
1990	1%	3.23%	3%	5.80%
1991	7%	9.62%	9%	7.55%
1992	8%	13.64%	8%	7.79%
1993	15%	19.05%	16%	17.14%
1994	21%	28.57%	28%	27.18%
1995	25%	25.00%	28%	32.39%
1996	37%	49.12%	25%	11.67%
1997	27%	41.00%	24%	34.72%
1998	32%	39.76%	27%	27.50%
1999	25%	37.00%	37%	33.91%
2000	19%	30.56%	40%	48.33%
2001	42%	43.82%	39%	31.58%
2002	31%	39.82%	53%	46.67%
2003	30%	16.55%	59%	51.58%
2004	54%	46.75%	48%	43.71%
2005	56%	51.28%	59%	54.25%
2006	63%	39.91%	61%	59.18%
2007	61%	62.42%	69%	61.16%
2008	73%	59.76%	72%	66.25%
2009	78%	73.41%	74%	71.67%
2010	83%	82.84%	81%	81.26%
2011	83%	89.57%	87%	80.45%
2012	92%	95.14%	86%	82.50%
2013	90%	93.51%	94%	96.23%

Information obtained from interviews with teachers and students did not show any trend or preference in either continuous or discrete mathematical modeling problem teaching and learning. Teachers that author of this study interviewed were all trying their best to introduce and cover as many classical models and methods used in mathematical modeling to students.

Students learn mathematical modeling both in class and from other resources by themselves. The choice of mathematical modeling contest problems, continuous or discrete mathematics, were mainly determined by their preference in mathematical knowledge and their understanding on the context of contest problems (personal communication, August 2013).

Mathematics Modeling Questions on NCEE Mathematics Tests

Author of this study surveyed the NCEE mathematics examinations from 1951 to 2013, in search for mathematical modeling problems on the NCEE. As it was defined in the literature review of this study, mathematical modeling problem requires a full process of mathematical modeling, which includes “formulating situations mathematically”, “employing mathematical concepts, facts, procedures, and reasoning”, and “evaluating and improve the mathematical outcomes” in the context of the problem (OECD, 2003). According to the definition of mathematical modeling problem, none of the mathematical problems on the NCEE are mathematical modeling problems. However, there are mathematical application problems by the definition used in this study, which includes the first two steps of the full mathematical modeling process.

Based on the analysis, NCEE from 1951 to 1959 focused purely on mathematical concepts and computation skills. There were no mathematical application problems on the NCEE in this period. It is very understandable considering that China fully adopted and implemented Russian mathematics teaching and learning pedagogies since 1952, which put an emphasis on pure mathematics’ rigid proofs and computations.

The idea of the combination of study and production was emphasized after the Great Leap Forward ended in 1959. Application is emphasized in all areas, including education. During 1960 to 1965, mathematical application problems appeared on the NCEE mathematics tests. In

this period, the mathematical knowledge used in these application problems was often geometry and percentage, and the context used in these problems reflects the construction and development in China, such as building a factory, making estimation of production increase, and locating a ship in the sea, etc. However, the context used in the problems didn't pose any difficulties for students to "formulate the situations mathematically".

The NCEE was abolished during the Cultural Revolution from 1966-1976, and re-established in 1977. Since it was the first year that NCEE served as the national standard for students to be admitted to college after a 10-year abeyance, the 1977 NCEE was designed and administered by provinces and municipalities, respectively. The context of the mathematical application problems used on the NCEE was very similar to the ones before the Cultural Revolution. Most of the mathematical application problems employ knowledge in geometry and percentage to reflect the needs in construction and production.

The 1978 NCEE was the first national unified test since the Cultural Revolution. However, there was no mathematical application question of any kind on the test.

The mathematical application questions re-appeared on the NCEE from 1979 to 1986, with an exception in 1985. In addition to geometry and percentage, permutation and combination was added to test for application problems. In terms of the problem context, it reflected most of the hot issues during that time, for example, population growth, production growth, and different ways for company to obtain businesses, etc. Compared to the mathematical application problems in the 1960s, the context was closer to the real situation, even though it was still very simplified.

The trend of including mathematical application problems stopped from 1987 to 1994. During this period, no application was on the NCEE mathematical tests. Everything went back to pure calculation and understanding of concepts.

After eight years of no mathematical application problems on the NCEE, many scholars realized that students didn't pay attention to the practicality of mathematical knowledge, and that the inclusion of mathematical application problems in NCEE would pose a positive influence and good direction to secondary mathematics teaching and learning (The Beijing Discussion Group of "Application", 1994; Yan, 1994; Yan et al., 1993). The mathematical application questions re-appeared since 1995. There have been one or two mathematical application questions every year on the NCEE until now.

From 1995 to 2004, the mathematical application on the NCEE showed quite a variety. The mathematical knowledge tested through mathematical application problems was functions, optimizations, percentage, probability, and permutation and combination. The context used in the mathematical application problems was quite close to the real situations. In fact, many problems came from the simplified version of the real problems, for example, the weather forecast problem in 2003, the tunnel design problem in 2003, and the subway operation errors problem in 2004.

Since 2000, more provinces and municipalities obtained autonomy in designing and administering their customized versions of the NCEE. The mathematical application questions in this period reflected the context unique to their own regional situations, for instance, the subway operation errors in Beijing, and optimization of the resources in Liaoning and Jiangsu, etc. Since 2005, probability questions have dominated the mathematical application questions. Even though the context of the problem has shown varieties, they are essentially typical probability questions that don't require much effort to identify the mathematics used to formulate the situation. In addition to the dominance of the probability questions used in mathematical application problems, some provinces and municipalities, such as Shandong and Shanghai, also tested function optimizations in the mathematical applications. However, compare to the number of

mathematical application problems that tested probability, other mathematical knowledge used to formulate mathematical application problems is the minority.

Since the new High School Mathematics Curriculum Standards promulgated in 2003, the mathematical modeling was included as part of high school mathematics curriculum (WENR, 2012). Due to the criticality of the NCEE, the changes in NCEE often reflect the focus of the curriculum. Therefore, based on the mathematical application problems shown on NCEE in the past ten years, the mathematical modeling mentioned in the Chinese mathematics curriculum is not defined quite the same as the mathematical modeling used in this study. Instead, the mathematical modeling mentioned in the Chinese mathematics curriculum is more towards the mathematical application defined in this study. Since all of the mathematical application problems in the NCEE are closed-ended questions with definite and unique answers, nothing has been expected for students to re-evaluate and re-apply the mathematical models they use to solve the problems as it is usually required in the real mathematical modeling problems.

Although the NCEE doesn't pose a direct influence on students' ability in mathematical modeling, it does point to a direction that students who finish a high school mathematics curriculum should be able to apply what they learned to simplified real-world situations, and pose solutions to the simple models built in these situations, which are the first two steps of the mathematical modeling process. This focus laid a solid mathematics foundation for students' future study and application of mathematics.

CHAPTER VI

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The purpose of the study is to identify reasons for the Chinese teams' rapid ascent and extraordinary performance in the MCM and ICM. The answers to the following five research questions revealed the reasons.

1. To what extent has the Chinese government influenced the modeling success of the Chinese teams?
2. How do relevant Chinese organizations identify and implement government policy pertaining to mathematical modeling?
3. How have other resources and sponsored activities been assisted the modeling success of the Chinese teams?
4. What is the relationship between Chinese teams' choice of problems in the MCM and the winning results over the years?
5. To what extent has the Chinese National College Entrance Examination (NCEE) influenced the modeling success of the Chinese teams?

Conclusions

Research Question 1

The purpose of the Research Question 1 is to determine the extent of Chinese government influence on the modeling success of the Chinese teams. The Chinese government's support of mathematical modeling, especially in its initial stages, was indispensable to the success of the development of mathematical modeling in China.

The Department of Higher Education in the Ministry of Education showed great interest and granted immense policy support to the CUMCM in its initial stages. Having deemed that the mathematical modeling contest was a beneficial undergraduate level activity, the Department of Higher Education issued three notices in 1993, 1994 and 1995 respectively, advising that local governments and organizations should support the development of the CUMCM.

The Department of Higher Education was also very supportive in training teachers in mathematical modeling. The department has supported many schools and organizations to hold national teacher training workshops in mathematical modeling.

As the CUMCM prospered, the Department of Higher Education also supported other mathematical modeling related projects and activities, such as the project of “Incorporating the idea of mathematical modeling into the Main mathematical courses in universities and colleges.”

In addition, the Chinese government financially supported the development of mathematical modeling activities, such as the CUMCM.

Research Question 2

The purpose of Research Question 2 is to identify leading Chinese mathematical modeling organizations and determine relevant mathematical modeling activities that have been implemented and organized.

The CSIAM and CUMCM Committee are the two organizations that collaboratively lead national mathematical modeling activities in China. These two organizations have operated national mathematical modeling activities with passion and expertise, which has resulted in the popularity of mathematical modeling in China.

The major mathematical modeling activities led by the two organizations are the CUMCM and the Summer Camp of Mathematical Modeling. Of these, the CUMCM has grown

to become the largest undergraduate extracurricular activity in China. The Summer Camp of Mathematical Modeling provides an opportunity for mathematical modeling enthusiasts to practice mathematical modeling in real-world research projects. In 2013, there were 23,339 teams from 1,326 Chinese higher education institutions that participated in the CUMCM. Consequently, the popularity of the CUMCM has posed great influence in the development of other mathematical modeling activities in China, including successfully introducing mathematical modeling to the undergraduate education, promoting the national recognition of mathematical modeling, as well as supporting mathematical modeling activities of all kinds and of all scales. The Summer Camp of Mathematical Modeling is an extension of the CUMCM, which provides students and mathematical modeling enthusiasts with in-depth exposure and means in which to further hone their mathematical modeling skills.

The Chinese teams' dramatic increase in participation and performance in the MCM and ICM is only a reflection of the popularity of mathematical modeling in China. In fact, the number of participating MCM and ICM teams accounts for only a small fraction of the total number of participating CUMCM teams.

In addition, the CSIAM and the CUMCM Committee have invested great effort in teacher training and research in mathematical modeling workshops for educators. The two national mathematical modeling conferences, the CCTMMA and the NCMMTA, have provided teachers, researchers, experts and practitioners of mathematical modeling platforms on which to exchange and communicate their ideas in mathematical modeling.

Research Question 3

The purpose of Research Question 3 is to determine how certain resources have been assisted in the success of Chinese teams. Initiators of mathematical modeling education in China

began popularizing mathematical modeling in the early 1980s. Due to their experience in college education and work in the late 1950s to late 1970s, they realized the nation-wide need for mathematical modeling in order to help bridge the science and technology gap between China and other developed countries. These early pioneers possessed solid backgrounds in pure mathematics, as well as the ability to solve practical problems with mathematics. In addition, they also felt a responsibility to cultivate future talent for China by training the next generation of mathematicians and applied mathematicians. As a result of their knowledge and passion, many of them have dedicated in excess of 30 years in the mathematical modeling education field, which ultimately laid a foundation for the later success and popularization of mathematical modeling in China.

In addition to receiving national support from the Department of Higher Education, the CSIAM, CUMCM Committee, and other resources have contributed to the popularity of mathematical modeling in China.

Local effort in mathematical modeling is indispensable for the development of mathematical modeling in China. Historically, local CSIAMs have always facilitated the work of the CSIAM, which has enabled the organization of mathematical modeling activities to operate at a large and effective scale. The local CSIAM in Shanghai and Shaanxi were the initiators that also held mathematical modeling contests in China. The regional mathematical modeling contests that they held in 1990 and 1991 provided critical experience for the later large-scale holding of the CUMCM in China. Besides, regional and school-wide mathematical modeling contests provided students with many opportunities in which to practice mathematical modeling. In addition, approximately 20 major websites that have been dedicated to mathematical modeling

learning and information sharing have served as communication platforms for people who love mathematical modeling.

Chinese news media helped publicize and raise public awareness of mathematical modeling activities in China and brought mathematical modeling into the national conversation.

Industry sponsorship provided not only financial support, but also served to increase the publicity of mathematical modeling activities in the general public.

Research Question 4

The purpose of Research Question 4 was to determine the relationship between Chinese teams' choice of problems in the MCM and the winning results over the years. Based on the analysis, Chinese teams have shown a preference for discrete mathematical problems (problem B) over continuous mathematical problems (problem A) in 21 out of the 24 years since Chinese teams first participated in the MCM. However, compared to the winning rate over these 24 years, continuous mathematical modeling problems have a higher overall winning rate than discrete mathematical modeling problems in 15 of the 24 years. Similarly, comparing the participation rate to the winning rate of MCM problems, the participation rate is lower than the winning rate for continuous mathematical modeling problems in 17 of 24 years. Lastly, the participation rate is higher than the winning rate for discrete mathematical modeling problems in 16 of 24 years.

Although Chinese teams have favored discrete mathematical problems over continuous problems, based on the interviews, no such preference exists during the training process of mathematical modeling for students in China. Students choose problems based on their mathematical competency, preference and interests within their areas of mathematical knowledge used in the contest problems.

Research Question 5

The purpose of Research Question 5 is to determine to the extent of influence the Chinese National College Entrance Examination (NCEE) has on the Chinese team's modeling success. Based on the analysis of NCEE mathematics exams from 1951 to 2013, there existed no true mathematical modeling problems in the test material. Instead, mathematical application problems have appeared during certain periods on the NCEE. Mathematical modeling application questions first appeared on the NCEE from 1960 to 1965. After the 10-year Cultural Revolution, mathematical modeling questions appeared on the 1977-1986 NCEE with an exception of the 1985 NCEE. From 1987 to 1994, no mathematical modeling problems appeared on NCEE exams. Since 1995, the mathematical modeling questions have appeared on the NCEE until the present day.

In terms of mathematical knowledge contexts used for the mathematical modeling exam questions, a variety of mathematical application problems appeared in some of the examples from 1995 to 2004. Since 2005, the mathematical application exam questions have consisted mainly of typical probability questions.

Although the NCEE doesn't pose a direct influence on students' ability in mathematical modeling, it does point to a direction that students who finish a high school mathematics curriculum should be able to apply what they learned to simplified real-world situations, and pose solutions to the simple models built in these situations. This focus laid a solid mathematics foundation for students' future study and application of mathematics.

Recommendations

Due to widespread recognition of the advantages of mathematical modeling in China, mathematical modeling education has become successfully integrated into Chinese undergraduate education.

With increasing popularity of mathematical modeling education in Chinese higher education, mathematics education at precollege levels has gradually focused on students' mathematical modeling competency. The most recently promulgated 2003 High School Mathematics Curriculum Standards included mathematical modeling as part of the high school mathematics curriculum. Ma (2007) noted that this is a milestone for the development of secondary education in the aspect of mathematical modeling and application, and that it marked the official inclusion of mathematical modeling into the Chinese high school mathematics education. Chinese practices in mathematical modeling at precollege levels warrant future research interest.

More recently, an increasing number of Chinese students have begun to participate in international high school mathematical modeling contests. Their performance over the years may provide researchers with an overview of Chinese precollege mathematical modeling education.

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Appendix I

Number of Teams Participated in MCM and ICM

Year	Total			MCM							ICM		
	Number of		Percent age of Chinese teams	Number of		Percentage of Chinese teams	Number of				Number of		Percent age of Chinese teams
	All team s	Chin ese team s		All teams	Chines e teams		All teams chose proble m A	All teams chose proble m B	Chines e teams chose proble m A	Chinese teams chose problem B	All team s	Chinese teams	
1989	211	4	1.90%	211	4	1.90%					-	-	-
1990	236	6	2.54%	236	6	2.54%	74	162	1	5	-	-	-
1991	260	21	8.08%	260	21	8.08%	127	133	9	12	-	-	-
1992	292	24	8.22%	292	24	8.22%	107	185	9	15	-	-	-
1993	259	40	15.44%	259	40	15.44%	88	171	13	27	-	-	-
1994	315	84	26.67%	315	84	26.67%	70	245	15	69	-	-	-
1995	320	84	26.25%	320	84	26.25%	146	174	36	48	-	-	-
1996	393	113	28.75%	393	113	28.75%	126	267	46	67	-	-	-
1997	410	107	26.10%	410	107	26.10%	234	176	64	43	-	-	-
1998	472	138	29.18%	472	138	29.18%	189	283	61	77	-	-	-
1999	478	155	32.43%	418	130	31.10%	212	206	53	77	60	25	41.67%
2000	496	169	34.07%	427	138	32.32%	156	271	30	108	69	31	44.93%
2001	580	237	40.86%	497	200	40.24%	216	281	91	109	83	37	44.58%
2002	629	271	43.08%	523	216	41.30%	280	243	87	129	106	55	51.89%
2003	639	297	46.48%	493	214	43.41%	267	226	80	134	146	83	56.85%
2004	743	402	54.10%	600	299	49.83%	203	397	109	190	143	103	72.03%
2005	828	513	61.96%	664	387	58.28%	172	492	96	291	164	126	76.83%

2006	971	659	67.87%	747	466	62.38%	516	231	324	142	224	193	86.16%
2007	1222	861	70.46%	949	627	66.07%	351	598	215	412	273	234	85.71%
2008	1542	1199	77.76%	1162	844	72.63%	568	594	417	427	380	355	93.42%
2009	2049	1621	79.11%	1675	1281	76.48%	1124	551	873	408	374	340	90.91%
2010	2611	2186	83.72%	2255	1853	82.17%	949	1306	792	1061	356	333	93.54%
2011	3511	3060	87.15%	2775	2372	85.48%	1291	1484	1077	1295	736	688	93.48%
2012	5027	4554	90.59%	3697	3275	88.59%	1587	2110	1465	1810	1330	1279	96.17%
2013	6594	6125	92.89%	5637	5195	92.16%	2607	3030	2337	2858	957	930	97.18%

Appendix II

Number of Participations in CUMCM from 1992 to 2013

Year	Institutions	Teams
1992	74	314
1993	101	429
1994	196	867
1995	259	1234
1996	337	1683
1997	373	1874
1998	400	2103
1999	460	2657
2000	517	3210
2001	529	3887
2002	572	4448
2003	637	5406
2004	724	6881
2005	795	8492
2006	857	9898
2007	969	11742
2008	1023	12846
2009	1135	15042
2010	1196	17311
2011	1251	19490
2012	1284	21219
2013	1326	23339

Appendix III

Problems in the Summer Camp of Mathematical Modeling

2001 A	The optimization design for the side ramps of the Three Gorges Projects
2001 B	City traffic analysis and management, and mammary cancer diagnosis
2001 C	Mammary cancer diagnosis
2006 A	The market research, evaluation, and prediction methods for textbook publishers
2006 B	Train dispatching for Beijing-Shanghai line considering the process of speeding up trains
2006 C	Tourism demand prediction
2011 A	Garbage classification and disposal
2011 B	Water resource shortage risk evaluation
2011 C	Automatic division of sequence stratigraphy using well logs
2011 D	The analysis on Shenzhen's traffic based on the GPS data in the taxis
2012 A	The prediction of the relationship on population and medical demand in Shenzhen
2012 B	Accurate recognition model for mobile users
2012 C	Environmental friendly computer lab design
2012 D	The improvement of production efficiency for hole punchers
2013 A	Food safety random inspection data analysis
2013 B	Traffic jam investigation and administration
2013 C	Quantitative analysis of society and individuals on garbage classification
2013 D	Investigation of natural disaster insurances

(CUMCM Committee, 2013c, 2004, 2007; CUMCM Committee & Science and Technology Association of Shenzhen, 2013a, 2013b)

Appendix IV

Statistics of Chinese teams' choice in MCM's problem A and problem B

Year	Number of Chinese Teams in		Percentage of Chinese teams compete in		Number of teams won in Problem A		Percentage of Chinese teams in all winning teams that chose problem A	Number of teams won in Problem B		Percentage of Chinese teams in all winning teams that chose problem B
	Problem A	Problem B	Problem A	Problem B	All teams	Chinese teams		All teams	Chinese teams	
1990	1	5	1%	3%	31	1	3.23%	69	4	5.80%
1991	9	12	7%	9%	52	5	9.62%	53	4	7.55%
1992	9	15	8%	8%	44	6	13.64%	77	6	7.79%
1993	13	27	15%	16%	42	8	19.05%	70	12	17.14%
1994	15	69	21%	28%	35	10	28.57%	103	28	27.18%
1995	36	48	25%	28%	64	16	25.00%	71	23	32.39%
1996	46	67	37%	25%	57	28	49.12%	120	14	11.67%
1997	64	43	27%	24%	100	41	41.00%	72	25	34.72%
1998	61	77	32%	27%	83	33	39.76%	120	33	27.50%
1999	53	77	25%	37%	100	37	37.00%	115	39	33.91%
2000	30	108	19%	40%	72	22	30.56%	120	58	48.33%
2001	91	109	42%	39%	89	39	43.82%	114	36	31.58%
2002	87	129	31%	53%	113	45	39.82%	105	49	46.67%
2003	80	134	30%	59%	139	23	16.55%	95	49	51.58%
2004	109	190	54%	48%	77	36	46.75%	151	66	43.71%
2005	96	291	56%	59%	78	40	51.28%	212	115	54.25%
2006	324	142	63%	61%	223	89	39.91%	98	58	59.18%
2007	215	412	61%	69%	149	93	62.42%	242	148	61.16%
2008	417	427	73%	72%	251	150	59.76%	397	263	66.25%
2009	873	408	78%	74%	361	265	73.41%	240	172	71.67%
2010	792	1061	83%	81%	408	338	82.84%	587	477	81.26%
2011	1077	1295	83%	87%	470	421	89.57%	757	609	80.45%
2012	1465	1810	92%	86%	720	685	95.14%	760	627	82.50%
2013	2337	2858	90%	94%	1125	1052	93.51%	1407	1354	96.23%

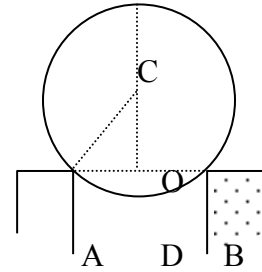
Appendix V

Selected Mathematical Application Problems from 1960 to 2013

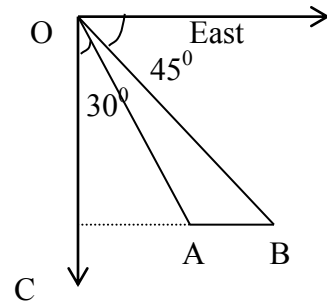
The following selected mathematical application problems do not include all the application problems appeared on NCEE from 1960 to 2013. Since some of the questions are very similar, the author only pick some of the problems to list here as examples.

1960

1. As it is shown in the figure, a steel ball is used to measure the diameter of a hole in a machine. The center of the ball is denoted as O , and its diameter is 12mm. CD , which is the distance from the top of the ball to the level of the hole, is 9mm. What is the value of AB , the diameter of the hole?

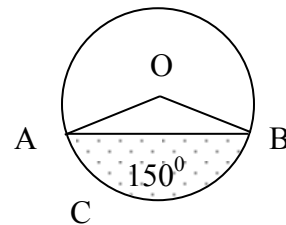


2. A ship started from point O , and found a lighthouse at A , south and 30° toward east. Then the ship ran 30 miles per hour toward southeast. Half an hour later, the ship found the lighthouse at its west. What is the distance of the ship and the lighthouse now? (Accurate to 0.1)



1961

1. A cylinder shaped pipe laid horizontally. The radius of the cylinder is 12cm. The part filled with water is a 150° arc. What is the area of the part filled water (the shaded part).



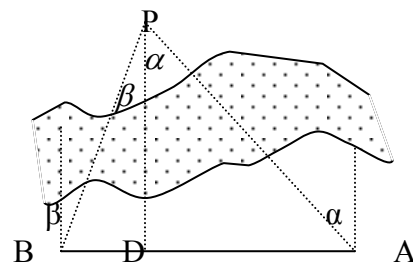
2. A factory plans a three-year manufacture increase, which is to increase a same amount of machines compared to the previous year. If 1000 more machines were produced in the third year than the original plan, then the rates of increase of every year compared to the previous year in the three years are the same. Besides, the number of machines produced in the third year is equal to the half of the total number of production in the original plan. What is the amount of the machines produced every year in the original plan?

1962

The amount of production in the third year is 21% more than the first year, what is the average increase each year compared to the previous year? What is the percentage of the amount of production in the third year is equivalent to the production in the first year?

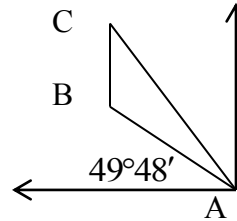
1964

People A and B started from point D. A walked towards east and B walked towards west. A walks a meters faster every minute than B. 10 minutes later, A saw P at α degree north towards west, and B saw P at β degree north toward east. What is the length of PD?



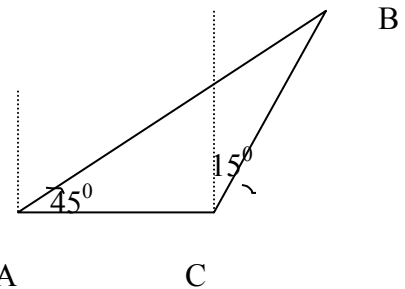
1965

Ship A is located at A and sees ship B located at B, north towards west at $49^{\circ}48'$. B is running 22 miles toward north. If ship A starts from A and runs at 26 miles per hour north towards west at angle α to chase ship B. What is the angle α so that ship A and C can meet each other at C? ($\lg 2.2=0.3424$, $\lg 2.6=0.4150$)



1977 Beijing

A boat runs 20 miles per hour towards east. When the was at A, a light house was at B, 45° north toward east of A. One hour later, the ship arrived at C and saw the lighthouse 15° east of C. What is the distance of CB?



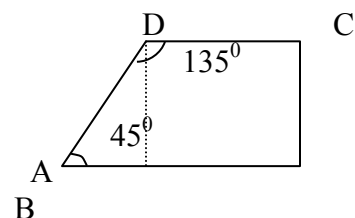
1977 Shanghai

1. A production team raised 96 pigs last year, and 120 pigs this year. What is the percentage increase of this year compared to last year? If the plan is to raise 40% more pigs next year than this year, how many pigs should the production team raise?

2. The concentration of vitriol A is 96% and that of B is 36%. Now 600-liter vitriol of 70% concentration is to be made out of the combination of two kinds of vitriol. How much should be used from A and B respectively?

1977 Hebei Province

A production team plans to build a field in a shape of right trapezoid. AD and DC are walls around the filed. Angles are listed on the figure. The length of AB and BC together is 30 meters. What are the lengths of AB



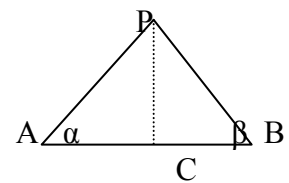
and BC respectively so that the area of the field reaches its maximum? What is the maximum area?

1977 Fujian Province

A farming machine factory held an event “ Learn from Daqing”, 1,000 tractors were produced in October, thus, the total production amount from January to October met the goal of the annual production. Factory workers decided to produce another 2,310 machines by the end of the year. (1) What is the monthly growth rate of November and December? (2) How many machines originally did the factory planned to produce?

1979

1. Foreign ships cannot enter areas that are D sea miles from our coastline without permission. A and B are two stations to guard sea areas. The distance of A and B is S sea miles. The coastline is a straight line that goes through A and B . A foreign ship is at P . Observations from A and B show that $\angle BAP = \alpha$, and $\angle PAB = \beta$. What trigonometry inequality relationship does α and β fulfill so that warning should be sent out to foreign ships.



2. The price in the U.S. went from 100 in 1939 to 500 in 1979. If the annual increase rate stays the same, what is the annual increase rate? (if $x < 0.1$, the following can be used: $\ln(1+x) \approx x$, use $\lg 2 = 0.3, \ln 10 = 2.3$).

1980

The output value of light industry accounted for 20% of the total gross industrial output value in 1979 in an area. If the 1980 gross industrial output value increased 10% compared to

last year, and the light industry output value is 24% of the gross industrial output value, what is the percentage increase of the light industry output value in 1980 compared to last year?

1981

There are four candidates, A, B, C and D.

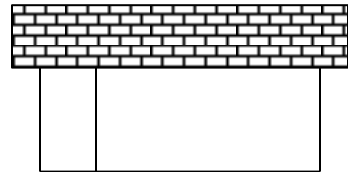
(1) How many ways are there to elect one class representative and one assistant.

List all the election results.

(2) How many ways are there to elect three class representatives? List all the election results.

1982

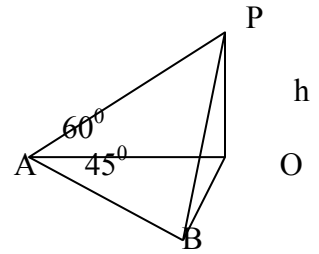
A rectangular field was fenced on the three sides and the other side is a wall. Another fence was built within the field and is parallel to the left side. The total length of the fence is L , what is the length and width of the field so that the area reaches its maximum? What is the maximum area?



1983

1. 10 students are in a group, where 4 out of them are girls and the rest are boys. In order to elect 3 representatives from the 10 students, including at least 1 girl, how many ways to elect the 3 representatives?

2. A mast OP has a height of h. In order to measure its height, we selected 2 points A and B. AB is 20 meters, and the angles $\angle OAP=30^\circ$ $\angle OBP=45^\circ$ $\angle AOB=60^\circ$ what is the height h?



1984

1. There are 6 singers and 4 dancers performing individually in a gala. It is required that any two dancing shows cannot be next to each other. How many ways are there to arrange the 10 shows? (No calculation is required, expressions are good enough)

2. A factory produced 20,000 products in 1983. Starting from 1984, an 20% increase in production is expected compared to the previous year. Which year will the factory be able to produce 120,000 products? ($\lg 2=0.3010$, $\lg 3=0.4771$)

1986

1. Four people are working on 8 projects. A is working on 3 projects, B is working on 1 project, and C and D are working on 2 projects respectively. How many ways are there to work on the projects?

1995

In order to promote fresh water aquaculture and control its price within a reasonable scale, local government decided to provide allowance to the fresh water aquaculture industry. Let's assume that the market price for fresh water fish is x yuan/kilogram, and government allowance

is t yuan/kilogram, according to market research, when $8 \leq x \leq 14$, the daily market supply of fresh water fish, P kilogram, and daily market demand Q can be closely represented by

$$P=1000(x+t-8) \quad (x \geq 8, \quad t \geq 0) \quad \text{and} \quad Q=500 \sqrt{40-(x-8)^2} \quad (8 \leq x \leq 14)$$

When $P=Q$, the market price is the market-clearing price.

- (1) Please represent market-clearing price by the function of government allowance, also specify the domain of the function.
- (2) How much should the government allowance be per kilogram so that the market-clearing price is not higher than 10 yuan per kilogram?

1996

There is 1,000-acre cultivable land. It is planned that the produce from the land increases 22% in 10 years, and food per capita increases 10% compared to that currently. Now that population growth rate is 1%, how many acres of cultivable land can be reduced at most per year? (Production per acre = total production/total acres of land. Food per capita = total production/total population)

1997

The distance between A and B is s kilometers, and a car is running between A and B in an even speed. When the speed does not exceed c kilometers/hour, the cost of transportation per hour is composed of two parts: a changing part and a fixed part. The fixed part is a yuan, the changing part is in direct proportion to speed v squared (kilometers/hour), the coefficient is b .

- (1) Represent the transportation cost y (yuan) in the function of v (kilometer/hour), and specify the domain of this function.
- (2) In order to make the total transportation cost minimum, what speed should the car be operated?

1998

A cuboid without lid is built for sewage water disposal. The width of the cuboid is 2 meters, length is a meters, and height is b meters. The sewage water enters from A and exit from B, and sediments will be left in the cuboid. It is known that the mass fraction of sediments in water is inversely proportional to the product of ab. Assume that the material for such a cuboid is 60 square meters, what should the value of a and b be so that the mass fraction is minimum. (The area of holes A and B can be ignored)

1999

A cold-rolling mill is shown in the figure. A steel strip enters from the left side and exit from the right side. As the strip goes through the mill, it will be thinner.

- (1) Let's assume the entering thickness of the strip is a , and exit strip is β , the rate of thinning by each pair of rollers does not exceed r_0 , how many pairs of rollers does the mill need? ($r_0 = \frac{\text{entering thickness} - \text{exit thickness}}{\text{entering thickness}}$)
- (2) Assume there are 4 pairs of rollers with a $r_0 = 20\%$, each roller has a circumference of 1,600mm, if the k^{th} pair of rollers are defected, which leave a mark on the steel strip as the strip goes by, the distance between two marks is L_k , in order to make the repair work easier, please calculate L_1, L_2, L_3 , and fill out the following table.

K	1	2	3	4
Lengths between two marks (mm)				1,600

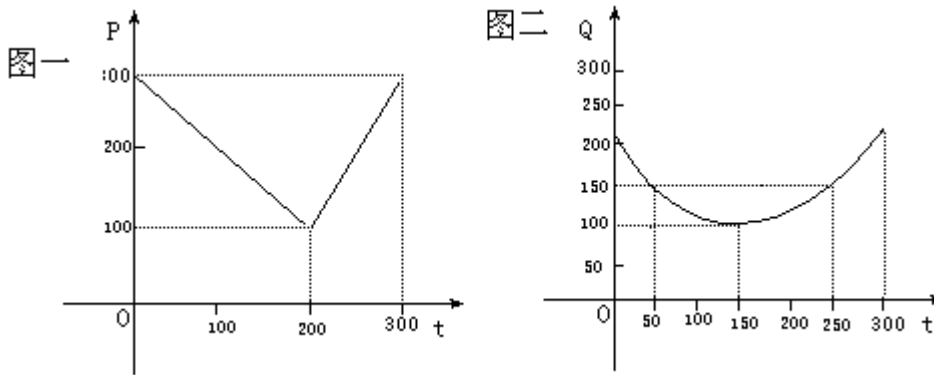
2000

Within 300 days starting from February, the left figure represents the relationship between the price of tomatoes and the time to market. The right figure represents the relationship between the cost and the time to market, which is a parabola.

(1) Please write a function representing the market price and time $p=f(t)$ for figure one

Please write a function representing the cost and time $Q=g(t)$ for figure two

(2) The profit is calculated by the revenue subtracts cost, thus, in order to make the profit maximum, when should the tomatoes be on the market?



2001

A local government decides to invest in environmental protection, so that it can better serve the tourism industry. According to the plan, 8,000,000 yuan is invested this year, and a $1/5$ decrease in investment will be conducted each year in the following years. The revenue of local tourism industry is approximately 4,000,000 yuan this year. It is expected that the future revenue from local tourism industry will increase $1/4$ compared to the previous year because of the investment in environmental protection.

- (1) Assume that within n years, the total investment is a_n (10,000 yuan) and revenue from tourism industry is b_n (10,000 yuan). Please give expressions for a_n and b_n .
- (2) How many years does it take for total tourism revenue exceed total investment?

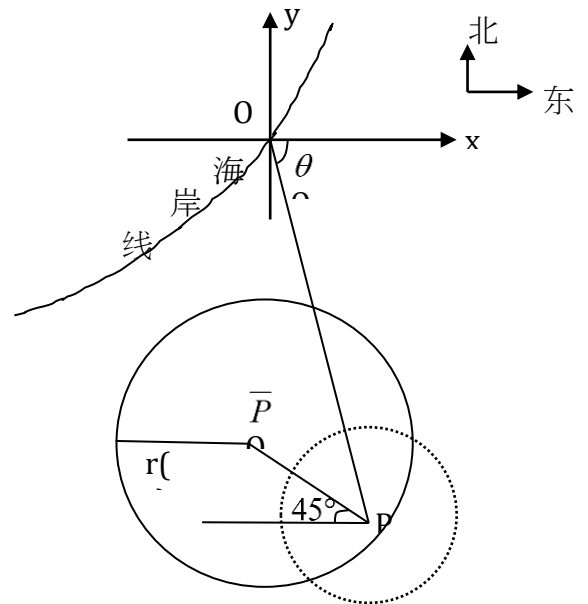
2002

Six workers are conducting their work via Internet. The probability for each worker to be online is 0.5 and they are all independent.

- (1) What is the probability of at least 3 people are online?
- (2) How many people have to be online at the same time so that the probability is less than 0.3?

2003

According to prediction, a hurricane is coming. The center of the hurricane is at P, 300 kilometers and θ ($\cos \theta = \frac{\sqrt{2}}{10}$) east to the south of city O. It 's moving 45° west toward north. The radius is 60 kilometers, and enlarging at 10 kilometers/hour. How long does it take for the city to be affected by the hurricane?



2004

There are three stations, A, B, and C, on a segment of the railroad. $AB=15\text{km}$, $BC=3\text{km}$. According to the schedule, the train starts at 8:00 from A and arrives at B at 8:07, then it stops at B for one minute, and arrives at C at 8:12. Assume that the train starts from A at 8:00 sharp, stops at B for 1 minute, and the train runs at speed v km/hour. The absolute difference between the schedule time and the actual arriving/leaving time is regarded as the operation error.

- (1) What is the operation error at B and C?
- (2) If the sum of operation error at B and C is less than 2 minutes, what is v ?

Since the majority of application problems after 2005 are probability questions, the author will use one example from 2005 Jiangsu as an example.

2005 Jiangsu Province

The probability of A hitting the target is $\frac{2}{3}$, the probability of B hitting the target is $\frac{3}{4}$. Assume the activities of the two people are independent.

- (I) If A shoots four times, what is the probability of hitting the target at least once
- (II) If A and B each shoots four times, what is the probability that A hit the target twice and B hit the target three times
- (III) It is required to stop shooting if missing target twice. What is the probability for B to stop after he shoots exactly five times?

Appendix VI

Personal Communications

Interview with Professor Qixiao Ye

Interviewer: You were very prescient back then to introduce the Mathematical Contest in Modeling to China.

Ye: I believe if it were not I, Ye Qixiao, that introduced the contest to China, there would be another person, for example, Liu Qixiao, Li Qixiao, that introduced it to China. Due to the Cultural Revolution, the development of education was in abeyance during that period. It was until 1971 that students who were workers, peasants, and soldiers were gradually recruited to universities. In 1978, Xiaoping Deng implemented “the reform and open-up” policy and fully resumed the college education. It was then that we were sent to America to study as faculty members by Peking University. The majority of scholars of our time are very aspiring, patriotic, and ambitious. We understand that China was lagging far behind comparing to other powerful countries. Improvement of technology, mathematics and education were badly needed. As a result, there had been a lot of discussions on realizing the improvements in those areas. Apparently, those were not emerged all of a sudden.

Actually, the discussion of education reform dated back to the “great leap forward” period. During the “great leap forward” period, a few students of mathematics major in Peking University advocated “down with Cauchy and its system”, and “down with Newton and its system”. Because students were immediately exposed to the very abstract ideas and notions in Mathematical Analysis, such as ϵ , δ , right after secondary education, and it was like a head-on blow for the students, and not everybody was able to quickly accustom to the intangible mathematics structure. Personally, I didn’t agree with students’ advocacy, but the arguments

were existent since then. Consequently, the debate was extended to mathematics courses offered to non-mathematics majors. Besides, the mathematics teaching system by then was a copy of the former soviet mathematics education system. I think that judging whether the soviet mathematics teaching system was good or not depends on the academic level of audiences and schools. It applies to American schools as well. Mathematics majors in schools like Harvard, Stanford and Princeton have high standards for sure. When I taught in Duke University, the requirements set for students in mathematics major were quite high as well. Learning from Soviet education system is not as bad, depending on the audiences. The same applies to Mathematics Olympiad. Kids who like mathematics should have the opportunity to be exposed to the problems in Mathematics Olympiad, as long as it is not done in a utilitarian way.

Then the series of mathematics textbooks by Smirnov were introduced to China mainly for engineering programs. The debate arose as whether engineering programs should be taught the same kind of mathematics as what was offered to mathematics majors. If it should not be the same, which parts should be omitted? Some people said that the indefinite integral should be omitted; others would question the legitimacy of doing so if the knowledge were used in the later part of the book. I always believe that learning mathematics cultivates people's thinking ability by solving different problems. The ability cannot be acquired by looking at others' answers. You may feel you understand the problem by looking at other's answer. But it is quite likely to be stuck at the critical point when a similar problem appears.

The consequences of Cultural Revolution and other political movements are very debatable. But just because of the experience, I, as well as other intellectuals, knew how poor it was in China's rural area back then. We reevaluated our knowledge and the way we saw this world. As a fourth year college student in 1958 (we were in a five-year college program), the

political movement (great leap forward) advocated that all the students should solve practical problems. Therefore, I was assigned to The Institute of Water Resources and Hydropower Research to do some practical work. Then I had to go to Jiangxi province to do labor work.

In 1973, Peking University created its own computer, and I learned computer by myself earlier. I went to the Beijing Research Institute of Metallurgy to ask for problems to solve. They were not very interested in my background since I was a pure mathematics major. They didn't think that I could solve any problems like physics or mechanics majors. The problems they gave me had models built up already, and I just need to solve them. I solved the problems within two weeks with the aid of the computer, and they were really surprised.

In 1974, a meeting was held in Xinyang, Henan province, to discuss a problem about the mechanical properties of the beams and walls in constructing buildings. More than 100 engineers were in the meeting. I presented a mathematical solution. Right after my presentation, they were heatedly debating with each other. All the people at the conference appreciated my work. Nobody expected that a pure mathematics guy like me could provide a solution to the engineering problem

There was another example about the construction of Gezhou Dam in 1970s, where I participated in the design of the lock in the middle of the dam. Only very few people in the project experienced the whole mathematical modeling process of building the models of the lock of the dam, and I was one of them. The whole modeling process included building a model, solving the model, and evaluate and modify the model. At that time, experts from state department of transportation, state department of water and electricity, and engineering experts from Peking University built a quite reasonable simplified model. We studied the structure of the soil layers where the dam was to be built. The problem was a system of partial differential

equations with piecewise constant coefficients. The computer we had then didn't have memory that was large enough to perform the calculation of the 400th order system of linear equations with Gauss method. Instead, we use the method proposed by professor Boju Jiang. I knew that the coefficient matrix is sparse, in which some parts are always zero, and others are always non-zero. With that in mind, we can store information wisely into the computer. That saved us a lot of space in the computer. That's the beauty of mathematics. You would never realize that unless you know mathematics. The state departments that were involved in the project obtained some relevant data from domestic and abroad and asked us to evaluate our model with these data. Luckily, all the numerical results obtained from our model fitted those data quite well. I presented the model, and I was very confident that the model was a good one. Right after my presentation, an engineering expert questioned our model, stating that the result produced by the model was different from the experiment result he obtained. Two weeks later, the expert told me that there was a mistake in his experiment that prevented him from obtaining the correct data. I was relieved.

Then we began to teach engineers how we built the model and solved the model, including the way we coded it into the computers. Only one engineer, Li Ma, truly understood the whole process and was able to make modifications to the model. It was very understandable. I only mastered the whole process of mathematical modeling after going through several projects. It is not something that you can easily understand without really doing some projects.

Other well-known scholars, such as professor Buqing Su, professor Daqian Li and professor Yongji Tan, involved in a petroleum project. They were also very capable people with very strong mathematical background. Without strong mathematical background, it is impossible to accomplish projects like the ones I mentioned above. Compared to the U.S., China went

through more political movements. However, no matter how the political environment changes, most scholars in China were very capable and dedicated to making contributions to the country by applying their mathematical skills.

Interviewer: Just to summarize it, you realized the practicality of mathematics after participating in several projects using mathematical modeling.

Ye: Yes, that's exactly right. Please note that it is a long process. It cannot be achieved within a short time. It has also been a trend worldwide that scientists in other fields rely not only on experiments, but also on mathematical explanations. For example, my research focus, reaction diffusion equation, is widely used in chemistry and biology. It is also very important to note that pure mathematics is equally important. The development of mathematics is like a chain. No part should be missing. Pure mathematics provides a foundation. Applied mathematics cannot solve problems well without it. The two parts rely on each other. We need people doing research in pure mathematics and in applied mathematics. Therefore, as you can probably see, even though many projects were done using applied mathematics during the Cultural Revolution, doing all applications with little research in pure mathematics was quite extreme and not sustainable to the development of mathematics.

I was sent to the Minnesota University as a visiting scholar by the Chinese government in early 1979 and came back to China in 1981. By then, some scholars had already been sent abroad as early as in late 1978. We were the first class of scholars sent to abroad by the Chinese government. Initially, U.S. was not an option for us due to political issues. Even though the diplomatic relationship had already been established on January 1st 1979, many details of inter-country activities were not clear. The president of my university (Peking University), Peiyuan Zhou, went to the U.S. to negotiate with the counterparts in the U.S. As a result of the

negotiation, scholars in China could go to U.S. as visiting scholars. As far as I know that all the scholars from the department of mathematics of Peking University came back to China after the visiting period. Nobody stayed abroad.

You must have already known that Fudan University offered an undergraduate mathematical modeling course in 1982. Zhejiang University also offered the course in the same year. Tsinghua University and Chongqing University offered the course in 1983. Peking University first offered mathematical modeling courses in 1985, etc. At that time, there were almost no resources on mathematical modeling available in China. All the schools that offered the course used the mathematical modeling textbooks from the U.S. Professor Shutie Xiao used “An Introduction to Mathematical Modeling” authored by Edward. A. Bender and other materials. In Peking University, we used some materials from the four volume books “Modules in Applied Mathematics” edited by W. F. Lucas. Peking University had a very strong focus on pure mathematics research, and teachers, who offered the mathematical modeling course, including me, were trained pure mathematicians as well. However, we all recognized the importance of mathematical applications. Therefore, the mathematical modeling was offered to students. At the initial stage of offering this course at Peking University, we didn’t give any test to students. As long as they completed the course, they would get credits. Nowadays, Peking University thinks highly of mathematical modeling. Peking University named its school-wide mathematical modeling competition after the founder of University’s mathematics department and famous mathematician, Zehan Jiang, which was a very important acknowledgement for the importance of mathematical modeling.

After Professor Lingxi Qian’s report about how to do applied math, and mentioned “Oxford Study Group with Industry” in 1985, I began to search literatures abroad on

mathematical modeling activities. I found the MCM from the U.S., and I contacted the founder Dr. Fusaro. He was very kind and mailed me materials about the contest problems. When he came to China in 1990, I invited him to give talks about the contest to the university that I worked at, Beijing Institute of Technology. After I served as a visiting scholar for one semester at Duke University in 1988, Dr. Fusaro invited me to his university to see how they trained mathematical modeling teachers. I have to mention that by then, personal computer was very prevalent in the U.S, which was quite different to the time in 1979 when I first visited U.S. However, there weren't many personal computers in China in 1988.

Our first participation of the MCM in 1989 received strong support from my school. The school permitted the contest student's access to dorm, library and computer labs in non-operating hours. In order to familiarize students with the contest, I asked three students and four teachers from the mathematics departments to form a seminar, where they can study together. Tsinghua University formed two teams. Peking University formed one team. All the schools had already offered mathematical modeling courses. Therefore, participating students had some knowledge about mathematical modeling. Most importantly, they were very excited and curious about the contest, the three-day duration and the format of which were quite different from the usual test. The next year, Fudan University participated in the MCM as well. Education officials of Department of Education in Shanghai and mathematical experts of Fudan University all supported students' participation in the contest.

After the CSIAM founded in 1990, we decided to hold our own mathematical contest in modeling in 1992. Educational officials and experts fully supported this activity. All we want to see was the success of the mathematical modeling activity. We didn't get any compensation from

it, and for a long time. Nobody asked for anything in return. Our motivation was to cultivate and benefit students, nothing else.

At that time, the news media were very interested in this activity. The central radio station broadcasted my article about the mathematical modeling contest in 1992. From then, more and more news agencies were interested in this activity.

Interviewer: Why do you think the mathematical modeling activities are so popular and develop so quickly in China?

Ye: First of all, we gained strong support from the educational officials. For example, Before the national mathematical modeling contest was held, Professor Qiyuan Jiang and I went to the Ministry of Education to talk to the officials about the contest. They were interested in it very much. Higher education officials, such as Yuanqing Zhou, showed their support to the mathematical modeling activities by attending many events. It is very necessary to have supports from relevant officials before the activities are held in large scale. Second, students have been very interested in the contest as well. They see the benefit of using and training in mathematics. Students who have experience in mathematical modeling also perform well in their later jobs. They also want to challenge themselves.

Now I'm doing some projects related to the mathematical modeling teaching and learning. One of projects is "Incorporating the idea of mathematical modeling into college calculus teaching and learning". It is a more detailed project compared to professor Daqian Li's "Incorporating the Idea and the Method of Mathematical Modeling into the Main Mathematical Courses in Universities and Colleges". I focused on the first two classes of the college calculus. I designed some mathematical modeling problems to introduce Calculus to students. Approximately 20 universities in China now are using my approach to introduce Calculus to

freshmen in some extent. I think the project is very critical. College students' interests in learning mathematics are not as strong. Forging students' interests in college level mathematics is critical for the development of our country. It has been proven that people with strong mathematical training have more chances of success in the future. I suggest that teachers who teach Calculus learn some basic examples of mathematical applications in students' majors. Therefore, students can really find the usefulness of mathematical modeling in their fields of interests. There are reasons why students don't like mathematics. However, we have to do something to make sure students really learn the subjects because it is too important. For example, nowadays, people who excel in computer science, economics and all other fields all need strong mathematics background. Looking at the Noble Prize winners, many of them had very strong mathematics trainings no matter which fields they ended up working in. If only a portion of students in China really learn the subject well, we would expect a strong country. This is my point of view.

Now the funding for mathematical modeling activities is pretty sufficient. For example, Beijing Department of Education gives 200,000 RMB (approximately more than 30,000 USD) each year to the mathematical modeling activities held in Beijing. Schools and local government also support the mathematical modeling activities as well.

I organized teacher-training sessions in Beijing since 1992, and the session lasted till 1997. After then, there are increasing amount of teacher training session in China at all levels. Many teachers back then were not familiar with mathematical modeling process. I gave some examples and most importantly, I asked them to do it themselves. Like I said earlier, you would never understand mathematical modeling without doing it. Before they learned what mathematical modeling is, most teachers were very afraid of the subject. They thought it was a

very complicated process. Well, I have to admit that mathematical modeling can be very complicated. However, we just want teachers to know the basic steps and ideas of mathematical modeling, not necessarily to solve some cutting-edge problems. Of course, if they can achieve that level, that would be very nice, too.

I brought up the idea of “three stages” in the mathematical modeling contests, which were training before the contest, solving problems during the contest and further research after the contest. Now, I’m focusing on the third step. The CUMCM Committee put aside 10,000 RMB each year for each contest problem that students propose to do further research.

Recently, I’m also giving talks about the role of mathematics especially mathematical modeling from the history of science to university students across the country. The talks are very welcomed by students and teachers.

For my academic research, I’m still doing some work on the reaction diffusion equation.

Interviewer: What do you think of mathematical modeling in high school?

It’s a complicated question. In order to teach mathematical modeling in high school, teachers must feel very confident about the subject. I talked to some top teachers in high schools; most of them were with many years of teaching experience. When they were in college studying mathematics, mathematical modeling might not be as prevalent as it is in the curriculum now. As a result, their understanding of mathematical modeling is not optimal. They are afraid that if students ask them questions about mathematical modeling, they might not give good answers or approaches, as they would have in other mathematical problems. They don’t want to risk their good reputation that has been built over a long time.

Interviewer: What is teachers' motivation in advising students in mathematical modeling activities? From the information that I learned, many school mainly look at teachers' research outcome as promoting standards.

Ye: Yes, that's right. Research is very important when evaluating teachers at universities. However, many school do take teachers' extra work and time in advising students' in mathematical modeling activities into consideration. Especially when students do get good awards from the contests or other activities, teachers will get credit as well. Besides, more and more teachers in college realize that advising students in these mathematical modeling activities not only benefit students but also improve their own academic research competency. Often times, it helps them do better in their own research.

Interviewer: What is students' motivation in participating mathematical modeling contests?

Ye: Students join the contests because of many reasons. The advantages they expected to have if they win in the contests, such as having more chances to be admitted to graduate school or companies, can be a factor. However, considering the every low awarding rate, especially in CUMCM, they must really know mathematical modeling to get good awards. Besides, it might just be their curiosity. Students just entering colleges hear the contests from students in sophomore or junior years. Students who have participated in the contests would tell new students that "you would never know what it was like to compete for three days in a row", or "you would never know how different the questions were in the contests compared to mathematical problems you learned through curriculum". Students who have competed in the contests, no matter what awards they get, feel the benefits and excitement. Then they pass along this excitement. Therefore, students constantly join mathematical modeling contests.

Interview with Professor Yongji Tan

Interviewer: Based on the data from COMAP, I see a sharp increase of number of Chinese participants in MCM/ICM since 2005. Do you remember anything that was done to cause this increase?

Tan: I think there might be two reasons. Initially COMAP posed a limit on the number of teams that from the same institution. Then the limit was loose a little bit. Some colleges might decide to participate in the MCM independently from the university it affiliates to. That might cause the increase in the number of teams from China. Another reason is that the publicity of MCM/ICM and CUMCM both increased due to company's preference in candidates with mathematical modeling experiences. For example, IBM China recruiting team advertised on their recruiting advertisements that they prefer candidates with mathematical modeling experiences. So are Chinese companies. Besides, students who excel in the mathematical modeling contests have an advantage when applying for graduate schools in China and abroad. Most of the participants are not mathematics majors. When they apply for graduate schools, students with awards from mathematical modeling contests are regarded as students with strong mathematical competency by graduate school professors. Therefore, some students participated in the contests with the anticipation of these potential benefits that the contests give to them. That might cause the increase as well. The priority for teachers, however, is to cultivate students' competency in using mathematics.

Interviewer: When did IBM start to sponsor CUMCM? I know that companies like Skyworth, NetEase, and Higher Education Press sponsored or are sponsoring CUMCM since 1999, who financially sponsored the CUMCM before the first enterprise sponsorship came in in 1999?

Tan: I think it's pretty recently, not very long ago. However, they've always been very interested in our contest. They like to recruit students who excelled in the CUMCM or MCM/ICM, and students with mathematical modeling experiences.

Before 1999, we don't have any company or corporation sponsors. However, students who want to participate in the CUMCM didn't pay by themselves. Schools that they were in would pay for them for both CUMCM and MCM/ICM. Therefore, we had funds available for us to operate. Nowadays, since there are so many participants, some schools would ask students to participate first, and if they get awards, school would pay for them. Other schools, however, would do a pre-selection for the contests. Schools would pay the participation of selected teams. Others teams would pay for themselves.

Interviewer: I know that you and professor Wenci Yu offered the earliest mathematical modeling course in China. What made you interest in teaching mathematical modeling courses to students?

Tan: Yeah I was professor Yu's teaching assistant. He taught the course and I helped him answering questions from students.

In terms of mathematical modeling, professor Daqian Li and I along with other scholars have been doing it for a long time. We were working on a petroleum project in 1977. Even earlier, we had been working on many projects that require applying mathematics before Cultural Revolution in 1960s. Unlike nowadays, technology and skills can be imported from abroad. At that time, we had to solve everything by ourselves. Therefore, if they had any problems that need the knowledge of mathematics, they asked us. When I was a student, I began to work on projects like those in 1960s. There were more people working on mathematical applications during the Cultural Revolution.

Interviewer: It is very interesting that you mentioned that more people did mathematical applications during the Cultural Revolution. I know that Hwa Lo-Keng worked on a lot of mathematical modeling problems during that period.

Tan: I had the honor working with him for a while in 1970s. I wrote an article in the notices Chinese Mathematics Society. Right after we learned that there were mathematical modeling courses in other countries, we began to offer our own in 1982. We had our first class of applied mathematics majors in 1979. By the time they were juniors in 1982, they were required to take two mathematical modeling courses. Afterwards, as the reform of setting of college majors, applied mathematics majors and pure mathematics majors were merged for undergraduate students.

Interviewer: Can you talk about your work on training mathematical modeling teachers?

Tan: Professor Shutie Xiao of Tsinghua University began to train mathematical modeling teachers from 1983. Many of his students back then are mathematical modeling experts nowadays.

I did some training to college teachers as well. Teachers of early times were very afraid of mathematical modeling, because they didn't know or knew very little about mathematical modeling when they were students. In addition, mathematical modeling requires knowledge of many branches of mathematics. Often times, college teachers of early age had their specialties, for example some specialized in teaching calculus, other might be good at teaching and doing research on other mathematics subjects. They don't research much on other mathematical subjects. This posed a difficulty for teachers to teach mathematical modeling. I felt that this was the problem to tackle first.

The training in 1980s mainly trained teachers for teaching mathematical modeling courses, considering that schools began to offer mathematical modeling courses already. Trainings in 1990s began to focus not only on teaching mathematical modeling courses but also on advising students in the mathematical modeling contests. Nowadays, national teacher training is held once every two years regularly. In addition to national training, school-wide and religion-wide training were held in between, too. Because the Ministry of Education showed strong support in mathematical modeling activities, sufficient financial support is allocated to this area. Therefore, teachers who participated in the national teacher training don't need to worry about the cost. Schools that teachers affiliated to provided a lot of financial support. Then, provinces began to organize their own teacher training sessions. Some provinces collaborated with others to hold teacher-training sessions together.

Interview with Professor Qiyuan Jiang

Jiang: The CUMCM has been a very popular mathematical modeling activity in China. Chinese teams that have participated in the MCM/ICM have achieved very good awards. However, our work focus is to incorporating the idea of mathematical modeling into K-12 mathematics education. Participating in the mathematical modeling contests is only a way for students to know it. Cultivating students' mathematical modeling competency, and to use this competency to analyze and solve real-world problems is our goal. Nowadays, there are more than 1000 higher education institutions that offer mathematical modeling courses and over 20,000 teams participate the CUMCM every year. The majority of MCM/ICM participants are from China as well. I have to admit that there are students who participate in the mathematical modeling contests expecting the benefits of the awards to facilitate their future career. However, going through a mathematical modeling training is nothing but beneficial.

Interview with Professor Dr. William P. Fox

Interviewer: Since you decide what problems are put in the MCM, how do you make the decision? Where do you get those problems?

Fox: I solicit possible contest problem every year from judges and advisors and keep a running list on files. I have a committee that narrow down the list to the top three in each problem category. There is a smaller sub-committee narrows down the 3 to the top candidates. Then they are reviewed and edited as well as web search for possible solutions. This may cause us to go back and select the next candidate.

Interviewer: What is your opinion about Chinese team's rise?

Fox: Two issues here: One rise is just the sheer numbers (92+% of all papers) as well as China having a preliminary contest so that only the best teams enter. We have noticed that many of the winning colleges such as MIT, Harvard, Harvey Mudd, University of Washington St Louis, NCSMS, etc. are not competing as often. Harvey Mudd did not compete in the MCM for the last 2 years and they have always been an outstanding team. I do not know why although we will be asking these schools why they no longer compete. On the other side, over the last 21 years in the contest, the writing of the Chinese teams has vastly improved. Additionally, the Chinese teams appear to read the commentaries and many teams provide the MCM paper in the format and style the judges desire as well as THEY appear to be using more “real” modeling rather than just throwing tons of theory at the problem without resolution to a solution.

Interviewer: This year, two Chinese professors, came to U.S to judge the Final round. What is the reason for their involvement?

Fox: Since China is such a large contributor, we want to have a Chinese team be actively involved in the TRIAGE judging. This year we did a small experiment with a Chinese team that

went very well. TRIAGE is where 2-3 judges read and judge the paper on a 7-point scale. The TOP papers move to final judging and the remaining all awards rating based upon their normalized total score. It was important for the Chinese judges to be part of the final judging so they realize what our US judges are looking for at the finals, as it will help with TRIAGE. What is the judging process? I heard from Dr. Garfunkel that there are 20 or so judges since the beginning of the competition. Is it always the 20 judges that judge all the papers, or are there other people involved in the judging process? We have three to four Triage sites and judges in other areas judging remotely. Our current sites are California at NPS, Montana at Carroll College, NY at USMA, North Carolina at App. State University, Maryland, and this year China. This is just for the MCM. We judge over 5,500 papers with 2 or more reads each selecting the top 200-250 total papers to come to Monterey for the final judging. Here we bring in 22-26 judges broken into 2 groups: judging A and Judging B. We have a head judge for each that controls the judging. First, they perform a screening round award papers a score from 1-7. Each judge reads

Between 10-12 papers and not only scores but also rates the papers 1 of __, 2 of __ etc. Then the judges discuss the papers and come up with a 100-point scale putting points in areas of the contest format concentrating on discriminators among the papers. Area might include: letters, executive summary, clarity & style, restatement of the problem, assumptions with JUSTIFICATIONS, modeling process, analysis, testing or sensitivity, strengths and weaknesses, etc. Then they read and a score 3-4 rounds to get the list down to the finalists. We make copies of the finalists' papers and all judges read and rate the finalists as Outstanding or Meritorious. The papers rating are placed on a board and the finalist papers are discussed to reach consensus on the top 3-6 papers to be Outstanding.