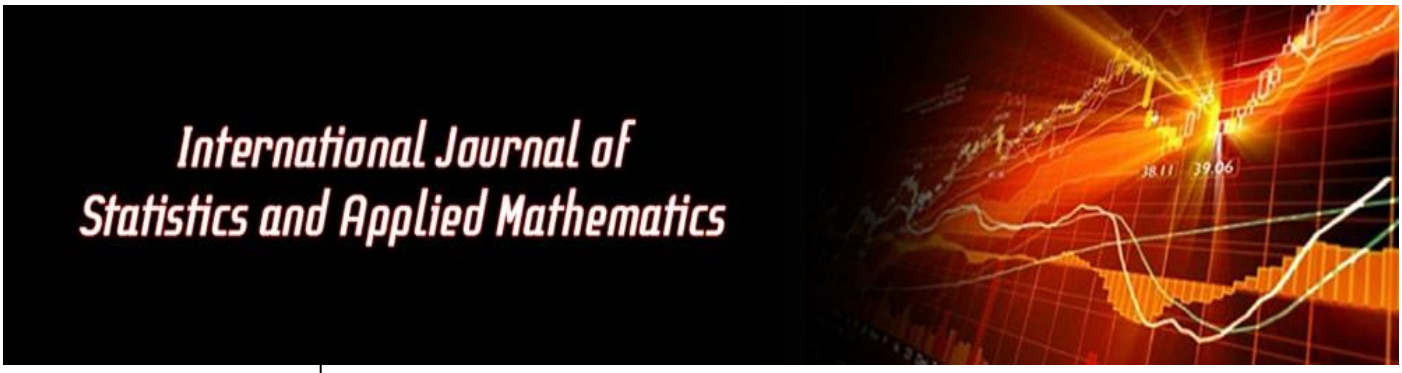
International Journal of Statistics and Applied Mathematics 2018; 3(6): 46-50



ISSN: 2456-1452
Maths 2018; 3(6): 46-50

www.mathsjournal.com
Received: 09-09-2018
Accepted: 10-10-2018

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Complexity level of mathematics: An index based measurement

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DOI: https://doi.org/10.22271/maths.2018.v3.i6a.09

Abstract
Irrespective of varieties in learning attitudes in different societies around the world, it is generally agreed that Mathematics is one of the difficult subjects. Many research articles supported this fact with different intensities at different levels of education and in the context of varied qualities of teaching and learning. This article intended to identify the level of complexity in Mathematics as a subject of learning. Forty Five (45) subject experts were contacted for making a set of parameters based on which Five Hundred Fifty One (551) students were reached. Weightage values on the parameters were set according to the experts' suggestion that were calculated with quantitative responses of the learners to develop an appropriate formula. Weighted Average Cost of Capital (WACC) formula was taken into account as the base of thoughts. Finally, the formula yielded the index value 395.03 to identify the position within the range of complexity level of Mathematics. The formula can be generalized for other similar subjects by aligning the parameters with the context.

Keywords: Index, teaching and learning, complexity level, weightage, WACC

1. Introduction
Mathematics is many a times considered a difficult subject to learn. Several reports and scholarly articles support this fact on the context of Bangladesh as well as other regions of the world. A World Bank report published in 2013 depicts the fact on Bangladesh education that an assessment of literacy and numeracy in grade 5 indicated only 33 percent master Mathematics competencies. At the grade 8 level, competencies in Mathematics is 35 percent [1]. The factors concealed behind difficulty level of Mathematics can be identified mostly by four groups of negative influences which appear to be crucial for learners of Mathematics: influence from society, the socio-cultural context of mathematical thinking, influence of teaching materials, and role of teachers. Lutfuzzaman *et al*. (2006) identified one of the reasons behind receding numbers of science-students is poor quality of Mathematics teaching [2].

The achievements of Mathematics are an unsatisfactory way of arriving at an idea of its importance. It is worthwhile to spend a little thought in getting at the root as to why Mathematics must always remain one of the most important topics for thought. The abstraction has been recognized as one of the most relevant features of Mathematics from a cognitive viewpoint as well as one of the main reasons for failure in Mathematics learning. Eventually, Mathematics is considered as a hard subject [3]. It was reported in 1997 that, the leading characteristic of Mathematics is that it deals with properties and ideas which are applicable to things just because they are things, and apart from any particular feelings, or emotions, or sensation, in any way connected with them [4]. That is what is meant by calling Mathematics an abstract science. The result which we have reached deserves attention. It is natural to think that an abstract science cannot be of much importance in the affairs of human life, because it has been omitted from its consideration everything of real interest.

The concept of mathematical ability cannot be obtained at a certain level since success in Mathematics depends on systematic, cumulative learning, and each new skill needs to be built on a solid foundation laid at earlier stages. People learn new information in the context of their

own prior knowledge. For example in learning new mathematical concepts, students draw on their existing knowledge of related mathematical concepts and procedures that are mostly lead the difficulty level of Mathematics. Understanding how learners build on prior knowledge is crucial to identify how cognitive development occurs [5].

There are mathematical objects in a self-contained universe with respect to reality. Acceptance of Mathematics is contentious from a logical point of view as sense of logical belongingness is not same. Although the syllabus in Mathematics is not updated in accordance to standard level also the scarcity of suitable text books covering the syllabus leads to complexity and difficulty level of Mathematics learning. The syllabus contains no specification of methods to be used by students to formulate and solve context-based problems. The Mathematics syllabus cannot contribute to develop of problem solving skills through the application of their mathematical knowledge and skills to appropriate contexts and situations.

A recent study identified some significant reasons of being Mathematics a difficult subject. Reasons include students are willing to learning by memorizing rather than understanding of what is being taught. The students also lose their enthusiasm in learning Mathematics as they are usually not awarded with partial marks, rather a straight zero for an incorrect answer. Seniors in family or surrounding do not encourage rather catalytically influence to get frightened about Mathematics [3].

2. Literature Review

A national NGO, the Campaign for Popular Education (CAMPE) administered a rigorous research and published the periodical Education Watch titled "The State of Secondary Education: Quality and Equity Challenges", results of which show that the students performed lowest in Mathematics comparing to other three subjects; General Science, Bengali and English. Students also identified Mathematics as the most difficult subject [6]. An investigation done in India in 2015 claimed that, Mathematics is perceived by majority as a difficult subject to learn and to teach. A questionnaire survey was conducted on a random sample of 51 standard IX students to obtain data on their Mathematics related expectancies, task value beliefs, self-efficacy beliefs, epistemological beliefs, goal orientation, interest and anxiety. Among these students, 88% selected Mathematics as the subject hated by them and only 6% report they like Mathematics. Among the 51 students, 82% of students reported that they do not like Mathematics, and among these students 75% has a belief that Mathematics is a difficult subject even as 63% find it as boring and 58% of students fear Mathematics, still, 17% felt learning Mathematics as interesting. Despite this, 82% of students are willing to learn Mathematics [7].

The Programme for International Student Assessment (PISA) investigated in 2012 in Singapore that 70% of disadvantaged students but only 49% of advantaged students reported worrying that it will be difficult for them in Mathematics classes; 47% of disadvantaged students but only 28% of advantaged students reported getting very nervous doing Mathematics problems; and 47% of disadvantaged students but only 23% of advantaged students reported getting very tense when they have to do Mathematics homework [8]. However, on average across OECD countries, 43% of students reported that they agree or strongly agree that they are not good at Mathematics; 59% reported that they get good grades in Mathematics; 37% reported that they understand even the most difficult work; 52% reported that they learn Mathematics quickly; and 38% reported to have always believed that Mathematics is one of their best subjects.

Several other studies reported that, one hundred scripts were sampled related to Mathematics where only fifteen were the top scoring candidates and eighty five candidates were low scorers. It is widely claimed in the literature [9-11]. The Cockcroft Report from the Department of Education and Science published in 1982 showed Brigid Sewell's experience that half of the members of the public she stopped to interview on the street immediately declined and walked away when they learnt it was about Mathematics, indicating a negative reaction [11].

2.1 Mathematics anxiety

Discussions of the nature of Mathematics date back to the fourth century BC. Educators attempt to explain this phenomenon through the widespread beliefs or mathematical myths that "learning Mathematics is a question more of ability than effort" [12]. Scarpello reported in 2007 that seventy-five percent of Americans stop the study of Mathematics and stay away from many careers that related to Mathematics [13]. Mathematics is most liked subject for only 6% students and it is the hated one for 88% students [14]. Feeling Mathematics as difficult for students affects not only their liking of Mathematics but also their perseverance, interest, boredom and self-efficacy beliefs related to Mathematics. Whereas feeling of Mathematics as a difficult subject is significantly associated with low perseverance [15].

Muis investigated and pointed out in 2008 that 20% students rated Mathematics as a very difficult subject, 54% reported medium difficulty, and only 10% consider it as an easy subject. Even around 42% fails to identify the ways to solve problems provided in their textbook [16]. While many students worry about their performance in school, and are anxious when they have to take exams, large proportions of students report feeling anxious about Mathematics in particular [17].

Mathematics anxiety is not merely a psychological phenomenon that limits the ability to solve mathematical problems; individuals who suffer from Mathematics anxiety may experience a physical reaction to Mathematics that can be likened to pain. As a result, individuals who experience Mathematics anxiety generally avoid Mathematics, Mathematics courses and career paths that require the mastery of some mathematical skills [17]. For these individuals, avoiding Mathematics is as natural a response as avoiding pain, since, to them, even the mere anticipation of being confronted with a mathematical problem can be painful [18].

2.2 Preparing an index

According to the definition by the Merriam-Webster Dictionary, index is a number (such as a ratio) derived from a series of observations and used as an indicator or measure. For example, an index can represent health condition of an individual, or investment condition of a capital market, or economic condition of a nation. Every index is developed on the relevant set of parametric values of the certain subject matter. The level of complexity of Mathematics as a subject can be represented by an index. A set of the relevant parameters were taken into consideration for preparing a formula to estimate the index of the hardness of Mathematics. This formula, stated in the section 4.2, was influenced by the widely used weighted average cost of capital (WACC) formula in the field of business and investment [19].

3. Design and Methodology

This research was conducted in an inductive approach. It worked with primary data that were collected through two pre-designed questionnaire; one was designed for subject experts and the other was designed for the academic learners of Mathematics. Subject experts are university teachers who teach Mathematics and various engineering courses for undergraduate students. Academic learners are the students of undergraduate programs who take various Mathematics courses. The following three sections describe the details of design and methodology of this research.

3.1 Study objective

The objective of this study was to find answer of the research question "how complex is Mathematics as a subject?" represented by an index. It was presumed that a numerical value may reflect the degree of difficulty level of the subject. The index was calculated by using a newly developed formula stated in the section 4.2. The parameter values of the method of calculation were collected through a work plan.

3.2 Work plan

The researchers had identified eight different areas of considerations that had influence to the perception of difficulty level of Mathematics. Primarily the list of eight parameters was indentified from the literatures on the subject and findings of researchers previously published through various articles. Secondly, the questionnaire with the list of eight parameters was distributed to the subject experts for their allocations of weightage values for each parameter in the list. One open ended question brought answers from the experts with their own opinions and comments. Thirdly, quantitative data were collected from the learners through another questionnaire. Fourthly, the average weightage values suggested by the experts were combined with raw scores of learners for preparing the intended index. Finally, the calculated result was curbed by including a balancing constant in the index for making it more meaningful.

3.3 Data sample

The sample size was five hundred ninety six. The whole sample was identified in two phases; first was the school of forty five subject experts and the second was the group of five hundred fifty one students at undergraduate level. Experts were chosen on the convenient sampling technique by the researchers. The students were also selected from the classes that researchers were teaching the undergraduate courses of Mathematics. The gender distribution of the sample is shown in the Table-1.

Table 1: Demographic distribution of the sample by gender

Respondents	Male	Female	Total
Subject experts	38	7	45
Undergraduate students	416	135	551
Total	454	142	596

The questionnaire for the experts was designed for collecting the quantitative responses on the weightage calculation and the questionnaire for students was for collecting their quantitative responses from their own experiences. Both of the questionnaires had one open ended question for the qualitative analysis of the study.

4. Data Analysis and Findings

The collected data were analyzed with appropriate statistical tools of software application. Descriptive tools were taken into considerations for calculating the index that is assigned as a numerical value of the difficulty level of Mathematics. Analyses and findings are described in the following two sections, and the third section describes the discussions on the calculated index value.

4.1 Descriptive findings

The descriptive statistics of the two sets of data are given below in Table-2.

Table 2: Descriptive findings of the Experts' data set

Parameter	Experts' responses regarding the weightage on the total of 100%		Students' responses regarding the Likert scale from 1 (low) to 5 (high)	
	Mean (w_i)	Std. Deviation	Mean (v_i)	Std. Deviation
* Abstract subject, not connected to real life and everyday matters	6.20	4.822	2.05	1.382
* Society frightens learners, seniors or elders in family do not encourage	10.22	4.908	4.34	1.016
* Lot of practice needed, also perseverance is a key to success	15.78	5.187	4.63	0.823
* Not possible to learn at a certain level without previous knowledge	9.93	4.361	4.09	1.161
* Partial marks are not given, discouraged by poor scores in exam	9.89	5.028	3.70	0.960
* Based on logic, persons with logical reasons are rare in the society	16.82	6.763	3.72	1.322
* Syllabus is inappropriate and curriculum is disorganized	10.84	4.577	3.64	1.256
* Students depend on memorizing without understanding the methods	20.31	6.273	4.20	1.055
Valid N (List wise)	45		551	

4.2 Index calculation

The index of difficulty level of the subject is calculated by the formula derived as:

$$I_S = \sum_{i=1}^{n} (w_i \times v_i) + C$$

Here, i is the number of the parameters from 1 to n
w_i is the average of weightage from the experts' suggestion on the parameter i
v_i is the mean of responses given by the students on the parameter i
C is the balancing constant

Taking the set of eight parameters in this research, the balancing constant C is estimated with the following formula:

$$C = \sum_{i=1}^{8} \left(\frac{d}{8}\right) \times v_i$$

Here, i is the number of the parameters from 1 to 8
d is the difference of the total of all weightage values from 100%
v_i is the mean of responses given by the students on the parameter i
It was found in this research that, the difference d = 0.1, as the sum of the mean values of experts' responses is 99.9%. So, the balancing constant was calculated as C = 0.38 by using the formula given above. Thus, the Index value of Difficulty level of Mathematics was estimated as:
I_M = 394.65 + 0.38 = 395.03.

4.3 Discussion on index

The weightage of 100% was distributed among eight parameters by the experts and the students' responses were collected on each of these eight parameters from one to five. Therefore, the range of index value is 100 to 500. This whole range was divided into four parts in relation with the literal meaning of the difficulty level. The linear division of the range and the position of the Index are shown in the Figure-1 below.

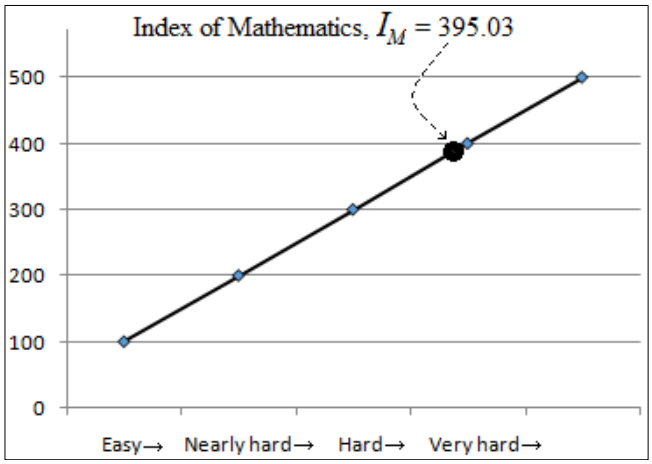

Fig 1: Position of the Index value

Here the ranges of indices are defined according to 100-200 as Easy, 200-300 as nearly hard, 300-400 as Hard, and 400-500 as Very hard. According to the value of the index calculated here (395.03) from the findings of this research, the researchers came to a decision that Mathematics is almost at the beginning of the range of 'very hard'. In other words, Mathematics is at the transition of 'hard' and 'very hard' ranges as a subject of learning.

5. Recommendation

Understanding the level of difficulty level of a subject like Mathematics may help the students to get prepared at an appropriate way. Teachers and guardians can also support the learners in a better way. The following set of recommendations is made based on the qualitative data collected from the experts. The concerned stakeholders may take these into their considerations for better handling about the difficulty level of Mathematics.

1) Teachers may adopt effective methods of teaching by using appropriate support-tools and modern technology so that the students can learn Mathematics better without anxiety.
2) Mathematical topics will be easier to understand if these are presented with real life examples. Learning a theory first, then apply the knowledge for solving real life example is not always effective. Rather, an attempt to solve a real life problem and relating the necessary theory in a guided environment may help students learn Mathematics in a better way.
3) Students are expected to be motivated for practicing Mathematical problems at a regular basis rather than memorizing with a large volume.
4) Policy makers are requested to keep the Mathematics curriculum updated with the concurrent changes in technological advancement in the world.

6. Conclusion

This method of preparing an index for understanding the difficulty level of an academic subject can be used for other science or engineering subjects. Other familiar subjects that are closely related to Mathematics can use the same set of values from the experts' opinions on weightage. Learner's responses can be used according to formula as proposed here and the index of the subject can be calculated. For other subjects from humanities or business disciplines will relate with different parameters and the new set of weightage values can be found accordingly. Then the same formula of index calculation can give us an index for those subjects.

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