Teachers' conceptions about students' mathematical reasoning: Gendered or not?

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Abstract. This study looks at how upper secondary school teachers gender stereotype aspects of students' mathematical reasoning. Girls were attributed gender symbols including insecurity, use of standard methods and imitative reasoning. Boys were assigned the symbols such as multiple strategies especially on the calculator, guessing and chance-taking.

Contents

1. Introduction

In Sweden at upper secondary level, the differences between boys and girls' performance in various mathematical courses are marginal. However, there is still a strong segregation especially in undergraduate and graduate education, among academics and as a professional field (Brandell et al., 2007). This segregation starts already at upper secondary level where fewer females than males study the more advanced mathematics courses. Previous research seems to show that a view of mathematics as a male domain exists among students at upper secondary school in Sweden, particularly in the Natural Science programme (Brandell et al., 2005). Brandell et al (ibid.) conclude that by combining their results there is "a picture with a clear gender marking of mathematics as male"[1](p. 84). Motivational beliefs, such as mathematics being enjoyable and a subject you will need for the future are especially ascribed to males. Boys are thought of as successful in mathematics and therefore logical and clever. Girl are considered diligent and hardworking, but since they are seen to have to work more and harder than boys, they are therefore not as clever (Brandell et al., 2005). Perceptions like this contribute to the thought of mathematics as a male domain.

But what about conceptions concerning mathematical reasoning? Is there a difference between what is attributed to boys and girls task solving?

Research looking at younger children (grade 1-3) gives evidence towards the claim that some gender differences exist in problem-solving strategies (Carr and Jessup, 1997). Girls tend to use observable strategies, while boys turn to mental ones. By the end of grade three, girls were more likely to use the strategies presented by the teacher and boys to invent their own ones. There was a link to the development of their conceptual understanding, where the boys inventions of algorithms was a reflection of a previous developed understanding. Girls, on the other hand, started to use the standard algorithm before demonstrating a conceptual understanding (Fennema et al., 1998). Research looking at high- ability secondary school students reports similar results (Gallagher and DeLisi, 1994). Boys are also considered being risk- takers and gamblers as they show greater guessing tendencies than girls do (Ben-Shakhar and Sinai, 1991). There is also some evidence that confidence (a property more likely

[1]Author's translation from Swedish

to be male than female) is related to mathematical achievement (Tartre and Fennema, 1995).

Using these results as a background and with a theoretical framework for looking at mathematical reasoning combined with a gender perspective, in this article I study upper secondary school teachers' conceptions about gender and aspects of students' mathematical reasoning.

2. Theoretical background

2.1. Gender perspective. To enable a discussion about gender and reasoning, I choose a perspective which suits the purpose of the study and where the focus is on the result of having a specific gender in a specific situation. This is in contrast with for example seeing boys and girls as different independent of the context or seeing sex- differences as a biological difference.

Gender is then thought of as an "analytic category which humans think about and organize their social activity rather than as a natural consequence of sex difference" (p. 17) (Harding, 1986). People have through history assigned gender to non-humans entities such as ships, countries and hurricanes. Here, I see the assignment in two ways: (1) you can attribute a gender to an object, characteristics or an action (e.g. a ship is female); or, (2) you can attribute an object, characteristic or an action to a gender (e.g. boys are more likely to use the graphic calculator). In both these cases, an element (object, characteristics or action) is identified and picked out as typical with the assignment to a specific gender.

Gender is asymmetrical; human thought, social organisation and individual identity and behaviour are categorised in an order making some more a 'boy-thing' or a 'girl- thing'. Harding (1986) emphasises the ranking within the asymmetrical organisation of gender saying "part of what it means to become gendered as masculine is to become that kind of social person who is valued more highly than woman" (p. 104).

Here, I see gender as a fundamental structure that constantly reproduces and changes, containing three aspects (Harding, 1986): (1) gender symbolism (or gender totemism); (2) gender structure; and (3) individual gender. By using these three aspects, it is easier to separate what is related to the structure (e.g. younger children are taught by women, the majority of the professors in mathematics are men), to the symbols in thoughts, word and pictures (e.g. males are considered being more logical than females) and to the individual gender. The structure confirms the symbolism, which then supports the structure. Both will influence the individual's choices. So even though most teachers at a lower level are female, and girls will perform as good or better than boys at compulsory school, the overall system through text books, teacher education and teaching practice will affect the students' view not only of mathematics as a subject but also of who could be a mathematician. For example, negative perceptions held by underachieving girls was considered a product of the type of school mathematics that was taught in the UK and USA (Boaler, 1997). Harding concluded (1986) (p.53):

> The proponents of equity recommended a variety of affirmitative action strategies and resocialization practices for female children in order to increase the representation of women in science. But these critiques often fail to see that the division of labor by gender in the larger society and the gender symbolism in which science participates are equally responsible for the small number of women in science and for the fact that girls usually do not want to develop skills and behaviors considered necessary for success in science.

As stated earlier, students at upper secondary school especially at the Natural Science programme perceive mathematics as a male domain (Brandell et al., 2005), which means that the structure, the symbols and the identity are all more likely to be pro-male. Such an environment could be connected to a potential underperformance by women since they are under a stereotype threat (Cadinu et al., 2005).

2.2. Mathematical reasoning. In order to talk about different types of mathematical reasoning, I turn to Lithner's work (2008). There are two major arguments for using this framework: (1) the focus is on mathematics, the intrinsic mathematical properties; and (2) reasoning, the line of thought, is not restricted to deductive mathematical reasoning or proofs. It is used to highlight the argumentation for the decisions made while solving problematic situations. This framework is a part of the conceptual framework used to capture the relevant reasoning phenomena and to provide the notions needed to communicate this.

Here, reasoning is defined as the line of thought adopted to produce assertions and reach conclusions in task solving. It doesn't have to be based on formal logic, and it may even be incorrect. The choice is to see reasoning as a product that appears in the form of a sequence of reasoning, starting with a task (e.g. exercises, tests etc.) and ends with an answer. Four steps describe the structure of reasoning: first a Problematic Situation (PS) is met; a Strategy Choice (SC) is made in order to solve the problematic situation; the Strategy is Implemented (SI); and finally, a Conclusion (C) is made. There are two main types of reasoning: creative and imitative mathematical reasoning.

Reasoning is defined as *Creative Mathematically Founded Reasoning* (CR) if it fulfils following conditions: (1) *Novelty.* A new (to the reasoner) sequence of solution reasoning is created, or a forgotten sequence is re-created.; (2) *Plausibility.* There are arguments supporting the strategy choice and/or strategy implementation, motivating why the conclusions are true or plausible; and (3) *Mathematical Foundation.* The argumentation is founded on intrinsic mathematical properties of the component involved in the reasoning. Creative mathematical thinking is not restricted to people with an exceptional ability in mathematics, but might be difficult to produce without sufficient key competencies and a supporting environment. Including in these competencies, are what Schoenfeld (1985) refers to as resources (basic knowledge), heuristics (rules of thumb for non-standard problems), control (meta-cognition), and beliefs system.

Imitative reasoning is a family of different types of superficial, from a mathematical point of view, reasoning. *Memorised Reasoning* (MR) is when the strategy choice is founded on recalling a answer and the strategy implementation consists of writing this answer down with no other consideration. The reasoning is classified as *Algorithmic Reasoning* (AR) when the strategy choice is recalling a certain algorithm (set of rules) will probably solve the problematic situation. The strategy implementation is straightforward once the rules are given (recalled). The strategy choice in *Familiar AR* is founded on identifying the task as being familiar, which can be solved by a corresponding algorithm. The last type of reasoning used in this study is *Delimiting AR.* An algorithm is chosen from a set that is delimited through, in relation to the task, surface property by the reasoner. Following the algorithm carries out the implementation of the strategy. If this implementation is not successful, the algorithm is abandoned and a new one is chosen. The argumentation aim to verify is made on surface considerations related to expectations on the solution or the answer.

2.3. Conception, gender symbol and research question. Thompson (1992) describes conceptions as "conscious or subconscious beliefs, concepts, meanings, rules, mental images, and preferences" (p. 132). I follow this description and conceptions are defined as abstract or general ideas that may have both affective and cognitive dimensions, inferred or derived from specific instances. Consequently, teachers' conceptions consist of their beliefs system, values and attitudes reflecting their experiences. Their conceptions will be studied by looking at if and how the teachers gender stereotype aspects of students school task solving. Gender stereotyping is identified with use of symbols (as discussed in section 2.1). The term 'gendered symbol' used in this paper is defined as the actions, objects, and characteristics that teachers pick out from students' work and attribute as having a particular gender. Actions include behaviours such as "follow rules" or "guess". Objects include particular mathematical tools, such as calculators, or more abstract entities like a particular kind of solutions. Characteristics include inclinations like "being careful" or "having a long memory." These symbols are asymmetric, meaning that it is clear that a particular action, or object, or characteristic may be either male or female, or more male or female.

The overall research question posed is 'What difference (if there is one) is it between girls and boys mathematical reasoning according to upper secondary school teachers in mathematics?', and more specifically 'Which gendered symbols are attributed by the teachers to students' reasoning?'.

3. Methods

3.1. Methods of data collection. This study consists of two parts: (1) a questionnaire with the aim to see if and how teachers gendered different cases of reasoning and to use as a stimuli to provide with arguments containing gender symbols; (2) interviews with the aim to clarify what elements within the reasoning were identified and assigned to a specific gender.

The questionnaire consists of eight cases (fictive and real, marked A-H) describing different aspects of reasoning[2] where following reasoning types were included: Creative Mathematically Founded Reasoning (CR); Memorised Reasoning (MR); Familiar Algorithmic Reasoning (FAR); and, Delimiting Algorithmic Reasoning (DAR). Two main aspects of each case were chosen. The reason for this was to keep a balance between having the questionnaire short and easy knowing the limited amount of time the teachers could spend on it and trying to grasp as much as possible. Therefore it was necessary to follow up the questionnaire with interviews.

[2]See Appendix A

Creative Mathematically Founded Reasoning (CR) has novelty, plausibility, and mathematical foundation as conditions. In this questionnaire, one case (B) describes a solution using a conventional strategy however not following the order most textbooks would present it. The reason for this was to stress the correct mathematical argumentation and the factor of novelty, while keeping it as close as possible to the standard task. The other case (E) presents a solution using an unconventional strategy. Both cases have their arguments based in adequate intrinsic mathematical properties.

Memorised Reasoning (MR) is here represented by two aspects of a guessing strategy: one (H) more within the context of the task than the other (F). The two cases describing Familiar Algorithmic Reasoning (FAR) uses the standard solution for a familiar task. One (A) emphasises a correct mathematical argumentation but the student doesn't trust his or hers own reasoning. The other case (C) describes a student who stops when not successful. Delimiting Algorithmic Reasoning (DAR) is represented by two cases involving multiple strategies: the first one (D) with a smaller number of strategies, half of them algebraic and the other half on the graphic calculator; and, the second one (G) describes several attempts with focus on the calculator.

For each case the teachers were asked to select one of the following responses to the question 'Who is more likely to behave like this?':

- *BD* boys definitely more likely than girls
- *BP* boys probably more likely than girls
- *ND* no difference between boys and girls
- *GP* girls probably more likely than boys
- *GD* girls definitely more likely than boys

The inspiration for this design comes from Leder and Forgasz's instrument *Who and mathematics*, a development from Fennema-Sherman's *Mathematics Attitudes Scales, MAS* (Forgasz et al., 1999). The freedom to code for male, female, and neutral was one important aspect of tis model. The instrument measures if and to which extent the teachers stereotype the cases as gendered. There was a chance to comment for the option selected.

Two pilot studies were made. The first one was with 15 prospective teachers to test the instrument. No instructions at all were given to them. Interviews were made to clarify how the instrument had worked. Most comments (written and verbal) focused on strategy choices and/ or conclusions, but a few small adjustments concerning the language in the fictive cases were made to avoid options selected of other reasons than the mathematical reasoning such as language. The results indicated that girls were connected to the cases describing FAR, and boys to DAR. The second one was with 23 teachers at three different upper secondary schools in three different locations in Sweden (rural north, rural south and city). Instructions were given saying that this questionnaire was about students' mathematical reasoning. No further interviews were made. The results indicated that were aspects more related to girls in FAR and to boys in DAR and MR. One case describing CR was changed as a result of this pilot study since the teachers had a different perception about the factor of novelty (or rather the lack of it) compared to the prospective teachers. What was considered a standard algorithm or a creative reasoning for a specific task differed between the two groups.

The questionnaire was handed out to six public upper secondary schools, chosen to have students participating in all levels of mathematics courses in four different towns with different locations and sizes. Because of the long distances the questionnaire was sometimes handed out by the head-teacher. The same information about the study was given to the teachers in both cases. There were no clear differences in the data from these two situations, so they are treated as one case.

With the questionnaire as a background, six semi- structured interviews were made with teachers from four different schools in three different towns. Four were face to face and two over the phone, all of them recorded. The aim of the interviews, as well as the comments given in the questionnaire, were to clarify *why* a certain reasoning was considered gendered. The teachers' arguments for their selected option contained gendered symbols. Data carrying information about these symbols were identified and marked, and classified in order find explanatory factors. All arguments are presented.

A post-questionnaire was made. It was sent out to the six teachers participating in the interview. They were asked to comment on the result of the gender symbols (see table 2). This worked as a triangulation.

3.2. Method of analysis. The goal of the analysis is to present and highlight teachers' gendered conceptions about students' reasoning:

1. The data from the interviews was transcribed. The interviews and the comments from the questionnaire consisted of teachers arguments for their option selected.

2. In the teachers' arguments, attributions are made about male and female characteristics. These attributions will be called "gendered symbols" because they are attributed to indicate that the teacher has picked out elements, parts of the reasoning, as 'typical' and there is a specific association to gender (this feels like a 'boy thing' or a 'girl thing') or considered neutral. This means that some element can be considered more gendered than others by the individual teacher making them stand out more than others. The same element can also be assigned by two different teachers to different genders (or thought of as neutral).

The identification process consists of three steps. First, passages carrying information about the teacher's conceptions, as defined in section 2.3, were marked.

Then, symbols that were indicated by points in the passages where teachers identified actions, objects, and/or characteristics as part of the reasoning in the students' solutions. As the last step, the elements were attributed to a specific gender (male or female) or was considered as neutral. This identification of gender symbols worked as the coding scheme.

The symbols were gathered case by case to analyse if there was some attributions more common than others for boys and girls respectively. Then the focus was on commonalities between the cases.

3. The last step was to analyse the arguments where the focus laid somewhere else than reasoning, for instance teachers choosing a specific gender only because of the language used in the description of the cases. This worked as an evaluation of the questionnaire.

4. The teachers comments from the post- questionnaire were summarised.

The questionnaire was the starting point for the analysis. The interviews provided an opportunity to investigate the conceptions further, with an emphasis on gendered symbols.

4. Results

4.1. Aspects of mathematical reasoning are seen as gendered. To order the data in the presentation, the interview responses are marked with 'Int' and a number and questionnaire with 'Q' and a number.

The number of teachers who saw a gender difference in one or more cases was compared to the number who did not. Nearly 81 % of the teachers (50 out of 62) choose to reply either 'boy' or 'girl' in one or several of the cases. The number of respondents who answered 'no difference' to all cases was then 19 %. Analysing the comments combined with a short interview with two of the teachers who chose to do this, two rather different reasons were presented.

The first one was about recognition based on actual observations. One teacher said in a short interview "I can't answer [this questionnaire]. I don't get a picture of any student. These are not our students" [Short Int teacher 1]. The second teacher adds to this view by saying "I don't recognise my students in these descriptions. When I read, I don't think 'This is Charlie'. But I do have my prejudices. And according to them boys just continue and 'bubbles on' even though they are wrong, and girls hesitate even though what they are doing is correct. But they just stop. They are 'stoppers'" [Short Int teacher 2]. In the questionnaire one teacher wrote "Have never observed any 'structural' differences" [Q 5]. Altogether, it seems likely that the reason why they decided to go for the middle option is because these teachers have not observed any differences in their particular students instead of an absence of stereotyped conceptions.

The second reason has to do with a moral and/ or political view. One teacher wrote that "From a educational perspective based on equality, I don't see any gender differences" [Q60]. Another teacher wrote "Can't see anything gender specific in [mathematical] reasoning" [Q62]. Here, it is more a question about an explicit decision of *not* to see any differences in the cases.

4.2. Questionnaire. The responses from the 50 teachers who marked a gender differences in one or several of the cases constitute the database for investigating the issue further. The original five response categories were condensed into three by combining the two male options into one and respectively with the female ones. The reason for doing so is at this point the main interest is if and how the teachers gender stereotype and not to the extent it is made; it is a question of either 'boys' (B), 'girls' (G) or 'no difference' (ND).

Reasoning-Answer	B	ND	G
A:FAR	11	13	26
B:CR	17	24	9
C:FAR	13	13	24
D:DAR	26	13	11
E:CR	24	13	13
F:MR	28	18	4
G:DAR	32	11	5
H:MR	27	17	6

Table 1

The most striking result is that most responses lean towards 'Boys' except for three cases: A,B and C. A and C are the two cases describing a Familiar Algorithmic Reasoning (FAR). Case B is a Creative Reasoning (CR) and is the only one with the largest proportions of answers in 'No difference'. In order to find out why, the written comments and the interviews were analysed.

4.3. Written comments and interviews. Let us start with case A and C which differs from the rest. These two cases describe two aspects of choosing the standard method for a routine task, but with different touches. In case A, the algorithm doesn't behave in a expected way and the student therefore concludes that the reasoning is incorrect despite a correct supporting mathematical argumentation. It is a matter of not trusting your own reasoning in a familiar situation. In case C, there is no supporting mathematical argumentation made by the student and when not successful the student stops without any further attempts. According to the majority of the teachers, there are elements in A and C which relate more to girls than to boys.

Case A Most of the written comments for A are about 'reflecting' and 'waiting' referring to that A takes time to reflect over the strategy choice [Q10, Q16, Q44, Q45, Q48] and it is attributed to girls. One of the gender symbols attributed is insecurity: "girlish dithering" [Q17] and "female insecurity" [Q12]. One teacher sums it up by writing "It is probably a girl since A knows how to solve it ($y' = 0$), solves it correctly but then is afraid to trust her own solution" [Q34]. Reflecting and insecurity are two gender symbols assigned to girls.

Analysing the interviews the same attributions are made. The first teacher argues for 'girl' by referring to insecurity and the time spent for reflection:

> [They] Assume they are going to fail, and if they succeed it is only because they were lucky. Boys assume they are going to succeed, and if they fail it is only because they are unlucky. [The student] Remembers something about what it means mathematically, but is unsure.; 40 seconds. If it was a boy it would be 5 seconds and then he would say "What the heck" and write something down [Int 1].

One teacher picks out the same element, time for reflection but assign it to boys: "Silent for 40 seconds - sounds like a guy [Int 5]. This shows that the same characteristics can produce two different gender stereotyping. However, all of the arguments given in the questionnaire assign long reflection time to girls.

The factor of insecurity recurs in interview 2 and 3, now connected to the conclusion:

> Girls don't believe in themselves: 'Is this really correct?'[Int 2].; Mathematics is often like that... confidence: 'This is what it is and this is just how it is'. [If] Hesitation, then it is a girl [Int 3].

Teacher 2 put the main argumentation with 'girl' and 'insecurity', but picks out 'mess' and assigns it to boys: "It becomes a mess.", "To start [without thinking] and then just stop" [Int 2]. This idea is supported by another teacher: "Typical for a student who doesn't know, makes a mess of most of it. Maybe a boy" [Int 4].

Summary case A: The gender symbols most frequently attributed are insecurity and long reflection time. They are, by most teachers, assigned to girls. Insecurity here is connected to the conclusion while solving a standard task with a well-known solution strategy and with a correct mathematical argumentation.

Messiness is thought of as a male property by two teachers [Int 2, Int 4], but it is not their main argument for case A: teacher 2 says it is more likely that student A is a girl because of the insecurity in the strategy choice and teacher 4's main option is 'No difference'.

Case C The majority of the written comments are about the student being unsure and stops [Q12, Q17, Q44, Q45,Q56]. One teacher uses reverse argumentation when saying that "a bloke would continue his solution attempt in any way" [Q17]. The safety aspect is emphasised with the attributions 'careful' [Q10, Q56] and 'ambitious'. [Q35]. One picks out the way of working as being typical female[Q1]:

> She wants to be completely sure before she answers. Controls her line of thought.

The implementation of the strategy is also picked out [Q12]:

> To write small number is typical female, and not to trust a technical solution is also a female property.

Just as in case A insecurity or to do something because it is safe appears to be a female characterisation. This is supported by the interview material:

> [A boy] would do the short version", [he] would use a method that is faster in front of one that he understand [Int 1].; To write like that, with minus sign in front, girls let it go so much later [than boys] [Int 3].

It is the safety aspect of the strategy choice and its implementation that is highlighted by these two teachers. This is partly supported by another teacher who goes for 'No difference' but identifies the implementation of the strategy as female behaviour:

> [The] Spontanous impression is that this is a bloke, but this way of writing minus sign... no, this could be either or. Even though I think this [behaviour] is slightly more common with girls, I still think neutral [Int 5].

Imitative reasoning is also attributed as female:

> My perception is that they are much more... [into] copying so to speak. They don't think so much... the weaker ones. Maybe have not released their ability to think. [They] Copy the teachers explanations model. Girls are often very industrious and then it is often rote learning. They follow rules. They are rule monitored so to speak [Int 3].; Girls often want to please and follow the [given] structure more than boys [Int 4].

Combining these two attributions imitative reasoning could be considered as a safe strategy and more likely to be performed by a girl.

A few comments were about boys. 'Fast solution' is one attribution: "A boy who wants quickly get to the answer. Boys don't take the time to rewrite, especially on vocational programmes " [Int 2]. Two aspects of control are raised: the lack of control [Int 2] and to control on the calculator [Int 4].

Summary case C: The overall result is that girls are assigned symbols such as imitative reasoning and security, the latter one including strategy choice and its implementation. The imitative reasoning is connected to the safety aspect: it is a safe strategy.

Case B This case has the largest proportions of its responses in 'No difference', and the situation is similar with the written comments. Half of them are about 'no difference' saying that this is a standard solution and it is produced by a good student [Q10, Q34, Q35, Q46]. One teacher says that this is a girl since she "Follows a strict solution method" [Q30].

Analysing the arguments given in the interview, the responses are equally nuanced. One teacher chose neutral; this is a a correct conclusion and it is carefully performed and it could be a good boy or a good girl [Int 1]. One teacher says it is a boy, a good boy with the argument that clever students more often are boys [Int 3].

Standard algorithm is assigned to girls in two different ways. The first way involves the textbook as a potential factor of influence which girls are more likely to follow. Because of this, girls uses the standard algorithm. Teacher 2 identify the algorithm used in case B as a standard method and choose 'Girl':

> They use more formal mathematics. [Girls] follow the standard algorithm, the book steers them. Boys are not affected in the same way.

Teacher 4 recognizes the reasoning made by student B and chooses 'Boy' [Int 4]:

> It is more typical that a boy is reasoning. A girl would have followed a more traditional strategy.

These two teachers uses the same property assigned to the same gender for arguing for two different result: to follow a traditional strategy is a female behaviour. This would indicate that different people would read different things from the cases when used as a stimuli. In this case the same attribution is made.

One teacher picks out the graphical element of the reasoning. According to this teacher girls are more verbal and boys more graphical:

> It is a guy... it is too 'swooshy'. To draw with your hand, I'v seen several of my guys doing that. [...] Their verbal language is not... .They feel comfortable to illustrate it [Int 5].

Summary case B: According to most of the teachers, this case describes neutral behaviour; it is a standard solution and it is produced by a good student. A few teachers stressed the element of following a standard solution method, and attribute this symbol to girls.

Case D Half of the written comments for case D refer to the use of the calculator [Q25, Q31, Q45]. Two more teachers argue for D being a boy. One writes "Consider himself as clever" [Q17] referring to the characteristics of being confident, and the other "takes a chance" [Q10] and focus on the action. One teacher says that this must be a girl since "Incorrect solution, but ambitious" [Q35].

Analysing the interviews, there is some information of what this 'use of the calculator' might be. The first symbol is multiple strategies:

> [He] Doesn't exactly have any clue what he is supposed to do, and then [using] several strategies [Int 1].; Typical calculator behaviour. Several strategies on the calculator [Int 4].

The other symbol is the calculator itself and the confidence to use it:

> [He] Throws himself over the calculator and uses it with pleasure. Has informed himself in all the possibilities [on what you can do on the calculator] [Int 1]; "Yes, I think so anyway": he is confident when he is unsure what to do. He knows what to do - to bring out the calculator. The calculator [...] is considered to be reliable [Int 2].

But is also how you use the calculator which points to D being a boy:

> Don't care about being diligent with details such as bad settings on the calculator [Int 1]; The way of speaking is more like a girl, but the way of using the calculator portrays more a bloke. I think this is a bloke [Int 5] .

Most of the teachers choose 'Boy', but one teacher argues for this is a girl because of insecurity: "She believes that she has done wrong" [Int 6].

Summary case D: The most common attribution is multiple strategies on the calculator, and this choice of strategy is seen as a male behaviour. The attribution contains various aspects about the calculator: how to think about the calculator as a tool and how to use it. One teacher mentions the language being gendered, but opts for a different choice based on the strategy choices and their implementations.

Case E The written comments do not really provide for any good explanations why most teachers would think that student E probably or definitely is a boy. Compared to case B, which had the largest proportions of the responses in the 'No difference' category, this case stresses the factor of novelty. The comments arguing for 'Boy' bring up a number of different aspects. One teacher refers to the factor of novelty when he or she says that the student "is not sticking to a conventional method in order to solve the problem and reason himself, however still unsure, to a solution" and must therefore be a boy [Q30]. Another one says that "boys solve [problems] more often with graphical solutions than algebraic" [Q45], and a third writes "dare to try" [Q17]. Some of the teachers arguing that this is a girl pick out various aspects of the strategy choice:

> More girls than boys go for a long-winded method during all circumstances [Q34]; Girls loves structure [Q12]; If this clumsy method was made by a boy, he would've used the graph function [on the calculator] [Q35].

The interview data goes in two directions. Two teachers argue for case E being neutral behaviour. One says that this is not a specific gender because it is "a creative solution by someone who dares to use an unconventional method" [Int 1]. The other teacher talks about personal preferation. It is neutral behaviour since "no one prefers to draw" [Int 4]. Two teachers say that this is a boy because of the graphic solution:

> Girls, I don't perceive them as sketchers. They do it more meticulous. More carefully [Int 2]; Boys [...] do it more [in a] graphic [way]. A girl would use a standard method. They [...] wouldn't even think that there is a graphic solution. It is more 'this is how we did it on the black board and this is how we should solve it' [Int 3].

Summary case E: Neither the written comments nor the interview material give any clear explanations why most teachers choose 'Boy' in the questionnaire. However, graphic solution might be one element that sticks out and it is assigned to boys and by using reversed argumentation it is excluded from girls.

Case F The most common argument in the written comments for case F is chance-taking [Q10, Q12, Q45, Q48]. One teacher writes that student F, a boy for sure, "must and wants to make a decision quickly" [Q30]. There is also comparisons between girls and boys: "Girls rarely dare to guess unless they are certain" [Q48]. Analysing the interviews, to take a chance and/ or to guess are also the main arguments:

> Because... well, he doesn't even bother to think. 'What the heck' - it is that type of principle. 'I'll take a litre. That will do' [Int 1].; Sounds like a bloke. The tiredness... a guess, get it done quickly: "I don't know, I can't be bothered to think." [Int 5].

Some teachers points out the asymmetry between boys and girls:

> He just grabs something. There is no deduction, just a guess. Girls, strangely enough, have learnt to remember. They have better memory than boys. They would try to deduce [Int 2].; A guess. [...] It is done so fast. It is more like this 'Oh well, just take something'. [..] Girls, they think a bit more [Int 3].; No clue, but a guess. [...] Here it is crystal clear 'I don't know, I guess. A bit random. Girls want to have the correct answer. [Int 6].

When boys are thought of as random guess-makers, girls are here assigned symbols such as 'good memory', 'deduction' and 'wanting *the* correct answer'. One teacher says that this is neutral behaviour since "units are difficult for everyone. If you don't know, you guess." [Int 4].

Summary case F: 'To take a chance' and 'to guess' are two actions assigned to boys by the majority of teachers, some stressing that this is a fast solution. Girls don't guess: they want *the* correct answer. In order to arrive with that they would, if they can, think. It is not clear though if this 'thinking' is deduction in terms of Creative Reasoning (CR) or just plain good memory.

Case G The most frequently used argument is multiple strategies on the calculator [Q16, Q30, Q31, Q34, Q35, Q45, Q46, Q57] especially as a tool for searching or exploring. This is illustrated by this expression [Q34]:

> Boys press all the buttons [on the calculator] and hope it will help.

Some teachers use reversed argumentation: "None of my female students have ever tried 14 tools." [Q35]; "Girls don't use the calculator in this way" [Q30]; and boys "investigates with the help of the graphic calculator more than girls" [Q46]. One concludes that boys "rely on the calculator, do *not* think beyond that" [Q25] emphasising the lack of consideration of the intrinsic mathematical properties. One teacher states that "this behaviour seems to frequently recur independent of the math course" [Q59] saying this is an overall male tendency. Another one puts an equal sign between the calculator and boys [Q10]. Braveness is also picked out and thought of as a male property [Q44].

Analysing the interviews the situation is similar. All teachers conclude that case G describes male behaviour:

> The typical boy. Absolute no clue but the calculator is an extended index finger [Int 1].; Tries with the calculator a lot. Testing strategies so to speak. A guy do that: look for tools, look for tools. Look for all the different tricks [Int 3].; [laughter] Well.. a bloke. The behaviour in itself [counts up all the different strategy choices] [Int 5].

This search for a strategy, especially on the calculator, is marked as male. Some points out how this behaviour differs to girls':

> He is unbelievable. He searches. He is fixated that the calculator is the thing which is going to solve this for him. Girls don't do that. They ask 'How do you solve this?'. Boys don't ask the teacher. They searches [...] or ask each other [Int 2].; It is undoubtable more common that boys searches through the calculator, that boys explores the calculator. Girls [...] do what they are suppose to do. They don't have to go through the whole lot [Int 4].

Summary case G: Just as in case D, multiple strategies on the calculator is the most frequently used argument. Here, this symbol is connected to an investigating property. Girls, on the other hand, are seen as more precise.

Case H There are not many written comments for case H. Only six teachers give their arguments: four for boy, one for girl and one chooses 'No difference'. Three of the arguments why this is a boy is "take a chance" [Q10,Q12, Q45]. The other one describes boys as "jugglers" as in using tricks more than girls [Q56]. One teacher opt for girl since student H "Admits ignorance" [Q16]. The teacher who goes for the middle category explains that this type of mistake is "gender indifferent" [Q35].

The interview material gives some more information. Two teachers say this is neutral behaviour with the argument that the guess described in case H is based on some mathematical properties. The guess is therefore within the context of the area and not a random one [Int 1, Int 4]. A third teacher refers to this element, but makes the conclusion that this is instead a familiar activity and therefore it is more likely to be a girl who performs this guess [Int 3]. Another teacher stresses the chance- taking and assign this to boys [Int 2]. One teacher argues for this is a boy simply because of the language: "Girls don't talk like that in our acquaintance" [Int 5].

Summary case H: There are several variations of different aspects in case H. The teachers who choose 'Boy' seem to pick out 'chance- taking' as one key element. One teacher based the choice on the language used in the case description.

4.4. Summary and Triangulation.

4.4.1. *Gender symbols.* Let us begin with a summary of the attributions made in the written comments and the interviews. For case A the gendered symbols most frequently attributed are insecurity and long reflection time. They are assigned to girls. Messiness is by two teachers attributed to boys. According to most of the teachers, case B describes neutral behaviour; it is a standard solution and it is produced by a good student. To follow a standard solution method is attributed to girls by a few teachers.

In case C symbols such as imitative reasoning and security are assigned to girls, where the imitative reasoning is thought of as a safe strategy. The most common attribution made by the teachers for case D is multiple strategies on the calculator. This is assigned to boys. Case E doesn't provide any strong evidence why most teachers choose 'Boy' in the questionnaire. Graphic solution is one gendered symbol, also mentioned in case B, and it is assigned to boys.

Moving on to case F, 'to take a chance' and 'to guess' are two actions assigned to boys. This is a fast solution, pointing out the asymmetry to the previously made attribution to girls: 'long reflection time'. Girls don't guess: they want *the* correct answer. In order to arrive with that they would, if they can, think. However, looking at the previous attributions such as imitative reasoning and to follow a standard method it seems more likely that this 'thinking' is 'trying to remember' more than producing a Creative Reasoning (CR). Multiple strategies on the calculator is the most frequently used argument in case G. Here, this symbol is connected to an investigating property whereas girls are seen as more precise. In case H several aspects were highlighted, but the teachers who choose 'Boy' seem to pick out 'chance- taking' as one key element. One teacher based the choice on the language used in the case description.

Summarising the result in a table, these are the gender symbols most frequently used in the arguments made by the teachers:

Boys	Neutral	Girls
(use the) calculator	good student	safety
multiple strategies	standard solution	use the standard method
chance- taking, to guess	guess within context	imitative reasoning
make a mess, not careful		insecurity
quick solution		long reflection time
graphic solution		wants *the* correct answer
explore		think

Table 2

Most of the attributions in the girls column describes someone who is insecure and wants safety. This girl uses the standard method and produces imitative reasoning. She doesn't guess. In order to arrive with 'The correct answer' she would spend more time on thinking, but if not successful guessing is not an option.

The attributions linked to boys portray a different personality. This is a rather messy and cheeky person who takes chances with making guesses and quick solutions. He would use multiple strategies on the calculator to search for an answer, strategies most likely not to be chosen based on the intrinsic mathematical properties of the task.

A standard solution performed by a good student and guessing based on mathematical properties are considered neutral.

4.4.2. *Post-questionnaire.* The purpose of the post-questionnaire was to test the results. As a post-questionnaire, Table 2 was sent out to the teachers participating in the interviews. They were asked to comment on the results. Two teachers declined the offer to comment with the explanation that it is not a question about gender differences; it is all about different personalities [Post 1, Post 4]. Most teachers agreed to the description, parts or the whole table, [Post 2, Post 3, Post 5, Post 6] with a few exceptions. One of the exceptions was careful compared to security:

> Girls don't show more insecurity, not more than boys. The difference is that girls don't want to mess things up. More structure to the solution. Think more initially. [...] You don't often find a solution scribbled down from a girl, if ever. Otherwise the table is how I perceive things [Post 2].

This teacher wants to put the emphasis from insecurity to carefulness. The column describing neutral behaviour is one issue being brought up:

> I think you have summarised male/female in mathematics in a good way. Then there are always some boys that remind of girls' methods and vice versa. The only thing that I found strange is neutral, "standard method" I find more female than male [Post 6]; I am a bit doubtful about the column describing neutral. [...] One cutting comment I've read is: If the necessity is the mother of inventions then the play is the father. And that maybe says a lot about our traditional putative behaviour [Post 5].

These two teachers don't just comment on the neutral column but they also illustrate the spectra of looking at female and male. Teacher 6 agrees to the table stressing that there are always exceptions from the rule, and teacher 5 wants to highlight the difference between exploring (male) and repeating (female) instead of focusing on specific actions.

As a summary of the post-questionnaire, most teachers confirm that Table 2 gives a valid description of teachers' conceptions of male and female behaviour but also recognise that boys and girls do not form homogeneous groups.

4.4.3. *Reasoning.* The aim of this study was to present a set of examples that differed with respect to the reasoning types used and see what kind of attributions the teachers made. The results in this study showed few attributions that were directly connected to the reasoning types, but that the different reasoning examples brought forward several other attributions that were related to other aspects of reasoning and/or task solving. Having the types of reasoning in focus (FAR, CR, DAR and MR) a few points can be raised. The cases describing Delimiting Algorithmic Reasoning (DAR) are by most of the respondents considered having elements that points towards a male way of reasoning. Most of the written comments (18 out of 23) argue for DAR being male where the main argument is the use of multiple algorithms especially on the graphic calculator both for case D and case G. But, analysing the questionnaire it is only case G which got the largest proportions of responses in one of the outer categories ('BD - boys definitely more likely than girls'). G also have very few responses in any of the 'girls' categories making this definitely not a female behaviour.

Memorised Reasoning (MR) seems to be perceived by the largest proportion of teachers as a male way of reasoning stressing properties such as risk-taking and gambling. Here, it is a case of 'throwing in something' just for the sake of giving an answer at all. However, this seems to be related to how much the answer is considered (by the teachers) to be within the context of the task. Analysing the questionnaire, the generality is not so strong except for the very few choosing any of the girl responses. The conclusion is that MR has aspects that are male and is not a female behaviour.

The cases describing aspects of Familiar Algorithmic Reasoning (FAR), case A and C, were the only ones with the largest of responses opting for 'Girl'. This type of reasoning has aspects connected to girls such as the strategy choice, to use the standard method, and the conclusion to stop and not continue with other strategies, the latter one connected to Delimiting Algorithmic Reasoning (DAR). Analysing the questionnaire not many teachers chose 'GD -girls definitely more likely than boys' indicating that Familiar Algorithmic Reasoning (FAR) has elements that ranks more to female than male.

Creative Reasoning (CR) is the type of reasoning where the cases have the least gender stereotyping and produce the fewest numbers of attributions. The most common response is that this is a good student producing a standard solution. Comparing the two cases B and E, the latter one has aspects considered male more than case B. It is difficult to say though if the differences in these two cases are because of the varied accentuation of the factor of novelty in the reasoning or because of the use of a graphic solution (case E). Further research is needed.

Reasoning-Answer	BD	BP	ND	GP	GD
A:FAR	3	8	13	21	5
B:CR	5	12	24	9	0
C:FAR	4	9	13	18	6
D:DAR	8	18	13	9	2
E:CR	5	19	13	11	2
F:MR	10	18	17	3	1
G:DAR	18	16	10	2	1
H:MR	10	17	16	6	0

Table 3

It is interesting to note that most of the teachers' responses were one of the 'boy' categories or neutral, and very few chose 'GD -girls definitely more likely than boys'. It could be that these cases capture what is considered a male behaviour. Or, maybe for one reason or another it is easier to attribute elements to boys.

Analysing the arguments where the focus is laid somewhere else than reasoning one teacher [Int 5 case H] based the choice on the language used in the case description. Even though trying to avoid this situation (that choices are made expressly based on the language) by making different pilot studies, it seems almost impossible to do so. Maybe it is not so surprising since reasoning and language are connected to each other.

5. Discussion

According to most of the teachers participating in this study there is a difference between girls and boys task solving. This difference might be dependent on what group you look at: different programmes or the different type of masculinities and femininities existing in the class room. The gender symbols and the association made between gender and different reasoning are still interesting since they provide a bigger picture of what is considered male and female as a group.

Although it might be tempting to think that the relationship between teachers' beliefs and/or conceptions and their way of instructing a class is straightforward, the situation is far more complex (Fennema et al., 1998). There is no coherency in the field and it seems to be a problem due to how a study is designed (Thompson, 1992). Nevertheless, the questions about the effect of these views in the classrooms or if these conceptions mirrors the reality are still interesting and worth some consideration.

Previous research has indicated that according to upper secondary school teachers, creative reasoning is only for high-ability students (Boesen, 2006). This study adds a gender perspective to this result. There is no significant gender difference in theory between high-ability students according to the teachers; a standard solution produced by a good student is often thought of as neutral behaviour. However, there is a difference in the symbols attributed to the students. Previous result has indicated that girls are diligent and successful because of their hard work (Brandell et al., 2005), and not because of their creative mathematical thinking. In this study girls are linked to imitative reasoning and the use of standard methods, a way of working that if you are diligent and careful you are most likely to be successful. This is strictly speaking not a Creative Reasoning (CR), but it wouldn't be improbable if it is thought of as a good way of working by both students and teachers; especially if the goal is to do well on exams.

The high-ability boys, on the other hand, are successful because of them being bright kids (Brandell et al., 2005). In this study, only one of the cases describing Creative reasoning (CR) brings forward attributions that could be interpreted as an indication of creativity. Case E stresses the factor of novelty and instead of using the conventional method the student solves the task with a graphic solution. Graphic solution is one of the symbols attributed to boys. It is not clear if it is the graphic solution in itself that creates the attribution or if it is the use of it instead of a standard method, or the combination of the two. Standard method is assigned to girls and by asymmetry not considered male.

Some of the gender symbols most frequently attributed to boys are multiple strategies (especially on the calculator), and to guess/ to take a chance. This would fit in with the view of boys being gamblers and risk- takers (Ben-Shakhar and Sinai, 1991) in the sense that they try different methods to increase the probability to stumble across something that might be right. Following comment illustrates this way of working: "Boys press all the buttons [on the calculator] and hope it will help [Q34]". This is not a strategy choice based on intrinsic mathematical properties of the task. In Delimiting Algorithmic Reasoning (DAR), the choices and the argumentation for these choices are made on surface reasons. In Memorised Reasoning the strategy choice is simply trying to recall an answer and writing it down without any other consideration.

Girls seem to be connected to Familiar Algorithmic Reasoning (FAR), a result in line with previous research saying that girls are more likely to choose the standard method and stick to it (Fennema et al., 1998). Familiar Algorithmic Reasoning (FAR) is effective if you want to be sure that you solve certain tasks, but highly restrictive when facing a genuine problem. It is also restraining the intellectual development (Pólya, 1945). If the teachers conceptions mirrors the reality, what is supporting the girls' choices? Previous research has indicated that decision making in mathematical reasoning is often based on beliefs about safety (e.g. this algorithm is safe), expectations (e.g. I'm supposed to solve this task with this algorithm) and negative motivation (e.g. I can't construct my own reasoning) (Sumpter, 2008). These beliefs could all work in a negative way with creative reasoning in focus, but they would act supportive for an imitative reasoning. For instance, I use this familiar algorithm because this algorithm feels safe, I'm suppose to use it and I'm not capable to construct my own reasoning. I might be successful solving the task, but if I'm not there is nothing in my argument that would support a shift to a creative reasoning. The question arising from this is, if these beliefs, single ones or whole groups, are considered gendered? And if so, are they perceived female?

Appendix A. Questionnaire: the cases

The cases from the questionnaire are translated from Swedish and presented with reference if real. It covers the same substance, but it is slightly compressed in its presentation.

Case A (Sumpter, 2008): Student A is trying to solve following task: Find the largest and smallest values of the function $y = 7 + 3x - x^2$ on the interval $[-1, 5]$. The student differentiate the function and put that equals to zero.

A: This shouldn't be correct since it should be like two roots. When I say that the derivative is zero, then I mean that the slope is zero. Wait a minute... you should be able to calculate $3 - 2x = 0$. That one should has two solutions. One positive and one negative, since it should be a maximum and a minimum. If you write it ... [writes $3 - 2x = 0$]

A: But wait a minute. [silence 40 seconds]
A: No. When I think that this should be zero, then it is just one way and that is $x = 1,5$, and if you take it negative it becomes another number.

A concludes that $x = 1,5$ is completely wrong.

Case B: Student B is trying to solve following task: Find the largest and smallest values of the function $y = 7 + 3x - x^2$ on the interval $[-1, 5]$.

B: Hold on. Second degree... it only turns once. Then either the smallest or the largest must be at the border of the interval.

B calculates the function values for $x = -1(y = 3)$ and $x = 5(y = -3)$.

B: And it only change direction once... so it is either one of these [draws with the hand in the air a $\smile$] or one of these [draws with the hand in the air a $\frown$]. Ok, it is one of these [$\frown$] since it is minus in front of x^2. [differentiate and puts it equal to zero, arriving with $y = 9,25$ when $x = 1,5$]

B: Ok, largest value must be $9,25$ and smallest –3.

Case C (Bergqvist et al., 2007): Student C is trying to solve following task: Solve the equation $4 - x = 3x + 14$. C writes:

$4 - 4 - x = 3x + 14 - 4$
$x = 3x + 14$
$x + x = 3x + x + 14$
$4x = 14$
$14/4 = 3,5$
$x = 3,5$

C tries to control the solution by using the calculator. C computes $4-3,5$, but stops. C is silent and looks at the equation and the calculator.

C: I don't know if I should take plus or minus $3x$. [stops the solution attempt]

Case D (Bergqvist et al., 2007): Student D is trying to solve following task: Find the largest and smallest values of the function $y = 7 + 3x - x^2$ on the interval $[-1, 5]$.

D: Here you are expected to differentiate so you can find maximum and minimum. Or at least I think so. [differentiates, puts the derivative equal to zero and arrives with $y = 9,25$ when $x = 1,5$]

D: Uhm... I wonder why.I thought I would arrive with two values and I don't know what I did wrong.

D looks at the graph on the calculator and tries to use the minimum function value tool. When D can't find anything, D moves on to the table function tool on the calculator and looks at the y-values for $x = -1, 0, \ldots, 5$.

D: Between –1 och 5 [referring to the interval for x]... then the smallest value should be –3 and the largest value 9. Here [points at the differentiation] I've got 9, 25. That's... clever.

D then solves $7 + 3x - x^2 = 0$ and gets $x_1 \approx 4,54$ and $x_2 \approx -1,54$ and give them as answers to the task.

Case E: Student E is trying to solve following task: Solve the equation $4 - x = 3x + 14$

E: Solve the equation... well, then I solve it by looking at the graphs. These are two straight lines, and where they intersect is the answer [to the equation]. Because that's where it [x] is the same. [sketches a coordinate system] Ok... $4 - x$, it is 4 when x is zero and then it is a negative slope. There we go... . And then there is $3x + 14$. [sketches $3x + 14$] Then x has to be negative. Like minus 2. Let see... if x is minus 2, the the left part is 6 and the right part 8. And minus 3 is not right as well... so x has to be -2,5. Then the left hand is 6,4 and the right hand is 14-7,5 which also is 6,5.

Case F: Student F is trying to solve following task: Rewrite $100cm^3$ in litres.

F: Well. Not easy to remember. But I guess it is 1 litre.

Case G (Sumpter, 2008): Student G is trying to solve following task: Find the largest and smallest values of the function $y = 7 + 3x - x^2$ on the interval $[-1, 5]$. The student first tries to calculate $7 + 3x - x2 = 0$, but can not remember the formula for a second degree equation. Then, G calculates the function values y for the border of the interval, $x = 5$ and $x = -1$, and says they are the largest and the smallest value. After that, G looks at the graph on the calculator. G can see where the largest value is on the graph and tries to use the minimum function value tool on the calculator to get the smallest value. When this is not successful, G looks at further 14 different tools on the calculator with no result before saying:

G: The answers are these ones [pointing at the borders of the interval].

Case H: Student H is trying to solve following task: Förenkla uttrycket $(x + y)^2 – z^2$.

H: That is a sneaky one. And I can't remember the trick. [silence]
H: I answer $(x + y - z)^2$.

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