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MATHEMATICAL COMPETENCE OF A CHILD – LIFE SUCCESS OF AN ADULT

Tina Bregant*

University Rehabilitation Institute of Republic of Slovenia
Ljubljana, Slovenia

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ABSTRACT

Aims: To provide a brief overview of literature studying the relationship between mathematical competences in childhood and adult life success measured in academic achievements, socioeconomic status, and health measures.

Results: Mathematical competences are determined by the ability to process mathematical symbols and quantity determination which is partially inborn. We can stimulate mathematical abilities by preschool stimulation, which leads to a less difficult behavioural pattern. Better mathematical competences correlate with positive socio-emotional control and positive attitudes towards learning and school which contribute to a more engaged academic life-style. Higher mathematical achievements correlate with better paid positions and also increased gross domestic product (GDP) on the national level. The Study of Mathematically Precocious Youth showed that their adult careers, accomplishments, and psychological well-being far exceeded base-rate expectations. On the other hand, children who are born preterm or near term experience mathematical learning difficulties which, despite the absence of overt health problems, present an obstacle into leading an otherwise fulfilling life.

Conclusions: We can conclude from the findings, that mathematical precocity early in life predicts later creative contributions and leadership in critical occupational roles. Mathematical abilities are partially inborn. However, mathematical literacy can be further nurtured in preschool and school programmes. Since it is connected to a higher prosperity on individual as well as on national level, mathematical intervention should be offered especially to those who are underprivileged. When stimulating mathematical competences, a greater prosperity for all can be anticipated.

KEY WORDS

mathematics, competence, academic achievement, health, PISA

CLASSIFICATION

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*Corresponding author, η: tina.bregant@siol.net; ++386 41 749 061;
Linhartova 51, 1000 Ljubljana, Slovenia

INTRODUCTION

The holy grail of today's education remains the same as decades ago. Educators as well as the parents and students do not know what to learn in order to succeed. We can ask the same question as Eleanor Roosvelt in 1930: "What is the purpose of education? This question agitates scholars, teachers, statesmen, every group, in fact, of thoughtful men and women." [1; p.312].

Parents and teachers want schooling to support children's ability to become lifelong learners who are able to love, work, and act as responsible members of the community [2]. Educational philosophers have answered these questions in a variety of ways, ranging from individual happiness to national and managerial prosperity [3, 4]. General statements about the purpose of education also include teaching children to be socially responsible, healthy, and if possible, happy. It is not clear what skills, knowledge, and dispositions are needed for children to become engaged, responsible, healthy, economically-contributing participants in our society. Researchers tackle this demanding question from various perspectives. Research data can provide some insights into what and how to teach certain strategies and competences which in the long term can lead to the life success.

In the article, I will provide an overview of novel findings which studied the correlation between mathematical competencies in youth and later success in life.

MATHEMATICAL COMPETENCE

Mathematical competence is the ability to develop and apply mathematical thinking in order to solve a range of problems in everyday situations. This competence can be partially learned. However, the capability to process numerical data and infer a mathematical calculation based on that data is also inborn as, for instance, logical and spatial thinking, use of mathematically based presentations (formulas, models, constructs, graphs, charts), etc. [5].

The predominant international trend in mathematics education since World War II can be characterised as "mathematics for all" [6]. However, a twist in society can be observed, showing that even though mathematical knowledge is highly relevant in and to society, many, if not most, people have increasing difficulty at seeing that mathematics is relevant to them as individuals. One of the problems is the implementation of mathematics into everyday life and schooling. The other problem is that in order to do mathematics, one has to understand and use concepts that are considered demanding for an average individual, and who can, in the era of computers, calculators, and other technology, apply mathematical principles without deeper understanding of them.

Mathematical abilities can be seen as a manifestation of brain function. All domains of mathematics (algebra, analysis, geometry, and topology) recruit a bilateral network of prefrontal, parietal, and inferior temporal regions. These areas are activated when numbers are mentally recognised and manipulated. An indepth high-level mathematical thinking requires minimal use of language areas. It recruits circuits initially involved in space and number processing instead. Since these are the circuits which are active during early years of development, this could be the reason, why knowledge of number and space, already during early childhood, predicts later mathematical achievement [7]. As such, mathematical prodigy can be seen in the same viewpoint as sports prodigy; also some students cannot cope with average demands for mathematical competence.

As we are aware, a link between domain-general abilities, such as intelligence or executive functions, and later achievements in mathematics and reading exists [8, 9], we will not argue whether nature or nurture plays a more important role in mathematical achievements. Rather, we take it as an observation that both, nature and nurture, contribute to it. While the ability to detect quantity, for instance, is now accepted as an inborn ability shared among territorial animals and human babies, it can nonetheless be further cultivated [10].

THE IMPACT OF MATHEMATICAL COMPETENCE ON INDIVIDUAL AND SOCIETAL PROSPERITY

Literacy and numeracy problems have a robust structure of life course associations [11]. The data from larger state-populations such as Sweden shows that prolonged education has significant long-term health benefits for all children, such as reduced risk of dying between the ages of 40 and 70 years of age, particularly from cancer, ischaemic heart disease, and accidents [12]. Other data, focusing on the correlation between longer schooling and higher literacy and better numeracy, shows that higher literacy and numeracy mean better health in general [11]. Knowing that numeracy and literacy at school completion predict employability and wages in adulthood [13] and, in addition, basic quantitative and pre-literacy skills at school entry presage numeracy and literacy at school completion [14], we can acknowledge the importance of mathematical skills for academic achievements, general health, and socioeconomic status on individual level.

Intelligence is strongly linked to students' math achievement, but only in the initial development of competence in the subject [15]. Students' competences to learn mathematics involve factors that can be nurtured by education. It is possible, for instance, to stimulate mathematical abilities by preschool programmes, which include interventions directed at interaction between teachers of mathematics and students – the pay-off of which can be observed up to four years after the intervention [16]. Furthermore, when encouraging economically and socially deprivileged students, those interventions lead to less difficult behavioural patterns [17]. In addition, better mathematical competences correlate with positive socio-emotional control and positive attitudes towards learning and school, which contribute to a more engaged academic life-style. Hence, for deprivileged students, educational programs focusing on students' motivation and study skills could be an important way to advance their competency in mathematics as well as their later academic success.

At societal level, available cross-sectional test score data samples from international mathematics and science exams can be used in order to compare mathematics achievements in different countries. The Programme for International Student Assessment (PISA) is a triennial international survey, which aims to evaluate education systems worldwide by testing the skills and knowledge of 15-year-old students [18]. In December 2016 they will announce the latest results from the tests in 2015 which focused on science. In the last round in 2012 they focused on mathematics assessment. The data showed that countries with a higher gross domestic product (GDP per capita) seem to have a relatively higher advantage and have reached higher scores on mathematics testing. It has also been observed that one standard deviation increase in educational test scores in a particular nation is estimated to increase that nation's per capita income growth by roughly 1,4 % per year [19].

The PISA 2012 assessment also questioned students' approach to the subject. Three distinct learning styles were identified which correlated with achievement [20]. Some students relied predominantly on memorisation. They indicated that they grasped new topics in math by repeating problems over and over and trying to learn methods "by heart". Other students tackled new concepts more thoughtfully, relating them to those they already had mastered. The third group followed the so-called self-monitoring approach. They continuously evaluated their own understanding and focused their attention on concepts they had not yet learned. Those who used memorisation, turned out to be the lowest achievers, and countries with a high numbers of "memorisers" – the U.S. was in the top third – also had the highest proportion of teenagers doing poorly on the PISA mathematics assessment. Memorisers and self-monitoring students differed substantially in their mathematical knowledge. In France and Japan, for example, pupils who combined self-monitoring and relational strategies outscored students using memorisation by more than a year's worth of schooling. The data are congruent with other data. Performance measure on the PALMA Mathematics Achievement Test (basic arithmetic, algebra, and geometry) shows that students with higher achievements believe that the more they practice and use in-depth study techniques, the better at mathematics they get, while lower achievers rely more on memorisation when studying [15]. We can conclude, that mathematical knowledge which is learnt by in-depth study techniques leads to a higher achievement. Higher achievements are generally observed in countries with higher general prosperity.

MATHEMATICS PRODIGY

Two cohorts of intellectually talented teenagers were identified in the 1970s as being in the top 1 % of mathematical reasoning ability at Vanderbilt University [21]. The talents were followed for four decades and data on their careers, accomplishments, psychological well-being, families, and life style were collected. Their accomplishments far exceeded base-rate expectations. In the group of 1650 students 4,1 % had earned tenure at a major research university, 2,3 % were top executives at "name brand" or Fortune 500 companies, and 2,4 % were attorneys at major firms or organisations. Participants had published 85 books and 7 572 refereed articles, secured 681 patents, and amassed $358 million in grants. The main difference between men and women was that women expressed stronger preferences for and devoted more time to advancing family and community, compared with the men, but reported the same level of life satisfaction.

MATHEMATICAL LEARNING DIFFICULTIES IN CHILDREN WITH PERINATAL BRAIN INJURY

Disturbed perinatal brain development affects the outcome of preterm and term infants more than we previously thought. Brain injury in infants is of significant public health importance because of large number of survivors and the disabilities they face. The majority of affected infants come from preterm births, which occur at a rate of 12,3 % in the year 2006 for the USA [22]. However, 1 to6 per 1000 live births is attributed to perinatal hypoxia-ischaemia (HIE) which affects mainly term infants [23]. Most severe forms of HIE carry higher risk for neurodevelopmental disability while milder forms carry higher risk for cognitive disorders [24].

When we followed a cohort of near term born infants with HIE we analysed a large spectrum of long term morbidity in survivors ranging from mild motor and cognitive deficits to cerebral palsy and severe cognitive deficits. This has important implications for the prediction of outcome (specific types of cerebral palsy such as hemiplegia, bilateral hemiplegia, severe learning disorder etc.) and also serves as indication for intervention [25]. In our group, those adolescents with mild HIE reported good quality of life and minor motor deficits. However, loss of grey matter volume in specific brain regions, especially in hippocampus and right temporal lobe, was recorded [26]. When investigating further, we found out that several adolescents in our group had problems with mathematics. We discovered that they use different arithmetic processes and simple mathematical knowledge, which was learnt by heart. Furthermore, they exhibited specific eye-movements when performing simple arithmetic [27]. By using the eyetracker we compared subtracting two-digit numbers in healthy and HIE groups. No significant difference in correctness of answers between studied cohorts was found. However, HIE group calculated longer, with longer reaction times, too. Borrow problem had a significant impact on correctness of answers, but only in healthy group. HIE adolescents did not distinguish tasks with borrow or no-borrow problem. We could speculate that HIE adolescents did not perceive the difficulties of tasks, perhaps they calculated more automatically – by heart. In HIE group the durations of fixations were shorter than in healthy cohort implicating shorter span of attention. Our data implicate that term children with perinatal injury could have problems with acquiring mathematical competence due to slower processing even of simple tasks, solving the problems "by heart" and by having problems with attention. These problems can contribute and aggravate learning difficulties.

Studies show that very and extremely preterm children, born before 34 weeks of gestation, are more likely to have cognitive deficits and learning difficulties than children born at term [28]. The risk for such difficulties increases with decreasing gestation at birth. Furthermore, learning difficulties of preterm primary school children, in particular difficulties with mathematics, are associated with lower wealth in adulthood [29]. This is exactly what we are worried about regarding our HIE survivors, who otherwise reported good health but difficulties at school with mathematics.

Since the number of preterm births has increased in the last two decades, and more preterm children are surviving due to improved neonatal care, their outcomes should be improved. However, the prevalence of cognitive, behavioural and emotional problems in preterm populations has not changed. Furthermore, specific learning problems including difficulties with mathematics, visual-spatial skills, memory, and attention are increasingly recognised.

Significance of these long term consequences, and how to deal with them, is not well studied. The causes and the manifestation of specific learning difficulties with mathematics still need to be elucidated in preterm and near term groups of infants. Specific interventions in acquiring mathematical competence may be designed in order to enable these children to increase their mathematical literacy.

CONCLUSIONS

Focusing on math as a skill, and how to master it, could help increase our mathematical literacy and encourage more young people to enter the field. While intelligence, as assessed by IQ tests, is correlated with mathematical competence in the early stages of development, motivation and study skills play a more important role in students' subsequent growth in mathematical competences.

Moreover, by increasing mathematical competences in a population, their socio-economic prosperity could also be improved. However, one has to be aware of drawing conclusions which are partial or assuming causation from correlation, or the inaccuracies that can result when a geographical region is used as the unit of analysis. A recently published study "discovered" a correlation between chocolate consumption and the number of Nobel laureates in a country [30] and could, as such, give a false impression that there is, in fact, a causal relation between eating chocolate and the number of Nobel laureates. All in all, the study clearly shows how inferring from correlation to causation, especially when testing for complex correlations, should be done carefully.

The relation between mathematical thinking and life success represents a complex correlation. Numerous longitudinal, long term studies show that the correlation exists. Further studies are needed, but it seems reasonable to claim that the development of mathematical competence should be encouraged for everyone.

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