Computational Thinking Education in the Chinese Mathematics Curriculum: Issues and Challenges

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According to the International Association for the Evaluation of Educational Achievement (IEA)'s First International Mathematics Study (FIMS) (Husen, 1967), mathematics curriculum can be discussed from three levels (i.e., intended, implemented, and attained). The intended curriculum is mainly referred to as mathematics curriculum standards, which set goals and expectations for mathematics education. The implemented curriculum includes mathematics classroom teaching practice, which is based on teachers' knowledge and beliefs (Santos & Cai, 2016). The attained curriculum involves what is learned by students, which can be assessed by students' achievement and attitudes. The three levels of curriculum provide us with a framework to present an overview of computational thinking education in the Chinese mathematics curriculum.

Computing is frequently mentioned in the Chinese mathematics curriculum. For instance, the new standard of the senior high school mathematics curriculum (Ministry of Education, 2020) explains that with the rapid development of computer science and artificial intelligence, the research and application fields of mathematics have been greatly expanded. It lists mathematical operations as one of the core competences and emphasizes that students should learn to design operation programs, which is the basis of solving problems with the use of computers. It also asks students to "accumulate data analysis experience through computer simulation..." (Ministry of Education, 2020, p. 32). However, the term "computational thinking" has yet to appear in the Chinese mathematics curriculum standards. Moreover, while China has issued a series of policies to advocate programing, programming has not been paid special attention to in the mathematics curriculum.

There are some mathematics lesson plans and implementations aiming to develop students' computational thinking, most of which are designed for primary school students (e.g., Miao, 2020). Actually, in some big cities of China (e.g., Shanghai, Beijing, Shenzhen, etc.), we can expect to see innovations such as:

- Some primary schools are already offering experiences in coding and programming courses across all year levels, with strong support from parents.
- Programming gains its popularity in the private out-of-school sector.
- Schools are equipped with more information and communication technologies (e.g., iPad, etc.), where students can easily get access to programming apps (e.g., Scratch).
- Sometimes teachers encourage students to play with Scratch in after-school activities.
- Some parents set high expectations for the programming skills of their children.

However, these innovations contrast with more remote and rural areas where resources and teacher knowledge are more likely to limit innovation. Moreover, it is argued that very few plans and implementations successfully integrate mathematical ideas into computing or programming modules.

Given the important role of teachers' knowledge and belief in the implemented curriculum, a pilot test was conducted in Shanghai to examine teachers' perceptions of using Scratch to teach probability. It was found that:

- Some teachers mentioned that the use of Scratch can empower students to investigate how to solve the problems effectively, indicating they may recognize the importance of computational thinking education.
- Other teachers considered it may not be necessary to use Scratch due to the limited class hours.
- The majority of mathematics teachers said that they were not familiar with Scratch. However, in the pilot test these same teachers could understand and use Scratch program to explore what could be taught with a specific Scratch program.

This pilot test showed differences in mathematics teachers' perceptions of computational thinking education. Particularly, although the policies advocate programming education, most related courses are taking place in out-of-school activities, and school mathematics teachers' unfamiliarity with programming has been a worrying issue.

There appears to be a paucity of validated tools to assess students' computational thinking in China where few researchers have developed and validated scales to evaluate students' computational thinking within a mathematics context. More work is needed to address the gap and explore students' mathematics-specific computational thinking level.

In conclusion, there are many issues and challenges in computational thinking education in China:

- The intended curriculum has not put forward the concept of computational thinking.
- Despite a series of issued policies to advocate programming, programming has not been

paid special attention to in the mathematics curriculum.

- While we can expect to see innovations in big cities exploring the potential of computational thinking, coding and programming in the elementary and middle school years, these innovations are likely to be absent or limited in remote and rural areas.
- Despite its rapid development in commercially funded out-of-school activities, programming currently has limited status in school mathematics classrooms.
- Most Chinese mathematics teachers are not familiar with Scratch or other coding languages that have been developed for younger students, and some do not hold positive attitudes toward computational thinking education.
- There is a lack of validated tools to assess computational thinking within a mathematics context in China.

Since China has issued a series of policies to advocate programming and artificial intelligence education, we are confident that computational thinking education will become more highly valued in mathematics education in the near future.

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中国数学课程中的计算思维教育：问题与挑战

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根据国际教育成就评估协会(IEA)的第一次国际数学测评(FIMS) (Husen, 1967)，数学课程可以从三个层面(即期望、实施和获得)加以进行讨论。期望课程主要包括了数学课程标准，它设定了数学教育的目标和期望。实施课程包括数学课堂教学实践，在这其中，教师知识和信念扮演了很重要的角色(Santos & Cai, 2016)。获得课程主要指学生所学的内容，可以通过学生的成就和态度来评估。这三个层次的课程为我们提供了一个概述中国数学课程中计算思维教育的框架。

"计算"在中国数学课程中经常被提及。例如，《普通高中数学课程标准》(2017年版2020年修订)中提到，随着现代科学技术特别是计算机科学、人工智能的迅猛发展，数学的研究领域与应用领域得到极大拓展。数学运算被列为核心素养之一，学生应该学会设计运算程序，这是计算机解决问题的基础。课标还要求学生"通过……计算机模拟等活动，积累数

据分析的经验(教育部，2020，第32页)”。然而，“计算思维”尚未出现在中国数学课程标准中。此外，虽然中国也出台了一系列政策来提倡编程，但是在数学课程中编程并未得到特别重视。

当前，已有一些旨在培养学生计算思维的数学教学设计和实施，这些教学设计和实施大多是针对小学生设计的 (Miao, 2020)。事实上，在中国的一些大城市(如上海、北京、深圳等)，我们可以看到这样的新变化：

- 在家长的大力支持下，一些小学已经开始提供不同年级的编程实践和编程课程。
- 编程在校外教育中很流行。
- 学校配备了更多的信息和通信技术设备(如iPad等)，学生可以使用编程应用程序(如Scratch)。
- 有时教师鼓励学生在课外活动中玩Scratch。
- 一些家长对孩子的编程技能有很高的期望。

然而，这些大城市中的新变化与偏远和农村地区的情形形成对比，那里的资源和教师知识更有可能使得创新收到束缚。此外，有人认为很少有教学设计和实施成功地将数学思想整合到计算或编程模块中。

考虑到教师的知识和信念在实施的课程中所起的重要作用，我们在上海进行了一项试测，以了解教师对使用Scratch教概率的认识。结果发现：

- 一些教师提到，使用Scratch可以让学生研究如何有效地解决问题，这表明他们可能认识到计算思维教育的重要性。
- 其他一些教师认为，由于上课时间有限，可能没有必要使用Scratch。
- 大多数数学教师表示，他们不熟悉Scratch。然而，在试点测试中，这些教师可以理解并使用Scratch程序，能够探索特定的Scratch程序可以用于什么特定的教学内容。

试测结果表明，数学教师对计算思维教育的认识存在差异。特别是，虽然政策提倡编程教育，但大多数相关课程都是在校外活动中进行的，学校数学教师对编程感到陌生是一个令人担忧的问题。

中国似乎缺乏有效的评估学生计算思维的工具，几乎很少有研究人员开发在数学情境下评估学生计算思维的量表。需要做更多的工作来解决这一问题，并探索数学学科中学生的计算思维水平。

综上所述，中国的计算思维教育可能存在许多问题和挑战：

- 期望课程没有提出计算思维的概念。
- 尽管出台了一系列倡导编程的政策，但在数学课程中编程并未得到特别重视。
- 虽然我们可以看到大城市中小学和中学阶段已有培养学生计算思维、编程能力的创新探索，但这些创新在偏远和农村地区可能比较缺乏或有限。
- 尽管编程在校外商业活动中迅速发展，但在学校数学课堂中却只有有限的地位。
- 中国的数学教师大多不熟悉Scratch或其他针对低年级学生开发的编程语言，有的对计算思维教育的态度并不那么积极。
- 中国缺乏有效的工具来评估数学背景下的计算思维。

由于中国已经出台了一系列政策来倡导编程和人工智能教育，我们有信心，在不久的将来，计算思维教育将在数学教育中将得到越来越多的重视。

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