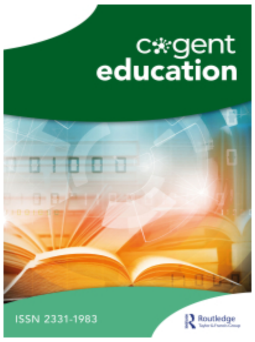

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Gender differences in early childhood mathematics: boys' and girls' responses to changing pattern task difficulty

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ABSTRACT

This paper presents a part of a study with 206 kindergarten children regarding repeating and growing patterns tasks. This part of the study examines the gender-based differences in children's responses to various tasks related to a particular pattern. The children were given a repeating pattern comprising red circles and yellow squares and were instructed to continue it. For each task, the children were given a set of shapes and had to choose the appropriate ones to complete the task. One set included only the necessary shapes, while the others had additional shapes and colors. The results of the study indicate a significant relationship between gender and performance concerning both correct responses and common errors.

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Introduction

Despite numerous studies and programs promoting gender equality, gender disparities persist in international assessments like PISA (Lu et al., 2023) and TIMSS (Mejía-Rodríguez et al., 2021). These differences can significantly impact individuals' self-efficacy, competence, and aspirations, particularly in STEM professions. The underrepresentation of women in leadership roles across mathematics, science, and engineering gaps (Kahn & Ginther, 2017) further underscores the urgency of comprehending these differences. Many studies examined gender differences in school (i.e Kaldo & Õun, 2020; Rodríguez et al., 2019), but comparatively few studies have investigated the emergence of early gender differences in preschool settings. Studying and understanding these differences from early childhood is essential. Early identification of potential disparities and understanding emerging gender differences in mathematics at a young age allows educators and policymakers to intervene. Identifying these differences at early ages can help implement targeted interventions and give all children equal opportunities to excel in mathematics. In this paper, we focus on this specific issue by examining the gender-related differences in the ability to solve patterning tasks in kindergarten.

Repeating patterns are an important topic in the mathematical curriculum for kindergarten in many countries. A pattern is a series of elements arranged according to a specific rule. Each element has a single value determined by its place in the series so that the elements appear predictably. Patterns and structures are considered the heart of algebraic thinking, which may be promoted by continuing a pattern, identifying and describing the 'general' element of a pattern, and expressing and justifying these generalizations (Mulligan et al., 2020).

Each patterning task has various characteristics that may affect the children's performance, such as the length of the given pattern, how it is presented to the children, the unit of repeat, and so forth. This study focused on how different genders respond differently when changing the difficulty level of a

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repeating pattern task, and giving the children surplus elements to solve the task regarding the correctness of the answers or the common errors. Understanding gender differences in how children respond can help educators focus their instructions and design specific tasks to better meet all students' needs. For example, if certain misconceptions are more common among boys or girls, educators can design activities and lessons to address and correct those misconceptions specifically. Moreover, patterns were found to be predictors of numeracy outcomes of children (Borriello et al., 2023; Wijns, Verschaffel, Smedt & Torbeyns, 2021). Understanding and overcoming gender gaps in patterns may lead to overcoming gender gaps in numeracy.

Literature review

Gender differences in mathematics learning

The question of gender differences in mathematics has occupied researchers and educators for decades. One reason for this is the underrepresentation of women in leadership positions in mathematics, science, and engineering. A comprehensive analysis of population datasets spanning seven decades and involving millions of students reveals that even though girls perform at least as well as boys in school science subjects, and even after many years of policies and efforts, there are consistent gender disparities in STEM Involvement. The gender-based trends in participation in STEM fields and professions have not shown significant change and women are notably lacking in fields such as physics, engineering, and computing (Smith & White, 2024).

Also, gender differences in mathematics performance were found in international tests such as the TIMSS (Mejía-Rodríguez et al., 2021) and PISA (Liu & Wilson, 2009; Lu et al., 2023).

In Israel, where this study was conducted, gender differences were found among students of various age stages in national and international tests (David, 2021). The differences were found both in national tests for elementary school, where differences in achievements were found in favor of the boys, and in the school's matriculation exams, where differences were found regarding the number of students learning high math level and excelling at it, and in the psychometric tests used as an entrance test for universities where differences indicate preferences, attitudes regarding mathematics or self-concept.

Previous studies found gender differences in mathematics learning concerning behavioral or emotional aspects such as motivation and other emotional factors such as anxiety, self-efficacy, and self-concept. For example, boys consistently reported significantly more positive attitudes about mathematics, whereas girls reported more significant mathematics anxiety than boys (Else-Quest et al., 2010; Skaalvik & Skaalvik, 2004), boys reported liking mathematics significantly more than girls (Ayebo & Dingel, 2021), girls exhibited less positive attitudes about mathematics than boys and also lower motivation, worse perception of competence, and higher rates of anxiety (Rodríguez et al., 2020). Other researchers indicated differences in learning strategies and found that girls showed more powerful organizing skills and had better learning strategies than boys (Kaldo & Õun, 2020).

In kindergarten, such behavioral and emotional differences were also found: Differences in self-regulation (Matthews et al., 2009), differences regarding attitudes toward mathematics (Patrick et al., 2009), differences in self-esteem or self-concept (Herbert & Stipek, 2005; Lindberg et al., 2013). The findings on gender differences in student knowledge, achievements, or performance are not just varied, but they hold significant implications for our understanding of mathematics education. While some studies suggest an advantage for boys, (Perez Mejias et al., 2021) or visual-spatial tasks (Carmichael, 2013), others indicate an advantage for girls (Carmichael, 2013; Zhu et al. 2025), particularly in word problems, and others found no differences (Ghasemi et al., 2019; Vessonen et al., 2024). Further studies reveal that differences may not be in achievements but in the solution strategies chosen by students of different genders (Carr & Davis, 2001; Gallagher et al., 2000) or both the solution strategy and the errors they make (Schreiber & Ashkenazi, 2024). All these studies indicate that girls prefer problems that require a systematic approach, or precise calculations. One of the possible reason they give is that girls tended to rate their mathematical ability as lower than men, even when actual performance was similar, and thet girls may feel less confident and therefore prefer a strategy that gives them confidence in arriving at the correct answer. In the present study I wanted to examine whether there are differences in solution strategies and whether they may indicate the reason for such differences.

Examining gender achievement differences in kindergarten shows similar results. While some studies found no differences (Fryer & Levitt, 2010; Singh & Krutikova, 2017), others found that the differences were found only at the top or at the bottom of the distribution (Cimpian et al., 2016; Penner & Paret, 2008) and another study showed that no gender differences were found between the mathematical achievements of the boys and girls, but the results suggest that they use different processes for solving mathematical problems (Klein et al., 2010).

As far as I know, the relationship between gender and the types of answers (correct and incorrect) of children has not been tested. In particular, such a relationship was not tested in kindergarten or regarding solving a repeating pattern task. This study examined whether typical answers or common errors exist for each gender.

Repeating patterns in kindergarten

The present study focuses on the mathematical topic of patterns, which is part of many countries' mathematics curricula for kindergartens. Its importance is highlighted in policy documents and curricula. Patterns and structures are considered the heart of algebraic thinking, which may be promoted by continuing a pattern, being able to identify and describe the 'general' element of a pattern, and expressing and justifying these generalizations (Mulligan et al., 2020). Patterns may form the basis for understanding recurring structures, which promote acquiring various mathematical concepts – such as variables, functions, and algebraic expressions (Mulligan et al., 2020). The curriculum for mathematics in kindergarten in Israel emphasizes that patterns may also lead to a high level of thinking – the ability to generalize. Patterns also may influence children's mathematical competencies (Lüken et al., 2014) and predict their broad mathematical and general numeracy knowledge (Zippert et al., 2020).

Recommendations for early ages suggest focusing on patterns with different characteristics, such as color, position, and quantity, and presenting patterns in various ways, such as pictures, concrete elements, sounds, or movements. They also recommend various activities and patterning tasks such as describing, creating, continuing, or completing a pattern (Mulligan et al., 2020, Papic et al., 2011; Wijns, Verschaffel, De Smedt, De Keyser, et al., 2021).

The present study incorporates the task 'Continue the pattern', which, according to the curriculum in many countries (including Israel) and many researchers, may promote mathematical thinking and generalization abilities (Mulligan et al., 2020; Papic, 2007; Warren et al., 2012).

Studies that explored the factors influencing children's performance and the difficulty level of repeating patterns tasks indicate the length and the complexity of the unit of repeat as significant factors (Threlfall, 1999; Tsamir et al., 2018; Warren et al., 2012). Another factor that may influence children's performance is what we provide them so they can perform a given task. For example, suppose children are asked to continue building a tower of blocks with a repeating pattern of yellow-blue-yellow-blue blocks. In that case, we can provide them only blue and yellow blocks (just the exact necessary blocks) or blocks in a wide range of colors, among them the blue and yellow required for the task. Such tasks with surplus elements are more difficult for the children because they first need to identify and choose the blocks appropriate for completing the task and then complete the task. Most studies that tested children's performance in repeating patterns in kindergarten gave them precisely what they needed (Papic, 2007; Rittle-Johnson et al., 2013; Wijns, Verschaffel, De Smedt, De Keyser, et al., 2021). It is unclear how surplus elements affect children's patterning performance, particularly gender differences, so the present study aims to investigate it.

Another aspect of patterning activities in kindergarten is the correct and wrong solutions children provide to a given task. Past studies indicate that children spontaneously create repeating patterns while playing and are naturally inclined toward them. However, it was also found that kindergarten children have difficulties providing a verbal description of patterns and recognizing the basic repeating unit (Tsamir et al., 2018). According to past studies, some of the typical errors that children make in patterning tasks are continuing a pattern randomly, repeating one element of the pattern systematically (Clements & Sarama, 2007; Rittle-Johnson et al., 2013), copying the pattern (Lüken & Sauzet, 2021), or producing another repeating pattern (Rittle-Johnson et al., 2013). It is unclear whether different genders make different errors in patterning tasks in kindergarten.

Research purpose and questions

The study aims to examine children's performance in patterning tasks that provides surplus elements. It also seeks to determine whether boys and girls respond differently and produce different solutions.

The research question is: Is there a relationship between children's gender and their solutions for a repeating pattern task when surplus elements are provided?

Methodology

Participants

Two hundred six children aged 4 to 6 (see the gender distribution in Table 1) participated in the study. All the children attended kindergartens in the same area in Israel and were of the same socioeconomic status (according to the Ministry of Education in Israel's criteria). The children had previous experience creating and continuing repeating patterns.

Instrument

The pattern chosen for this study consists of the following unit of repeat: red circle- yellow square. According to the mathematics curriculum for kindergarten in Israel, repeating patterns should be taught first with patterns that have one characteristic, such as color or shape (see examples in Figure 1a), and then patterns that have two characteristics, such as color and quantity or color and shape, which is the type of pattern chosen for the present study (see examples in Figure 1b).

The tasks were presented to the children as a computer game. The children performed in front of a computer screen using software developed specifically for the study. Each time, one pattern appeared on the computer screen with a set of shapes below it, from which the children chose the appropriate shape (see one of the questions in Figure 2). The shapes were displayed to the children as boxes with a figure of the shape so they could drag as many items of that shape as they wanted. The children were asked to continue the pattern by 'dragging' the shape they chose.

Table 1. Age and gender of participants.

	Age 4–5 years	Age 5–6 years	Total
Boys	57	57	114
Girls	42	50	92
Total	99	107	206

Figure 1. Examples of repeating patterns of one or two characteristics.

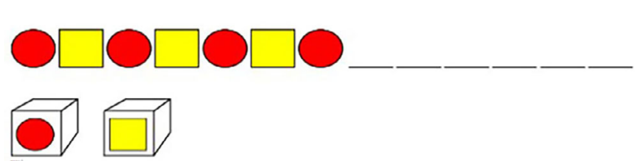

Figure 2. An example of the first question displayed on the computer screen.

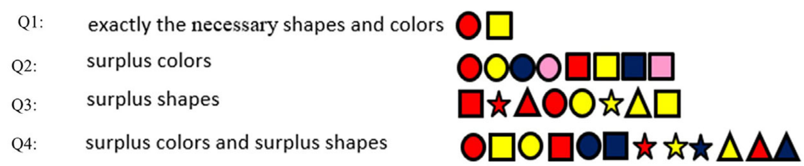

Figure 3. The set of shapes given to the children in each question.

It is important to note that computer software was also used in previous studies (Highfield & Mulligan, 2007). All the children who participated in this study were acquainted with computers and were used to playing and studying using computer software.

This paper is part of a broader study and focuses on four questions for each set of shapes (see the four sets in Figure 3).

Procedure

This paper presents part of a study in which the children participated in two sessions. There were no time limitations, the children could have as much time as they wanted. The sessions lasted approximately ten to fifteen minutes with each child. The four questions reported in this paper needed between 2 and 4 minutes. Each child responded to the questionnaire in a quiet kindergarten side room in the researcher's presence. The computer software documented and recorded the children's responses (how they continued or completed the pattern and their oral responses).

Ethics-statement

The Chief Scientist of Israel's Ministry of Education approved the study's ethics. This study was conducted as part of the requirements for a Ph.D. thesis in the Faculty of Education at TAU. The study's methodology was approved after being reviewed by senior faculty members. The research was carried out under the supervision of the Ethics Committee of the Faculty of Education at the university. It adhered to all the ethics rules: the participants' parents signed consent for their participation in the study, the privacy and anonymity of the participants were preserved, the information collected was used for research purposes only, and the personal details would not be revealed.

Results

Only two answers were observed for the first question when only the necessary shapes and colors were given. Both included the correct repeating unit- a yellow square and a red circle- but not all children started correctly: 81% of the children started correctly, and 19% started with a red circle instead of a yellow square (see Figure 4). Since both answers kept repeating the unit of repeat of the given pattern, both answers were considered correct.

The findings show that when children were presented with surplus shapes and colors, their performance suffered compared to tasks where they received only what was necessary. Approximately a third of the children did not continue the pattern correctly, and boys' performance suffered more than girls'. No differences were found between the three questions with surplus items, and although in question four, the children received more items than in questions two and three, the performance was similar.

Several incorrect answers were identified in these questions, and the repeating pattern was not maintained as expected (Figure 5 shows examples of incorrect continuations in children's answers to question 4. For answers to questions 2–3 see Appendices A and B):

1. Children continued the pattern randomly (see Figure 5a)
2. Children say it is impossible to continue the pattern.
3. Children continued the pattern with another repeating pattern (see Figure 5b)
4. Else – children who did not solve correctly and did not make one of the above errors. For example, copying the set of shapes, constantly inserting the same shape, or referring to only one of the variables (either the color or the shape).

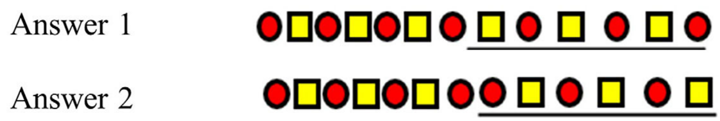

Figure 4. The correct answers for the repeating pattern task.

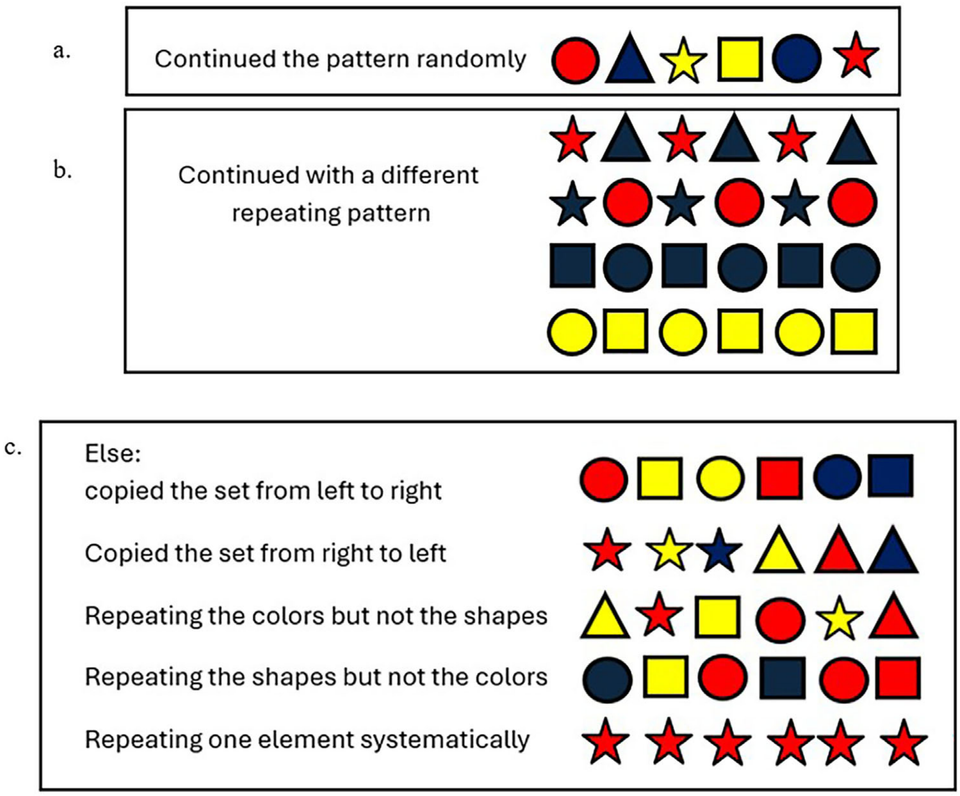

Figure 5. Examples of wrong continuations to the pattern in the fourth task.

Table 2. Number (and percent) of children answering each type of answer (Boys N = 114, Girls N = 92).

	Correct		Continued randomly		Impossible to continue		Different repeating pattern		Else		
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	χ^2
Q2	72 (63)	65 (71)	16 (14)	4 (4)	4 (4)	13 (14)	11 (10)	5 (5)	11 (10)	5 (5)	14.6**
Q3	70 (61)	69 (75)	15 (13)	3 (3)	4 (4)	9 (10)	18 (16)	10 (11)	7 (6)	1 (1)	14.5**
Q4	65 (57)	68 (74)	25 (22)	5 (5)	5 (5)	12 (13)	11 (10)	6 (6)	8 (7)	1 (1)	21.1**

**$p < 0.01$.

Examining the findings (see Table 2), it was observed that in the first question, which was relatively easy and where the children received only the shapes they needed, there were no differences between boys and girls: 100% of both genders solved the task correctly. However, in the more difficult questions, where the children received a set of shapes that included surplus shapes and colors, a significant relationship was found between gender and the type of answers the children gave.

The findings in Table 2 show that boys were significantly more inclined than girls to continue the pattern with another repeating pattern or to continue it randomly. Girls tended to either solve correctly or to answer that it was impossible to do the task.

Conclusions and discussion

This study examined kindergarten children's response to increasing difficulty in a repeating pattern task and gender differences in children's answers.

Two hundred six children were given a repeating pattern task with a repetition unit of two variables: color and shape (yellow square and red circle). In the first task, the children were asked to continue the pattern and were given only the items they needed to solve the task (yellow squares and red circles). In this task, all the children succeeded without gender differences – 100% of the children repeated the square-circle unit to continue the pattern they created. However, some started with a yellow square (as expected), and some started with a red circle. It can be assumed that the children who did not start with the correct shape solved the pattern rhythmically or copied the given pattern (Threlfall, 1999). They do not solve by identifying the repeat unit and continuing with it. This finding emphasizes the importance that when teaching the repeating patterns, the kindergarten teacher should emphasize the identification of the unit of repeat and continue in a way that keeps the repetition.

Increasing the difficulty level of the given repetitive model task was done when the children were given additional items besides the ones they needed to complete the task. In the first question, they were given surplus colors; in the second question, they were given surplus shapes; in the third question, they were given both surplus colors and surplus shapes. As expected, it was found that in these three questions, about a third of the children did not continue the pattern as expected, which created an incorrect continuation. In these questions, two innovative findings were found compared to previous studies.

The first and most significant finding is that significant differences were found between boys and girls concerning the type of answer received and the type of continuation of the pattern they created. Differences in students' types of answers were found in previous research in which differences were found regarding errors as well as in correct various ways to the right answer and also it was concerning high school older students and not kindergarteners (Schreiber & Ashkenazi, 2024). In the present research, several differences were found: (a) Girls were more likely to solve correctly, meaning that girls are more likely to recognize the repetition unit and act on it and are less prone to the distraction of surplus items. (b) Girls were more likely to say that there is no solution, a finding that was not observed in previous studies and which can indicate a lack of confidence or reluctance to answer when they do not find an immediate answer or are not sure of the correctness of their solution. The girls who said that there was no solution were girls who solved the pattern correctly. They did not answer at all or even try to answer. They immediately said there was no solution. This could indicate a lack of confidence, fear of making a mistake, fear of trying, or waiting and thinking if the answer is not immediate. This may indicate that this answer stems from a lack of self-efficacy because they are not confident about their ability to solve and prefer to avoid answering. This reinforces findings suggesting that girls tend to lack confidence in mathematics more than boys (e.g. Herbert & Stipek, 2005; Lindberg et al., 2013). This finding suggests that kindergarten teachers need to strengthen girls' self-efficacy and encourage a response even when insecurity and lack of cooperation are demonstrated. (c) Boys were more prone to continue the pattern randomly, an error observed in previous studies (e.g. Rittle-Johnson et al., 2013), or copying the items given to them in order. This can be explained by the fact that the children were distracted by the surplus items and did not concentrate on finding the items needed to continue the model. This finding may indicate that the boys do not solve the repeating pattern tasks by looking for the unit of repetition, and it emphasizes the need to do it in the teaching process. (d) Boys tended to continue the pattern by another repeating pattern, a finding observed in previous studies (e.g. Rittle-Johnson et al., 2013), which could be explained in several ways. Maybe the boys solve rhythmically and suggest a solution to another pattern with the same rhythmicity, or maybe the boys cannot find the items they need due to the distraction of surplus items. They look for an alternative solution since there is 'no' solution. This type of response has been found in other studies when children were given a task with no solution and looked for an alternative solution. This finding may suggest that kindergarten teachers need to strengthen the boys' recognition of the repetition unit, not allow a rhythmic solution, and let them identify the correct items that make up the repetition unit, even among many items.

The second finding is that no significant difference was found between the children's answers to these questions, even though the children were given more items in the third question than in the other two questions. This can be explained by the assumption that surplus items distract and confuse the children, and it does not matter if they receive a few more items. Also, almost everyone who did not answer the question with surplus colors correctly did not correctly answer the question with surplus shapes. Giving surplus items created different responses, and no one variable (color or shape) stood out to the children or was more significant for them than the other variable. This finding implies that the children solve repeating pattern tasks rhythmically without recognizing the unit of repeat and the rule of the pattern, as implied by the solution of the first task. This finding emphasizes the importance of identifying the repeating unit of the pattern, identifying its components, and repeating it. During the teaching, it is recommended that the kindergarten teacher give tasks of identifying the repetition unit and its components, as well as tasks in which the children must find the items they need to build and continue the model from an item folder.

The findings may suggest the way that pattern tasks are taught in kindergarten. This implies that teachers do not show and explain the rules according to which patterns are built and how to generalize them; instead, they show how to solve specific tasks, focusing on the given patterns and how to continue them technically. Such a method might help children solve repeating pattern tasks: previous studies indicated that children could succeed in continuing repeating patterns by using a procedural or rhythmic approach (Threlfall, 1999). This way does not fulfill the goal of mathematics teaching in kindergarten. The primary purpose of learning patterns is generalization – therefore, it should be an essential aspect of teaching patterns. The results emphasize that kindergarten teachers should focus their explanations on the pattern's structure – emphasize it, verbalize it, and give tasks in which the child is asked to identify the repeating unit and explain how the pattern is built.

Studying gender differences in mathematics at the kindergarten level is crucial for promoting equality, addressing biases, and ensuring all children reach their full potential in mathematics and beyond. This study's findings indicate that repeating patterns should be taught in kindergarten with a response adapted to the different genders. The study's limitations are the small number of participants and the small number of tasks. Therefore, it is possible to propose follow-up studies with more participants, patterns, and tasks.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

The data will be made available upon request from the corresponding author.

About the author

Iris Schreiber(Ph.D.): Head of the Mathematics Department at the Kibbutzim College of Education.Lecturer in Teacher Education at Bar Ilan University.Research Areas: (1) Mathematics Teachers' Knowledge, Beliefs, and Self-Efficacy; (2) Gender Differences in Mathematics Education; (3) Teachers' Education.

References

Ayebo, A., & Dingel, M. (2021). Exploring the relationship among mathematics attitude, gender, and achievement of undergraduate health science students. *Mathematics Teaching Research Journal*, *13*(3), 5–20.

Borriello, G. A., Grenell, A., Vest, N. A., Moore, K., & Fyfe, E. R. (2023). Links between repeating and growing pattern knowledge and math outcomes in children and adults. *Child Development*, *94*(2), e103–e118. https://doi.org/10.1111/cdev.13882

Carmichael, C. (2013 *Gender differences in Children's mathematics achievement: Perspectives from the longitudinal study of Australian children* [Paper presentation]. 36th Mathematics Education Research Group of Australasia (MERGA) Conference 2013. Mathematics Education Research Group of Australasia.

Carr, M., & Davis, H. (2001). Gender differences in arithmetic strategy use: A function of skill and preference. *Contemporary Educational Psychology*, *26*(3), 330–347. https://doi.org/10.1006/ceps.2000.1059

Cimpian, J. R., Lubienski, S. T., Timmer, J. D., Makowski, M. B., & Miller, E. K. (2016). Have gender gaps in math closed? Achievement, teacher perceptions, and learning behaviors across two ECLS-K cohorts. *AERA Open*, *2*(4), 1–19. https://doi.org/10.1177/2332858416673617

Clements, D. H., & Sarama, J. (2007). Effects of a preschool mathematics curriculum: Summative research on the Building Blocks project. *Journal for Research in Mathematics Education*, *38*(2), 136–163. https://doi.org/10.2307/30034954

David, H. (2021). *Mathematics gender gaps in the matriculation exams and the psychometrics in Israel*. https://www.researchgate.net/publication/338790170_hbdlym_mgdryym_bmbhny_hbgrwt_wbmbhn_hpsykwmtry_bmtmtyqh

Else-Quest, N. M., Hyde, J. S., & Linn, M. C. (2010). Cross-national patterns of gender differences in mathematics: A meta-analysis. *Psychological Bulletin*, *136*(1), 103–127. https://doi.org/10.1037/a0018053

Fryer, R. G., Jr,., & Levitt, S. D. (2010). An empirical analysis of the gender gap in mathematics. *American Economic Journal: Applied Economics*, *2*(2), 210–240. https://doi.org/10.1257/app.2.2.210

Gallagher, A. M., De Lisi, R., Holst, P. C., McGillicuddy-De Lisi, A. V., Morely, M., & Cahalan, C. (2000). Gender differences in advanced mathematical problem-solving. *Journal of Experimental Child Psychology*, *75*(3), 165–190. https://doi.org/10.1006/jecp.1999.2532

Ghasemi, E., Burley, H., & Safadel, P. (2019). Gender differences in general achievement in mathematics: An international study. *New Waves-Educational Research and Development Journal*, *22*(1), 27–54.

Herbert, J., & Stipek, D. (2005). The emergence of gender differences in children's perceptions of their academic competence. *Journal of Applied Developmental Psychology*, *26*(3), 276–295. https://doi.org/10.1016/j.appdev.2005.02.007

Kahn, S., & Ginther, D. (2017). *Women and STEM. No. w23525*. National Bureau of Economic Research. .

Kaldo, I., & Õun, K. (2020). Gender differences favouring females in learning strategies in mathematics. *Problems of Education in the 21st Century*, *78*(4), 595–611. https://doi.org/10.33225/pec/20.78.595

Klein, P. S., Adi-Japha, E., & Hakak-Benizri, S. (2010). Mathematical thinking of kindergarten boys and girls: Similar achievement, different contributing processes. *Educational Studies in Mathematics*, *73*(3), 233–246. https://doi.org/10.1007/s10649-009-9216-y

Lindberg, S., Linkersdörfer, J., Ehm, J.-H., Hasselhorn, M., & Lonnemann, J. (2013). Gender differences in children's math self-concept in the first years of elementary school. *Journal of Education and Learning*, *2*(3), 1–8. https://doi.org/10.5539/jel.v2n3p1

Liu, O. L., & Wilson, M. (2009). Gender differences in large-scale math assessments: PISA trend 2000 and 2003. *Applied Measurement in Education*, *22*(2), 164–184. https://doi.org/10.1080/08957340902754635

Lu, Y., Zhang, X., & Zhou, X. (2023). Assessing gender difference in mathematics achievement. *School Psychology International*, *44*(5), 553–567. https://doi.org/10.1177/01430343221149689

Lüken, M. M., Peter-Koop, A., & Kollhoff, S. (2014). *Influence of early repeating patterning ability on school mathematics learning*. North American Chapter of the International Group for the Psychology of Mathematics Education.

Lüken, M. M., & Sauzet, O. (2021). Patterning strategies in early childhood: A mixed methods study examining 3-to 5-year-old children's patterning competencies. *Mathematical Thinking and Learning*, *23*(1), 28–48. https://doi.org/10.1080/10986065.2020.1719452

Matthews, J. S., Ponitz, C. C., & Morrison, F. J. (2009). Early gender differences in self-regulation and academic achievement. *Journal of Educational Psychology*, *101*(3), 689–704. https://doi.org/10.1037/a0014240

Mejía-Rodríguez, A. M., Luyten, H., & Meelissen, M. R. M. (2021). Gender differences in mathematics self-concept across the world: An exploration of student and parent data of TIMSS 2015. *International Journal of Science and Mathematics Education*, *19*(6), 1229–1250. https://doi.org/10.1007/s10763-020-10100-x

Mulligan, J., Oslington, G., & English, L. (2020). Supporting early mathematical development through a 'pattern and structure' intervention program. *ZDM*, *52*(4), 663–676. https://doi.org/10.1007/s11858-020-01147-9

Papic, M. M. (2007). Promoting repeating patterns with young children – more than. *Just Alternating Colours! Australian Primary Mathematics Classroom*, *12*(3), 8–13. https://search.informit.org/doi/10.3316/informit.135529953955178

Papic, M. M., Mulligan, J. T., & Mitchelmore, M. C. (2011). Assessing the development of preschoolers' mathematical patterning. *Journal for Research in Mathematics Education*, *42*(3), 237–268. https://doi.org/10.5951/jresematheduc.42.3.0237

Patrick, H., Mantzicopoulos, P., & Samarapungavan, A. (2009). Motivation for learning science in kindergarten: Is there a gender gap and does integrated inquiry and literacy instruction make a difference. *Journal of Research in Science Teaching*, *46*(2), 166–191. https://doi.org/10.1002/tea.20276

Penner, A. M., & Paret, M. (2008). Gender differences in mathematics achievement: Exploring the early grades and the extremes. *Social Science Research*, *37*(1), 239–253. https://doi.org/10.1016/j.ssresearch.2007.06.012

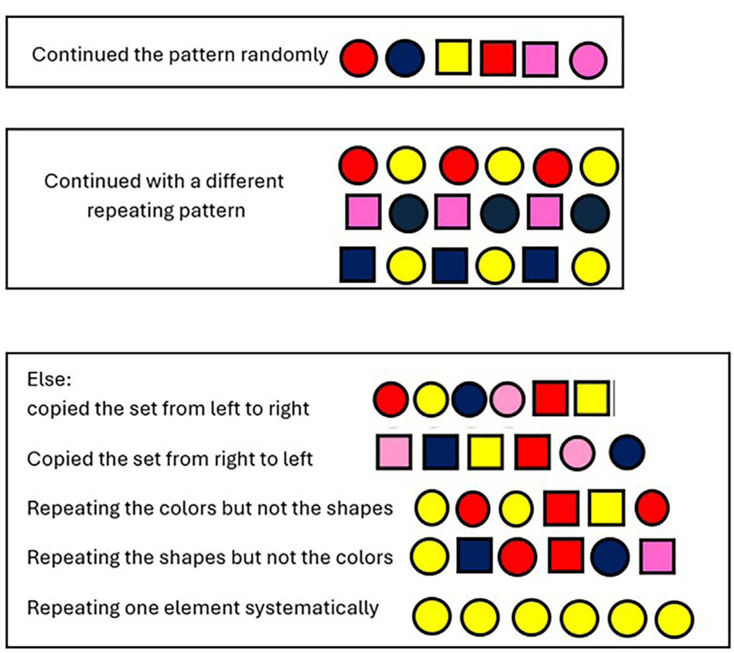
Perez Mejias, P., McAllister, D. E., Diaz, K. G., & Ravest, J. (2021). A longitudinal study of the gender gap in mathematics achievement: Evidence from Chile. *Educational Studies in Mathematics*, *107*(3), 583–605. https://doi.org/10.1007/s10649-021-10052-1

Rittle-Johnson, B., Fyfe, E. R., McLean, L. E., & McEldoon, K. L. (2013). Emerging understanding of patterning in 4-year-olds. *Journal of Cognition and Development*, *14*(3), 376–396. https://doi.org/10.1080/15248372.2012.689897

Rodríguez, S., Regueiro, B., Piñeiro, I., Estévez, I., & Valle, A. (2020). Gender differences in mathematics motivation: Differential effects on performance in primary education. *Frontiers in Psychology*, *10*, 3050. https://doi.org/10.3389/fpsyg.2019.03050
Schreiber, I., & Ashkenazi, H. (2024). The impact of various teaching methods on the knowledge of students of different genders: The case of mathematics word problems abstract. *Heliyon*, *10*(16), e35610. https://doi.org/10.1016/j.heliyon.2024.e35610
Singh, A., & Krutikova, S. (2017). *Starting together, growing apart: Gender gaps in learning from preschool to adulthood in four developing countries.* Younglives. https://hdl.handle.net/20.500.12820/453
Skaalvik, S., & Skaalvik, E. M. (2004). Gender differences in math and verbal self-concept, performance expectations, and motivation. *Sex Roles*, *50*(3/4), 241–252. https://doi.org/10.1023/B:SERS.0000015555.40976.e6
Smith, E., & White, P. (2024). Gender, participation and attainment in STEM: A comprehensive overview of long-term trends in the United Kingdom. *British Educational Research Journal, 1*, 1–14. https://doi.org/10.1002/berj.4102
Threlfall, J. (1999). Repeating pattern in the early primary years. In A. Orton (Ed.), *Pattern in the teaching and learning of mathematics* (pp. 18–29). Cassel.
Tsamir, P., Tirosh, D., Barkai, R., & Levenson, E. (2018). Copying and comparing repeating patterns: children's strategies and descriptions. In M. Carlsen, I. Erfjord, & P.S. Hundeland (Eds.), *Mathematics education in the early years* (pp. 63–78). Springer. https://doi.org/10.1007/978-3-030-34776-5_4
Vessonen, T., Hellstrand, H., Aunio, P., & Laine, A. (2024). Individual differences in mathematical problem-solving skills among 3-to 5-year-old preschoolers. *International Journal of Early Childhood*, *56*(2), 339–357. https://doi.org/10.1007/s13158-023-00361-2
Warren, E., Miller, J., & Cooper, T. (2012). Repeating patterns: Strategies to assist young students to generalise the mathematical structure. *Australasian Journal of Early Childhood*, *37*(3), 111–120. https://doi.org/10.1177/183693911203700315
Wijns, N., Verschaffel, L., De Smedt, B., De Keyser, L., & Torbeyns, J. (2021). Stimulating preschoolers' focus on structure in repeating and growing patterns. *Learning and Instruction*, *74*, 101444. https://doi.org/10.1016/j.learninstruc.2021.101444
Wijns, N., Verschaffel, L., De Smedt, B., & Torbeyns, J. (2021). Associations between repeating patterning, growing patterning, and numerical ability: A longitudinal panel study in 4-to 6-year olds. *Child Development*, *92*(4), 1354–1368. https://doi.org/10.1111/cdev.13490
Zhu, W., et al. (2025). Bridging the gender gap: The role of AI-powered math story creation in learning outcomes. In *Proceedings of the 15th International Learning Analytics and Knowledge Conference*. https://doi.org/10.1145/3706468.3706539
Zippert, E. L., Douglas, A.-A., & Rittle-Johnson, B. (2020). Finding patterns in objects and numbers: Repeating patterning in pre-K predicts kindergarten mathematics knowledge. *Journal of Experimental Child Psychology*, *200*, 104965. https://doi.org/10.1016/j.jecp.2020.104965

Appendix A

Examples of wrong continuations to the pattern in the second task



Appendix B

Examples of wrong continuations to the pattern in the third task