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The Sense of Didactic Self-efficacy in Mathematics Teachers with Various Personal Theories Regarding Gender Differences and Mathematical Giftedness

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Abstract

The paper presents a quasi-experimental study clarifying the variability of maths teachers' sense of self-efficacy based on their personal theories regarding differences in mathematical giftedness between girls and boys. Didactic self-efficacy is understood as a judgment of the possibility of teaching all learners. A 'personal theory' is understood as a verbalized group of judgments regarding the source of mathematical giftedness among girls and boys. The two variables, i.e. 'personal theories' and 'biological sex', were introduced in a two-factor NOVA model. A strong main effect for 'personal theories' was noted, while there was no statistically significant effect for biological sex. The result shows that gender stereotypes can weaken teachers' sense of didactic self-efficacy, and consequently block pupils' opportunity for development.

Keywords: *didactic self-efficacy, mathematics teachers, teachers' personal theories, gender differences, mathematical giftedness*

Introduction

The sense of self-efficacy is, according to A. Bandura, a variable responsible for the effects of one's behavior (Bandura, 1994). How one sees one's own ability to accomplish tasks has a bearing on how they are fulfilled (Bandura, 1986). Literature on the subject presents two different ways of understanding the term

self-efficacy. It is treated as a generalized personality disposition expressing in a fixed manner the assessment of the ability to behave effectively. This so-called generalized self-efficacy is not subject to differentiation based on the type of the task considered. The dispositions are comprised of the following constructs of a lower level of generality: the ability to postpone gratification, belief in oneself, developmental motivation and persistence, the ability to translate aims into a plan of action, immunity to the effects of frustration and stress, a sense of control and inner-direction. These constructions are subject to operationalization in the form of a test used to measure self-efficacy (Chomczynska-Rubacha&Rubacha, 2013). This variable is understood differently in the social cognitive theory, where self-efficacy is regarded as a judgment regarding the fulfillment of specific tasks under a concrete set of conditions (Bussey, Bandura, 1999). This means that self-efficacy varies for different types of action. This approach, known as microanalysis, allows for a definition of teachers' sense of didactic self-efficacy as a judgment of fulfilling those tasks deriving from the didactic processes, such as successful explanation of difficult problems to pupils, maintaining discipline in class or facilitating creativity in the classroom. It is in the latter understanding of the term that we will use the idea of self-efficacy in this paper, applying it to mathematics teachers and their assessment of their own ability to teach all their pupils. This is an issue particularly related to the 'hard sciences,' in which the idea of achievement is associated with mathematical giftedness. In general population, mathematical giftedness is dispersed normally, while in smaller populations it often skews in the direction of aptitudes below one standard deviation. Achievements are the result of giftedness, students' work and environmental factors, such as those related to the didactic process itself. From an objective standpoint, students' achievement in the form of, e.g., test results is a measure of the teacher's success, while subjectively the measure of success is the teacher's personal sense of didactic effectiveness. According to Bandura, this sense of effectiveness, on the one hand, relies on several factors, such as one's attitude, previous success in a given task, and the perception of different aspects connected to it. On the other hand, however, one's sense of didactic effectiveness also influences the actual fulfillment of the task (Bandura, 1994).

This paper concerns the changes in maths teachers' sense of didactic self-efficacy based on how they perceive one of the aspects connected to teaching, namely the differences in mathematical giftedness with regard to biological sex. The literature on the topic of mathematical aptitude and sex spans several decades and is systematized in the framework of meta-analyses conducted, on average, every 8 years. In the first years of research, the dominating explanation of differences between the sexes was based on the designated anatomical differences found in

the brain structure of men and women, as well as the dynamics of hormones, in favor of men (Lubinski, Bebnow, 1992). With the accumulation of numerous empirical studies, the focal point shifted to the process of socialization, which imparts different experiences to each of the sexes. It is important to also consider the experiences of socialization from the perspective of the structure and function of mathematical giftedness. Within the scope of these experiences lie: carrying out of logical operations on mathematical (numerical, spatial, symbolic) material, reduction of the reasoning process, pliability of thought, spatial orientation, and ability to change one's way of thinking (McClellan, 1985). Analysis has shown that socialization does not stimulate these structures in girls to the same extent as it does in boys. To be sure, during initial and elementary education boys achieve lower marks than girls. However, with the passing of time this situation is reversed. This is especially true when it comes to 'hard science' subjects (Clarricates, 1983). Detailed analysis of the situation in England shows that achievements of both sexes are similar up until the age of 11. However, starting with the O-level exams, or at the age of 16, around twice as many boys choose science-based subjects than girls, who generally situate themselves within the humanities. When it comes to the A-levels (at the age of 18), the ratio of boys to girls choosing hard science subjects is as follows: mathematics 4:1, chemistry 3:1, physics 6:1 (Meighan&Herber, 2007). Referencing the data, the authors of the study explain this state of affairs by invoking the difference in spatial ability between boys and girls, in favor of boys. The girls who have had socialization experiences similar to boys (girls who played with blocks with boys, or managed to cover a large area while playing, e.g., boys' younger sisters), achieve as good results in mathematics and technical drawing as boys do. Girls, however, are not encouraged by teachers to choose, e.g., technical drawing as a path, and so they do not go on to develop corresponding skills. The resultant shortfall is erroneously identified as biological and irremediable. This label of being spatially and mathematically ungifted lowers girls' self-esteem discourages them from choosing the hard sciences as subjects. The second observation, explaining the described effect, is connected to the amount of time each of the sexes receives from teachers during lessons. Studies show that maths teachers dedicate 10% more time to helping male pupils than female pupils, while the opposite is the case when it comes to first language lessons (Kaplan, 1990). In this way, boys have decidedly more opportunity, e.g. in computer science lessons, to practice competences typical of the hard sciences (Whyld, 1983). And finally, a great deal of insight into the nature of factors responsible for differences in ability is provided by studies examining the school system. In coeducational schools, teachers pay relatively more attention to boys than girls, leading to the

latter achieving lower marks and to their subsequent avoidance of the hard science subjects. On the other hand, in all-girl schools achievement as well as engagement in the hard sciences does not diverge from that of boys at single-sex and co-educational schools (Haag 2002, Francis, 2000).

It appears that gender stereotypes have an impact on these types of socialization practices, i.e., associating femininity with a lack of mathematical giftedness yet strong literary abilities, which is supposed to be justified by the choices women make as to their future profession. Ultimately, the problem of the nature of inter-sexual differences in mathematical giftedness has increasingly been studied in environmental research, which reveals the mechanism blocking girls from developing certain abilities. What does not show up, however, is biological evidence for the existence of mechanisms which translate anatomical and hormonal differences into people's mental activity. Nevertheless, it is difficult to claim that these differences have been scientifically explained. This fact, unfortunately, does not influence the way in which stereotypes are employed in judging the abilities of boys and girls. Such an example are teachers' personal theories regarding the source of perceived differences between boys' and girls' abilities. These are mental constructs similar to prejudice, unsupported by scientific evidence, and relatively unequivocal in their assessment of a given fragment of reality. In our case, it is a question of locating the reason for the differences between girls and boys in mathematical giftedness. These differences can be attributed to biology or to the environment. If teachers believe that the differences are biologically determined, they might be more inclined to reduce their engagement with girls. If, however, they believe that the differences are the result of environmental constraints, they might be more inclined to intensify their engagement. The purpose of our study is to see if we find variations in math teachers' sense of didactic self-efficacy depending on which theory they hold to account for the difference in mathematical giftedness in girls and boys. The above-presented problem undergoes operationalization in the following paragraph.

Research Methodology

Research General Background

The basis of our study is Albert Bandura's general social cognitive theory, both with regard to maths teachers' sense of didactic self-efficacy (the random variable), as well as personal theories as to the formation of differences in mathematical giftedness between girls and boys (the constant variable). What we understand

by the sense of didactic self-efficacy is a judgment concerning the fulfillment of requirements set down in tasks the basis of which is to teach maths to all pupils. Judgments will be made on the basis of four areas of mathematical competence: performance of logical operations on mathematical material (numerical, spatial, symbolic), reduction of the reasoning process, pliability of thought, and ability to change one's way of thinking. A personal theory is defined as a verbalized group of judgments regarding a chosen topic. According to Bussey and Bandura's (1999) social cognitive theory of gender development, a gender role is defined at the level of 'conceptions' and 'behavior connected with gender'. Personal theories regarding gender form 'conceptions of roles' for themselves, but also perceptions and judgments about the conceptions of others. For the purposes of the research, we are concerned here with the personal theory regarding the reason for differences in mathematical giftedness between girls and boys. We expect to obtain an explanation of the variability of self-efficacy based on the personal theory of the gender differences discussed.

Research Sample

123 maths teachers, 60 women and 63 men, were selected from secondary schools across the Lesser Poland Province. The sampling of participants within the framework of second type randomization (for the control groups) was in part random and in part non-random. Having previously assessed the personal theories pertaining to the cause of differences in mathematical giftedness between boys and girls, we chose 45 participants from each diagnostic group: A – the biological group, B – the environmental group. The number of participants in the control group corresponded to the number of participants in the smaller group, which was made up of teachers who situated the difference in environmental factors. Thus, 45 participants out of 78 were included in group A, while all of group B was included in the sample studied. This procedure allowed for the maximization of the sample size and the selection of equinumerous control groups. Other differentiating variables, such as teachers' age, work experience, and type of school, were not taken into account.

Instrument and Procedures

The study was conducted with the use of the quantitative method. It is a practical, diagnostic study with a quasi-experimental design. The sense of didactic self-efficacy was measured as a variable using the test method. The participants were asked to what extent they could manage to teach the following maths areas to each student: how to perform logical operations on numerical, spatial, symbolic material, procedures for shortening the process of reasoning, coming up with

qualitatively different ideas to solve problems, changing one's way of thinking while in the process of searching for a solution. Each question was answered with the use of a four-point scale: 1 – definitely not; 2 – rather not; 3 – rather yes; 4 definitely yes. The raw score in the form of a total was normalized using the average and standard deviation, which allowed us to determine three variant variables: weak, average, and strong sense of didactic self-efficacy. We decided on this way of operationalizing the variable 'sense of didactic self-efficacy' because the planned methods of data analysis required a measurement on the interval scale (discussed in the next paragraph). We used Bandura's classical micro-analytical measurement scheme.

The personal theories regarding the source of differences in mathematical giftedness between girls and boys was diagnosed with the use of structured interviews focusing on the personal theories. The study was conducted in two sessions. In the first one, the participants formulated their claims into a coherent whole and examined them for sound logic. This resulted in logically consistent constructs. Next, in the second session, the participants were presented with strips of paper with all the claims included, and a 'discussion with the theory' followed, with the participants either accepting or rejecting the counter-arguments presented by the researcher. In the following step, the participants definitively formulated their theories, on the basis of which they were assigned to either group A or B. Group A was made up of the participants who associated the source of the differences strictly with biological factors as well as the participants who made room for environmental factors, but considered them to be minor in comparison and without an impact on the biological ones. Group B consisted of the maths teachers who saw the source of differences solely in environmental factors as well as those who also identified a biological source, yet believed that it was not 'predestined' and the possible differences could be minimized in class.

First, the personal theories were measured, a few days after which data pertaining to didactic self-efficacy was collected. The sex of the participants was also registered, as it was introduced into the data analysis model. The data was organized using SPSS.

Data Analysis

Data analysis was designed as a two-factor analysis of variance model, UNI-ANOVA. The random variable was didactic self-efficacy. Personal theories and biological sex were variables playing the role of factors. Prior to going ahead with the analysis, the interval level of measurement for self-efficacy was secured and Levene's test was used to verify the assumption of homogeneity of variance.

Research Results

The first step tested the homogeneity of variance. With the null hypothesis, stating that the error variance of the (dependent) random variable is equal in all groups, the result presented in Table 1 was obtained. This result allowed for the performance of a two-factor analysis of variance of the data collected.

Table 1. Levene's Test for Equality of Error Variances.
Dependent variable: sense of didactic self-efficacy

F	df1	df2	significance
1.241	4	85	.300

Source: own analysis

The results of UNIANOVA presented in Table 2 show that a strong main effect was noted for the personal theory variable regarding the source of differences in mathematical giftedness between girls and boys, with a high Eta squared .098, which makes the measurement conditional on the sample size, with $p < .05$. By contrast, no statistically significant effect was noted for biological sex; thus there were also no significant interactive effects.

Table 2. Tests of inter-object effects for the dependent variable:
sense of didactic self-efficacy

Source	Type III sum of squares	df	Mean square	F	significance	Partial Eta squared	
Constant	Hypothesis	129.267	1	129.267	126.418	.006	.983
	Error	2.205	2.157	1.023 ^a			
otr	Hypothesis	19.155	2	9.577	42.016	.000	.659
	Error	9.922	43.529	.228 ^b			
sex	Hypothesis	1.720	1	1.720	38.363	.102	.975
	Error	.045	1	.045 ^c			
otr *	Hypothesis	.045	1	.045	.090	.765	.001
sex	Error	42.468	85	.500 ^d			

Source: own analysis

There is no basis, therefore, for looking for simple effects. The mean for the sense of didactic self-efficacy in group A (biological source of differences) amounts to 1.52 (interval 1.0–3.0) with a standard deviation of .7, and in group B (environmental source of differences) the mean was 2.44 with a standard deviation of .69.

Discussion

Basing our study on Bandura's social cognitive theory, we investigated the variability of a sense of didactic self-efficacy with regards to a chosen aspect of perceiving the situation, with reference to which we measured the sense of self-efficacy. This set up theoretically secures the whole study. The aspect in question was the participants' perception of the source of differences in mathematical giftedness between girls and boys. Teachers who believed that the differences were determined environmentally could, in reality, simultaneously be motivated to treat girls and boys equally during lessons. One can assume that these teachers recognize the space for such work, that they see themselves as one of the elements forming the environment, responsible for the mathematical achievements of their female pupils. Therefore, if they put the same amount of effort in teaching both sexes, and this would have to be a considerable amount, they could expect to succeed. This, again, is – according to Bandura – one of the most important predictors of a subsequent sense of self-efficacy (1986). In social cognitive theory, however, the sense of self-efficacy is treated as a factor conducive to the achievement of intended results. This interpretation sheds light on the circular dependency elucidating the noted effect. However, if the teacher fails to see the possibility of teaching girls effectively, but follows the stereotypes associated with gender with regard to maths, they most likely will not teach their pupils effectively because they generally will not make the effort. Such examples, taken from the literature, were presented in the first part of this paper. According to Bandura's theory, these examples also should not lead to a sense of self-efficacy, and the results obtained here can be explained in precisely the same manner.

The second effect, the effect of biological sex, turned out to be statistically insignificant. The absence of differences based on teachers' sex is not explained easily by Bandura's theories. One could expect that female teachers, given their own positive experiences with maths, would be an exception to the rule. They are, as it were, proof to themselves that biological factors had no negative impact on

their mathematical giftedness, and that environmental factors undoubtedly helped them. Had sex turned out to be a significant factor, the analysis of interactive and simple effects could have formed the basis for an explanation. This situation points to a need for further studies, not so much dealing with female maths teachers' self-efficacy, but rather with the mechanisms guiding them to adopt gender stereotypes. The force of the former seems, as it were, stronger than these teachers' self-knowledge.

Conclusions

The results of our study show that maths teachers' sense of self-efficacy changes based on how they perceive the wider context of teaching mathematics. Personal theories, based on incomplete knowledge, and as it turned out in the study, based also on prejudice, can modify the subjective sense of educational self-agency, but also – as evidenced by Bandura (1996) – can indirectly modify the results of pedagogical activity. An interesting thread which emerged during the study was gender stereotypes. Harboring and being guided by these stereotypes unfortunately confirms and reinforces them. Efforts to thwart these stereotypes give us a real picture of the world. The Ministry of Science and Higher Education in Poland launched a campaign in 2008: 'Girls at universities of technology'. In support of this campaign, events breaking the femininity stereotype pertaining to technical and mathematical giftedness were organized in high schools, scholarship funds for candidates applying for hard science majors were established, and other similar activities were organized. The result of this endeavor has been a steady increase in the number of women among students of the sciences and those attending universities of technology. This situation shows that, regardless of how the difference between girls and boys in mathematical and technical giftedness is explained, the relation between teachers and stereotypes is key when it comes to developing girls' mathematical abilities. Two recommendations stem from this. The first regards scientific studies which should also be conducted using qualitative strategies. This would allow for better acquaintance with and clarification of the personal motives for yielding to stereotypes in education generally, and more specifically in mathematics education. The second can be addressed to institutions and individuals organizing pedagogical preparation for teachers. They should include classes on 'gender studies' in their programs, not to mention anti-discrimination training sessions, both of which could provide a cognitive and emotional counterbalance to stereotypical simplifications.

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