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# Prescriptive modelling – mathematics teachers' discussions of the BMI

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*The study presented in this paper focuses on primary school teachers engaging with the Body Mass Index (BMI) as part of a university course. The BMI is seen as an example of prescriptive modelling where mathematics is used to keep track of the obesity phenomenon. Four categories are developed to characterize the teachers' discussions: the mathematical aspects of the BMI formula, meta-validation, the consequences of the use of the BMI and other indices in society, as well as on their teachability in the classroom. The results can contribute to developing an understanding of prescriptive modelling processes from a critical perspective.*

*Keywords: Prescriptive modelling, teachers' discussions, critical perspective.*

## Introduction

In this paper, we investigate the processes some in-service teachers go through when they discuss a task about a mathematical model like the BMI and its inclusion in mathematics education. Blum (2015) highlighted four purposes for using mathematical modelling in education: helping students to use mathematical knowledge to make sense of extra mathematical situations (pragmatic); developing argumentation and modelling competencies (formative); exploring the relationship of mathematics to real life and the mathematics' role in shaping society (cultural); and affective issues such as students' interest in mathematics (psychological). The study presented here is particularly situated in the cultural perspective, with a specific focus on a critical view of mathematics' role in society.

In mathematics curricula around the world, such as in the Department of Basic Education (2011) in South Africa, in the Common core state standards initiative (2010) in the USA, and in the Australian curriculum, assessment and reporting authority (2015), modelling and applications play a key role. Similarly, in the mathematics curriculum in Norway, *modelling & applications* is one of six core elements and concerns students' insight on how mathematical models are used to describe everyday life, work-life, and society, as well as students' competence to solve problems from reality by using mathematics (Ministry of Education and Research, 2020). *Democracy & citizenship* is an interdisciplinary topic in mathematics, aiming at students' awareness of the prerequisites and premises of the mathematical models used in society by giving them opportunities to work with real data sets from different fields. Modelling and models are seen as a possibility for students to understand the role of mathematics in society, which is the focus of socio-critical modelling and connected to the cultural arguments for using mathematical modelling in education (Blum, 2015). Barbosa (2006) defined this perspective as modelling as critic, where students' ability to criticize the mathematical models is achieved through the learning of mathematical concepts and modelling competencies.

Niss (2015) distinguished between two types of modelling. In descriptive modelling, the aim is to find a model that can be the answer to a problem from extra-mathematical domains. In prescriptive

modelling, the aim is “to pave the way for taking action based on decisions resulting from a certain kind of mathematical considerations, in other words ‘to change the world’ rather than just ‘to understand the world’” (p. 69). The differences between the two types of modelling centre around the process of modelling. While examples of research in mathematics education focus mainly on descriptive modelling, Niss (2015) called for research on prescriptive modelling because of the impact such modelling has on society. Indices, like the BMI, are examples of prescriptive use of models in our society. We consider the term *index* as a measure of one or several chosen variables connected to a relatively large sample taken from a population or set. BMI is computed as the ratio between the weight ( $m$ ) of a person in kilogram, and the squared height ( $h$ ) in meters:  $m/h^2$ . The BMI values should be between 18.5 to 24.9  $kg/m^2$  for an adult to be considered of normal weight. The model is used extensively e.g. in medical contexts, in keeping track of obesity in individuals and populations, even though it has known limitations (e.g. Hall & Barwell, 2015; Kacerja et al., 2017).

Given the emphasis on modelling in the curricula, mathematics teachers across the world have the task to make mathematical modelling an integral part of students’ learning of mathematics and connect it to students’ development of critical competence and critical citizenship. Following Niss’ (2015) call to focus on prescriptive modelling, we have used the BMI with in-service primary school teachers (grades 1.–7.) to facilitate discussions about the mathematical models’ impact in society. The novelty in our study consists in the use of prescriptive modelling examples in teacher education settings and in collecting empirical data from teachers’ discussions about indices. According to Niss, little is known about the processes when people engage with prescriptive modelling. In this paper, we address this gap by exploring the research question: what characterizes teachers’ discussions about indices and how they, the BMI in particular, can be used in mathematics education? We include a critical mathematics perspective to provide insights into teachers’ understanding of indices’ roles in education and society.

## **Theoretical considerations**

Several researchers have described processes involved in mathematical modelling. Niss (2012) defined the mathematical modelling cycle as the process that starts with “some extra-mathematical domain, moving into some mathematical realm so as to obtain mathematical conclusions and translating these back to the extra-mathematical domain” (p. 50). A model of the modelling cycle which is often referred to is the one by Blum and Leis (2007) with two connected worlds: the mathematics and the real world. Even though there are different modelling cycles presented for descriptive modelling, there are some common elements we find in all of them. An extra-mathematical problem is the starting point. Then through discussions, the problem is translated into a mathematical problem, and mathematical concepts and processes are used to find one or several models as solutions to the problem. An important phase of the modelling process is the de-mathematization of the solution, choosing the best solution (model) while interpreting it in relation to the original problem. If the solution does not make sense for the problem at hand, then a new modelling process must start.

In the socio-critical perspective in modelling, Rosa and Orey (2015) emphasized that “students are expected to understand, reflect, comprehend, analyze, and take action to solve problems taken from

their own reality” (p. 390). They presented a social-critical mathematical modelling cycle, where the real problems are environmental, political, social etc. This focus is in line with the purpose that the socio-critical perspective applies for mathematical modelling, where students should understand the role of mathematics in society, and develop tools for their social-critical efficacy, which they can further apply in other cases as well. In the modelling process, the emphasis is on the individual modeller, and it includes action since the aim is for students to be able to act upon reality.

Doerr, Ärlebäck and Misfeldt (2017) underlined the necessity to have several representations of mathematical modelling to capture the multiplicity of perspectives in mathematics education. The modelling cycles such as the ones by Blum and Leis (2007) and Rosa and Orey (2015) are different and capture different aspects of modelling. They are however not enough to describe students’ working processes when involved with prescriptive modelling (Niss, 2015). By exploring three examples, one of which is the BMI index, Niss argued for some of the limitations of the existing modelling cycles that “become very rudimentary when applied to the BMI model” (p. 71). In our study, while exploring an existing model such as the BMI index, the processes of idealizing the extra-mathematical situation and mathematizing the question posed, become trivial in the sense that the index already exists. As Niss (2015) discussed, the mathematical treatment reduces into replacing the weight and the height of a person into the BMI formula and the de-mathematization process reduces into finding the interval in which the person can be placed based on the number obtained (p. 70–71). Niss (2015) argued that two aspects of the modelling cycle that need to be more developed in existing models to adapt it to prescriptive modelling are meta-validation and critique of the model. Meta-validation requires looking critically at three points: how the modelling results influence the discourse around the problem that was modelled; how the obtained model is compared to other potentially relevant alternatives; and how a change in the requirements influences the modelling and its outcomes. An important contribution from our study is the attention towards teachers’ reflections upon the possible uses of BMI and other indices in their classroom teaching. In this paper, we analyze the teachers’ discussions to characterize how they talk about including the BMI in their teaching and which of these three, and other processes, they go through. This can be seen as a first step in developing an understanding of prescriptive modelling processes and their use in school settings.

## **Method**

The participants in our study were twelve in-service primary school teachers who attended a course on Numeracy across the curriculum. After a teaching session in which one teacher educator presented some uses and misuses of mathematics and the idea of an index, the teachers were divided into two groups and given 60 minutes to work with the BMI task. The task had three sets of questions: the first included questions about what BMI is, the formula and purpose of the BMI, what it measures, and how it could look differently; the second concerned the use of the BMI in different contexts in society and the meanings of the use; and the third focused on the teachers’ thoughts on using indices in their teaching of mathematics, possible reasons for including or excluding such topics in schools, as well as thoughts about similar index-related examples they have used. A picture of a muscular rugby player with a high BMI value was included. The purpose of the BMI task was to structure and guide the discussions towards the mathematics in the indices, the role that indices have in our society, and how teachers see possibilities and challenges in using indices to promote critical thinking with their

students. There were two teacher educators present, one in each group, to observe the discussions and provide a better understanding of what the teachers said, and make sure that the teachers addressed all three sets of questions of the BMI task. After a few minutes of discussion, the groups were given the BMI formula and the cut-off points for six weight categories. The teachers did not follow the structure of the question sheet, they jumped back and forth, but in the end, they had covered all the questions. The discussions were audiotaped and transcribed.

All the authors of this paper worked together through several cycles to analyze the data applying a thematic analysis approach (Braun & Clarke, 2006). The three sets of questions from the question sheet were used as initial, overarching codes, combined with the recommendations by Niss (2015) on meta-validation and critique of the model. The teachers' utterances were analyzed within the framing of the question sheet. We went systematically through some initial parts of the data as a whole group and analyzed the teachers' utterances according to the different codes. Then we continued the coding process in smaller groups to complete the first coding before we as a group compared and refined the coding to generate the final categories. The initial analysis was based on the question sheet, but the succeeding code and retrieve process was based on what the teachers said. The analytical process was therefore twofold in which the main part of the categories and subcategories were generated inductively from the data. We also used premade categories deductively, but also these categories were refined based on what the teachers said.

## Results

In Table 1 below, we present the results – the categories developed from the analysis of the teachers' discussions:

**Table 1: The categories (underlined categories are generated from the data, the others are premade)**

<p><b>A Investigating the index (BMI) concept and formula</b>            A1 What is an index (BMI)            A2 What does it measure?  <u>A3 Variables</u>            A4 Reflections about previous knowledge</p>	<p><b>B Evaluating alternatives (meta-validation)</b>            B1 Formula - how could it look differently  <u>B2 Challenges (neglected variables, measurement inaccuracy etc.)</u>  <u>B3 Point out existing alternatives, compare with alternatives, adapt the index</u></p>
<p><b>C Influence and use in society</b>  <u>C1 Pros of using BMI</u>  <u>C2 Cons of using BMI</u>  <u>C3 Seeking/giving information</u>  <u>C4 Critical</u>  <u>C5 Examples</u></p>	<p><b>D Teachability</b>  <u>D1 Reflections, appropriateness mathematically and thematically</u>  <u>D2 Reflections, appropriateness ethically</u>  <u>D3 Reflections on own knowledge about indices to use them in teaching</u></p>

Categories A (investigating the index) and B (evaluating alternatives) include the teachers' utterances when addressing mainly the first set of questions from the question sheet. Here the meta-validation questions by Niss (2015) are integrated as part of category B to characterize the discussions when teachers look at alternative formulas and point out challenges of the existing formula. Category C (influence and use in society), including critique, stems mainly from the teachers' discussions of the

second set of questions. Here the notion of critique by Niss (2015) is found on discussions where the inappropriate use of the model is criticized (cons) and the results of such use on the discourses around the obesity problem are brought forward. Category D (teachability) is connected to the third set of questions from the question sheet.

### **Investigating the index (BMI) concept and formula (category A)**

The following discussion takes place at the beginning of the discussion in group 1, where the teachers have not yet seen the formula of the BMI (the teachers are anonymized and numbered like this: T1, T2 ...). One of the groups starts the discussion with T1 reading aloud the first question: "What is BMI?" T2 answers "it has something to do with the body", focusing on what the index measures (an A2 category utterance). T3 includes variables, "it has to do with height and weight" (A3) and adds "it is a ratio" (A2). The teachers search for answers together by saying what they think BMI is and what they seem to remember concerning body, height, weight, and ratio. They have not yet seen the formula, but they are closing in as the ratio is between the weight and the square of height.

Towards the end of the group discussions, when talking about how to teach about something like indices, the teachers go back to their initial reflections trying to make sense not only of the BMI but also of what an index is or can be. The question by T4, "When we measure temperature and rainfall, do we work with indices?", is such an example, where the teachers are trying to find out what qualifies to be an index. Similarly, T5 asks: "if you some days in advance get a considerable increase in the air pressure, you quite often see an improvement of the weather [...]. Is that an index?" In this category, the teachers focus on what they know about BMI: what an index is and BMI in particular (A1); discussions about what it actually measures, usually related to different uses of BMI they know about (A2); the variables used to measure it, such as the weight and the height (A3); and in addition, they talk about their previous knowledge (A4) about BMI. The categories from A1-A3 are nuances of teachers' investigations of the BMI as they try to make sense of it. It is difficult to distinguish between the three subcategories as the answers are often intertwined, but they are valuable for being able to nuance the discussions.

### **Evaluating alternatives, meta-validation (category B)**

Another question in the first part of the question sheet asks if the formula could look differently. This question is connected to the meta-validation process as introduced by Niss (2015). To answer the question, the teachers present examples of the different uses of the BMI they know about. One such example is the picture of a rugby player on the question sheet with a muscular body, but with a BMI of 35.98 kg/m<sup>2</sup> is placed in the obese class II according to the cut-offs provided by the BMI model. T4 compares the rugby player with a person "who does not train, that has eaten too much, right. It does not say they are in the same shape; it just says they have the same weight". There is a discussion of muscles weighing more than fat, and how this is not taken into consideration in the BMI formula. This aspect is categorized as a challenge (B2) in terms of neglected variables in the formula.

Other examples, such as the use of weight and height graphs for small children, which even though they are not direct examples of the use of BMI, are referred to in the discussions. These graphs monitor children's development to ensure they grow as they should by comparing a child's measures to the curves of the average children at the same age. In these examples, the teachers focus more on

how the BMI or other indices are used, sometimes without considering geographical factors. Other challenges of the BMI are taken into the discussions, such as measurement inaccuracies (B2) and the effect these can have on the results of the formula. The teachers point out existing alternatives such as waist circumference as a better measure that in some respects takes into account the fat vs muscles issue. They often express the need to combine those two measures to get a better picture of someone's health. These discussions are categorized as B3, as adaptations or alternatives to the BMI.

### **Use and influence in society (category C)**

When the teachers in group 2 discuss the question “What do you think about BMI's role and use in society?”, they use examples to illustrate their answers (C5). Examples vary from personal ones about themselves or their family members, to examples of extreme cases where the formula does not fit. A representative example is T6 saying “I am worried about who shall decide what is right about weight”. T6 gives an example about a 14-year-old girl who was told her weight was a little high, but T6 did not agree with this at all. The example is personal (C5), and T6 is critical (C4) towards the uncritical use of BMI, without considering other factors besides the number from the BMI formula. The critique is also directed to the ones who use the formula and have decision power. The example can also be seen as being against the use of BMI (C2). Among the examples that support the use of the BMI (C1), we find: “I think, from a society perspective and when used sensible, that this is a good tool. What else shall health nurses or I use ... if we don't have standards?” The reasons for accepting the use of the BMI are often connected to the need of having standard tools. In these discussions, the teachers often elaborate on the examples by arguing for why the formula is necessary (C1), or on the contrary, giving reasons for why the formula should not be used (C2). They often ask questions seeking for information or giving information (C3), and it is usually when taking into consideration the different examples that they are critical towards the use of the index (C4).

### **Teachability (category D)**

The last section on the question sheet is connected to the participants' work as teachers and their thoughts about the possible use of indices in school teaching. In the following example from group 2, the participants are trying to make sense of the BMI formula, and T7 says, “I think it is very difficult to think that one also measures area”, and T8 adds, “yes, surface area”. At the same time, the teachers are thinking about their students, and T7 says: “Talking with the students about this and then you take kilos and then you divide it by the area of the body”. T7 is thinking aloud about how to present the topic so that students can make sense of it from a mathematical point of view, which is an example of discussions of the mathematical appropriateness of the BMI (D1). T7 adds immediately after “hm ... there is something wrong, isn't it?” showing uncertainty on how to present it since the teachers themselves are having problems with figuring out how to talk about this with the students (D3).

In the teachers' answers, we identified several reflections about the BMI and other indices' appropriateness to be used in teaching. They discuss both thematic appropriateness in terms of the mathematical level (D2) and ethical appropriateness in terms of BMI representing obesity that can be a sensitive topic for their students (D1). All of these aspects came in addition to their discussions of teachers' knowledge about indices to include them in their teaching (D3). At this point, they often ask themselves the question: what is an index?

## **Discussion and concluding comments**

In this paper, the focus has been on in-service primary school teachers' discussions of the BMI and the use of indices in education. We have looked at the discussions from a critical perspective where the aim is to facilitate an understanding of and criticize the role of mathematics in shaping society. As we found through the categories in the study, the teachers engaged in discussions about the mathematical aspects of the BMI formula and their knowledge of it (A); about alternatives to the BMI and its limitations, or meta-validation processes (B); about the BMI's use and influence in society (C) as well as about teachability of BMI and indices in general (D). These categories were also nuanced with subcategories that capture different aspects of teachers' discussions.

Like in several of the mathematical modelling cycles (e.g. Blum & Leis, 2007; Rosa & Orey, 2015), the starting point of the discussions in our data is an extra-mathematical situation, the BMI and its use in society. However, the discussion of the mathematics in prescriptive modelling is different from the aforementioned descriptive modelling cycles, as also Niss (2015) pointed out. In our data, teachers discuss an existing mathematical formula (categories A and B), by comparing it to alternative models (B3) and pointing out weaknesses such as missing variables (B2). Similarly to the socio-critical modelling cycle (Rosa & Orey, 2015), the teachers discuss the role of the BMI model in society (category C). At this point, our data allowed us to nuance the way teachers did this by weighing pros and cons for using BMI (C1 and C2), by being critical (C4), by seeking further information (C3) and by providing examples (C5). The categories and subcategories made it possible to further develop the aspects of meta-validation (B) and critique of the model (B and C) as processes of the prescriptive modelling cycle that Niss (2015) called for. Our study adds the teachability aspect (D) to prescriptive modelling. Since we work with teachers and their competence to engage students with examples of the uses of mathematics in society, it is important for us as teacher educators to know the teachers' challenges and possibilities for working this way. This adds another perspective for understanding ways of implementing these examples in teacher education and school mathematics.

The categories and subcategories are a step towards finding ways to represent working processes in prescriptive modelling. The importance of such representations was emphasized by Doerr, Ärlebäck and Misfeldt (2017) and Niss (2015). The representations can be used in further research about prescriptive modelling and socio-critical perspectives in modelling, but also for teaching about the mathematics' role in society. The categories show that the teachers were given the possibility to engage in critical discussions of BMI and indices in general, from different angles. Given this possibility, indices can be a starting point to develop a critical perspective in mathematics. As Niss (2015) and Hall and Barwell (2015) also recommended, focusing on such models allows for developing insights both into the mathematical and the societal aspects of the models and their consequences, which lies at the heart of the critical mathematics perspective.

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