Higher-Order Thinking Skills Profile of Students in Mathematics: Gender Perspective

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Abstract. The Higher-Order Thinking Skill (HOTS) is the skill required in the 21st century to face the challenges in the era. Therefore, it is necessary to integrate HOTS into the teaching and learning process, including mathematics. This research aims to provide the profile of HOTS of mathematics students and identify any significant difference between male and female students. HOTS of this research refer to HOTS in Revised Taxonomy Bloom. The subject of this study was 25 middle school students: 7 male and 18 female. To reach the objective of this study, the researchers used a quantitative descriptive design. The findings showed that: 1) HOTS of students in mathematics is in a low category (32%); 2) students with C4 and C6 skills are in a low category, while there is a medium category for C5 skills; 3) there is no significant difference between HOTS of male and female students for each level (C4, C5, C6) or in general; 4) there is no significant difference between HOTS of male and female students for each mathematics domain except algebra.

Keywords: Higher-Order Thinking Skills; Mathematics; Revised Taxonomy Bloom; Gender; Analyze; Evaluate; Create

INTRODUCTION

Higher-order thinking Skills, HOTS, are not ignored skills that society must possess in this era. Many experts defined HOTS from some point of view. HOTS refers to the ability to think creatively and critically to solve a problem by authors [1, 2]; the ability to analyze, evaluate, and create authors [3]; solve non-routine issues from various perspectives by authors [4, 5]; ability to solve the complex problem authors [6]. From those definitions, HOTS can enable someone to solve a problem in many ways. In addition, those definitions make HOTS related to 21st-century skills.

Nowadays, one way to adapt and retain in the rapid change and challenge in 21 this era is by mastering 21st-century skills. One of the most critical components of 21st-century skills is Learning & Innovation skills. The skills include creativity and innovation, critical thinking and problem-solving, communication, and collaboration [7]. Then, from the definition of HOTS above, it relates to 21st-century skills. Regardless of the definition of 21st-century skills that might vary across the nation, authors [8] those skills relate to higher-order thinking skills authors [9]. Therefore, higher-order thinking skills, HOTS, are essential for all society nowadays to adapt to the rapid development in the 21st century.

Regarding how vital higher-order thinking skills are, the curriculum must focus on developing these skills in the classroom authors [10, 11], significantly to develop 21st-century skills author [12]. Integrating HOTS into the curriculum can be a step forward in preparing students, as the next generation, to adapt to the changes in this era. Furthermore, integrated HOTS-based learning in the classroom must begin with assessing students' preliminary HOTS. Therefore, teachers can determine what teaching method they should apply and what problem they should propose in the teaching and learning process author [13]. Thus, the problem will be meaningful and truly can help students to develop their HOTS. Assessing students' preliminary knowledge or skill refers to what Vygotsky said as ZPD (Zone Proximal Development) when teachers must provide a particular task so students can enter their ZPD to boost their achievement authors [14, 15].

Higher-order thinking skills (HOTS) are not restricted to a particular subject. HOTS can be integrated with all subjects of school, especially mathematics, according to authors [16–18]. However, much research on mathematics shows different results regarding gender on students' mathematics ability. Much research showed that males are better than female authors [19, 20]; meanwhile, a lack of research showed the opposite result authors [21]. Others also showed no significant difference between authors of male and female mathematics abilities [22, 23]. Then, what about students' higher-order thinking skills in mathematics? Is there any difference between male and female students? Research showed different findings in male and female students' mathematics abilities. On the other hand, higher-order thinking skills in mathematics, of course, will also depend on students' mathematical ability authors [24, 25].

This research aims to provide the profile of students' HOTS performance to contribute to describing the HOTS profile of students in mathematics. The researchers also explored the differences between male and female students' HOTS in mathematics. The research about gender differences in mathematics HOTS was conducted by authors [26], which showed that male and female students have different HOTS in mathematical problem-solving. However, the research was qualitative and only had two samples: students with high HOTS ability. This research fails to provide teachers with a general view of the students' HOTS level in mathematics. It lacks empirical evidence on the difference between male and female HOTS in mathematics.

Authors conducted another research on students' HOTS in mathematics authors [27]; the finding shows that the HOTS of female and male students differ for each HOTS indicator. However, the research only focused on one mathematics topic, namely linear equations. Meanwhile, this research will focus on almost all mathematics topics for middle school students, namely algebra, geometry, statistics, and numbers. Therefore, investigating students' HOTS profiles is more profound than before. It will provide the teacher with a wide diversity of students' HOTS, not only from individual factors (gender) but also from a mathematics content point of view (algebra, geometry, statistics, and numbers). It can also help the teacher identify what students typically have HOTS levels and which mathematics topics are more challenging. As a result, the teacher can prepare appropriate hypothetical learning trajectories to support the development of students' HOTS in mathematics classrooms for specific topics. It can benefit the teacher to create differentiated learning for their students and build equity in mathematics, whether male or female.

To achieve the objective of this research, we proposed five research questions.

RQ 1: How is the profile of students' HOTS in mathematics, in general, and across gender (male and female)?

RQ 2: What are male and female students' performances in solving mathematics HOTS questions for each topic of mathematics?

RQ 3: Is there any significant difference between HOTS in mathematics for male and female students?

RQ 4: Is there any significant difference between HOTS in mathematics of male and female students for each level (C4, C5, and C6)?

RQ 5: Is there any significant difference between HOTS in mathematics for male and female students in each mathematics domain?

METHOD

This research used a quantitative approach because the data collected is numerical data author [28]. In addition, the researchers applied descriptive quantitative analysis to the design of this research. The researchers chose this design because it is preferred for gathering data without manipulating any variables [29] and for descriptive purposes [29, 30]. This approach is suitable for representing students' HOTS in mathematics. The sample of this research was 25 middle school students in Mataram City, West Nusa Tenggara, Indonesia. There are seven male students and 18 female students in the study. The researchers selected the research subjects through purposive sampling based on specific criteria. We chose students who have learned almost all mathematics content for the middle school level. Therefore, the researchers selected students in Grade 9 as research subjects and collected data through HOTS questions for mathematics. They assigned twenty questions to the subjects. The researchers conducted this research during the pandemic and collected data through Google Forms. The question covered almost all mathematics topics for middle school students and all HOTS levels. The HOTS criteria

in this research are based on the Revised Taxonomy Bloom [3]. Before the instrument is used, it has been justified by experts and, through trial, tests to identify the validity, reliability, power, and discrimination index. The collected data was then analyzed using descriptive and inferential statistics.

The researchers analyzed the data using descriptive statistics to answer RQ 1 and RQ 2, as both research questions aimed to describe students' HOTS profiles in general. Meanwhile, for RQ 3, RQ 4, and RQ 5, the data were analyzed using inferential statistics to identify whether there is any significant difference between male and female students' HOTS in mathematics. The significance level used in this research is 5 %. The hypotheses for RQ 3, RQ 4, and RQ 5 are presented in Table 1. A comparison test will be performed to check whether there is any significant difference between male and female students' HOTS in mathematics.

Table 1 − Research Hypotheses

Hypotheses	Statistical Hypotheses		Research Hypotheses
Hypotheses for RQ 3	$H_o: \mu_1 = \mu_2$ $H_1: \mu_1 \neq \mu_2$ $\alpha = 5\%$		H_o: There is no significant difference between male and female students' HOTS in mathematics H_1: There is a significant difference between male and female students' HOTS in mathematics
Hypotheses for RQ 4	C4	$H_o: \mu_1 = \mu_2$ $H_1: \mu_1 \neq \mu_2$ $\alpha = 5\%$	H_o: There is no significant difference between male and female students' Analysis Skills (C4) H_1: There is a significant difference between male and female students' Analysis Skills (C4)
	C5	$H_o: \mu_1 = \mu_2$ $H_1: \mu_1 \neq \mu_2$ $\alpha = 5\%$	H_o: There is no significant difference between male and female students' Evaluation Skills (C5) H_1: There is a significant difference between male and female students' Evaluation Skills (C5)
	C6	$H_o: \mu_1 = \mu_2$ $H_1: \mu_1 \neq \mu_2$ $\alpha = 5\%$	H_o: There is no significant difference between male and female students' Creation Skills (C6) H_1: There is a significant difference between male and female students' Creation Skills (C6)
Hypotheses for RQ 4	Number	$H_o: \mu_1 = \mu_2$ $H_1: \mu_1 \neq \mu_2$ $\alpha = 5\%$	H_o: There is no significant difference between male and female students HOTS in number domain H_1: There is a significant difference between male and female students HOTS in number domain
	Algebra	$H_o: \mu_1 = \mu_2$ $H_1: \mu_1 \neq \mu_2$ $\alpha = 5\%$	H_o: There is no significant difference between male and female students' HOTS in the algebra domain H_1: There is a significant difference between male and female student's HOTS in the algebra domain
	Geometry and Measurement	$H_o: \mu_1 = \mu_2$ $H_1: \mu_1 \neq \mu_2$ $\alpha = 5\%$	H_o: There is no significant difference between male and female students' HOTS in the geometry and measurement domain H_1: There is a significant difference between male and female students' HOTS in the geometry and measurement domain
	Statistics and Probability	$H_o: \mu_1 = \mu_2$ $H_1: \mu_1 \neq \mu_2$ $\alpha = 5\%$	H_o: There is no significant difference between male and female students' HOTS in statistics and probability domain H_1: There is a significant difference between male and female students' HOTS in the statistics and probability domain

Notes: μ_1 − The mean of male students' HOTS; μ_2 − The mean of female students' HOTS

The conversion of students' HOTS will be determined based on Table 2 to provide a better interpretation.

Table 2 – Category of HOTS Score

HOTS Score	Category
$x \geq 66.67\%$	High
$33.33\% \leq x < 66.67\%$	Moderate
$x < 33.33\%$	Low

RESULTS AND DISCUSSION

RQ 1: How is the profile of students' HOTS in mathematics, in general, and across gender (male and female)? Table 3 shows that, in general, the HOTS of students in mathematics is in a low category.

Table 3 – Students' HOTS

	Male (%)	Female (%)	Total (%)
Average HOTS Score	32.14	31.94	32.00
Category	Low	Low	Low

Male students get a higher score (32.14%) than female students (31.94%). For each indicator (Table 4), students can perform better in questions with C5 Level (39.43%). Meanwhile, the questions with C4 & C6 Levels are more challenging for them. From a gender view (Table 4), male students can perform better in answering questions with Levels C4 and C6 than female students.

Table 4 – Students' Achievement in HOTS for Each Level

Level	Male (%)	Female (%)	Total (%)	Category
C4	30.61	26.19	27.43	Low
C5	28.57	43.65	39.43	Moderate
C6	38.10	25.00	28.67	Low

On the other hand, female students are better than male students at the C5 level. Table 4 also showed that students' C5 Skills (evaluation) are in the medium category but low in C4 (analysis) and C6 (creation) skills. In addition, male students achieved a medium level in C6 Skills, while females achieved a medium level in C5 Skills.

RQ 2: What are male and female students' performances in solving mathematics HOTS questions for each topic of mathematics? From Table 5, geometry is the most challenging subject for students to answer; males or females get scores less than 33.33% in geometry topics, which means that both abilities in geometry topics are low.

Table 5 – Students' Achievement in HOTS for Each Mathematics Topic

Topic	Male (%)	Female (%)	Total (%)	Category
Number	30.61	34.13	33.14	Low
Algebra	28.57	38.89	36.00	Moderate
Geometry and Measurement	30.95	21.30	24.00	Low
Statistic and Probability	42.86	38.89	40.00	Moderate

However, female students achieved a medium level in numbers, algebra, and statistics, while male students only achieved a medium level in statistics. Overall, students can perform well in almost all topics except geometry.

RQ 3: Is there any significant difference between HOTS in mathematics for male and female students? Using SPSS 26, the Normality and Homogeneity Test result is presented in Table 6.

Table 6 – Normality & Homogeneity Test for RQ 3

	p-value	Decision
Normality Test	0.881	Data is normally distributed
Homogeneity Test	0.826	Data is homogeneous

Since both showed that the data is expected (p>0.05) and homogenous (p>0.05), a t-test will be performed to compare male and female students' HOTS in mathematics; the result of the t-test is presented in Table 7.

Table 7 – Comparison Test Between Male and Female Students' HOTS

	t-value	p-value (2-tailed)	Decision
HOTS Score	0.32	0.975	There is no significant difference (Retain H_o)

It showed no significant difference between the HOTS of male and female students in mathematics, with a significance level of 5% (H_o I accepted).

RQ 4: Is there any significant difference between HOTS in mathematics of male and female students for each level (C4, C5, and C6)? Using SPSS 26, the Normality and Homogeneity Test result for RQ 4's data is presented in Table 8.

Table 8 – Normality & Homogeneity Test for RQ 4

Skill	Test	p-value	Decision
C4 (Analyze)	Normality	0.031	Data is not normally distributed
	Homogeneity	0.380	Data is homogeneous
C5 (Evaluate)	Normality	0.930	Data is normally distributed
	Homogeneity	0.356	Data is homogeneous
C6 (Create)	Normality	0.260	Data is normally distributed
	Homogeneity	0.185	Data is homogeneous

The table shows that the data for C5 and C6 are regular and homogenous. Then, a t-test will be performed to compare male and female students' HOTS in mathematics for C5 Skills. However, if data for C4 is not standard (p<0.05) but homogeneous, then the Mann-Whitney test will be applied to the case. With a significance level of 5%, the results of the comparison test between male and female students for C4, C5, and C6 are presented in Table 8. It showed no significant difference between male and female students in C4, C5, and C6 Skills.

Table 9 – Comparison Test Between Male and Female Students' HOTS For Each Level

	p-value (2-tailed)	Decision
C4	0.960	There is no significant difference (Retain H_o)
C5	0.096	There is no significant difference (Retain H_o)
C6	0.158	There is no significant difference (Retain H_o)

RQ 5: Is there any significant difference between HOTS in mathematics for male and female students in each mathematics domain? Table 10 shows the result of the Normality and Homogeneity Test for RQ 5.

Table 10 – Normality & Homogeneity Test for RQ 5

Domain	Test	p $-value$	*Decision*
Number	Normality	0.006	Data is not normally distributed
	Homogeneity	0.000	Data is not homogeneous
Algebra	Normality	0.355	Data is normally distributed
	Homogeneity	0.024	Data is not homogeneous
Geometry and Measurement	Normality	0.056	Data is normally distributed
	Homogeneity	0.178	Data is homogeneous
Statistics and Probability	Normality	0.238	Data is normally distributed
	Homogeneity	0.230	Data is homogeneous

The table showed that data for Geometry and Statistics are typically distributed and homogenous. Then, a t-test will compare male and female students' HOTS in mathematics in both domains. However, if data for algebra is regular but not homogeneous, then the Welch test will be applied to the case. Meanwhile, the data are not typical and homogeneous for the number domain, so the Welch test will be used to analyze the domain. With a significance level of 5%, the result of the comparison test between male and female students for numbers, algebra, geometry, and statistics is presented in Table 11.

Table 11 – Comparison Test Between Male and Female Students' HOTS For Each Mathematics Domain

	p-value (2-tailed)	Decision
Number	0.071	There is no significant difference (Retain H_o)
Algebra	0.021	There is a significant difference (Reject H_o)
Geometry and Measurement	0.168	There is no significant difference (Retain H_o)
Statistics and Probability	0.158	There is no significant difference (Retain H_o)

It showed no significant difference between male and female students for numbers, geometry, and statistics, but it does in the algebra domain.

This research focuses on describing the HOTS profile of students in mathematics subject and whether it is different between male and female students. The result shows that middle school students have low HOTS in mathematics. In addition, this research confirms no significant difference between male and female students' HOTS in mathematics in general or for each indicator. Nevertheless, if we view it from the mathematics domain, there is a significant difference in the algebra domain between male and female students, while female students surpass male students. Meanwhile, we cannot find any differences between male and female students for other domains.

Research shows that male students outperform in mathematics more than female students [31–33]. Based on Table 3, male students can perform better than female students in solving mathematics HOTS questions. However, the differences between male and female students are not significant. Therefore, for that sample, the HOTS skills level of male and female students is the same. This research shows the opposite finding from the previous research [26, 27]. However, this research supports the earlier study that males and females do not have differences in mathematics [23, 34]. It may happen since the sample used in this research is different, and the topic of mathematics covered is more comprehensive than in the previous research.

HOTS is a skill; therefore, it must be frequently trained to be fluent [34, 35]. However, based on our interview with teachers at that school, HOTS problems are rarely used in the class. It may be why there is no significant difference between males and females. The teacher seldom applies HOTS since students, even for comprehension tests, still need more achievement. HOTS problems require students to use reasoning [36], but how can they do reasoning if the fundamental concept still cannot be understood? Also, teachers rarely apply HOTS problems during instruction, which may be another reason students have low ability in HOTS in mathematics.

Gender Differences in HOTS Indicators. Among C4 (analyze), C5 (evaluate), and C6 (create) skills, students can perform better only in C5 skills. The result depicted that the student showed medium

ability in evaluation (C5) skills. Meanwhile, both in C4 and C6, students showed low ability.

Analysis skills include dividing data or information into pieces and determining their relationship [3]. The analysis skill consists of three processes: differentiate, organize, and attribute. Figure 1 shows the example of analyzing level questions or C4. In the question, students were asked to measure the magnitude of ∠ACD. Only 12% of students can answer this question correctly, with 29% male and 5% female students. This question indicates that male students may analyze better than female students; male students can differentiate information, determine valuable information, and organize the helpful information to find the answer better than female students.
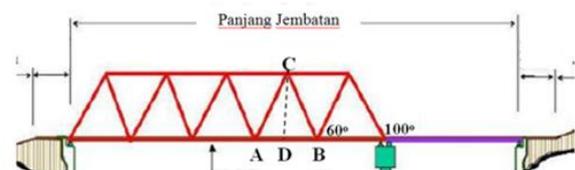

Figure 1 – Example of C4 Question (in Indonesian)

Meanwhile, the evaluation is the ability to decide based on specific criteria or standards [3]. Evaluation skills involve two main processes, namely, checking and criticizing. Figure 2 is an example of a question for the C5 Level.

Figure 2 – Example of C5 Question (in Indonesian)

The students were asked to determine the best choice to purchase bags and shoes to get a cheaper price based on the criteria given. Most

students can answer the question (60%) correctly. However, if we view it from gender, only 43% of male students can answer the question, while 67% of female students can answer it correctly. Based on this question, female students can make better decisions than male students. Female students may have better evaluation skills at this level than male students.

On the other hand, the creation skill is the opposite of analysis. The skill refers to compiling a piece of information into a whole [3]. This skill also consists of three processes: formulated, planned, and produced. Figure 3 shows the example of a question in C6 Level that asked students to determine when the sales results of two companies are equal.
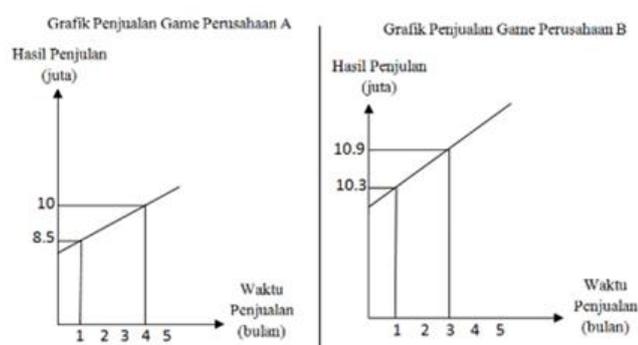
Figure 3 – Example of C6 Question (in Indonesian)

The question required students to create a line equation for each company based on the graphic given. Only 36% can answer that question correctly, with 57% male and 28% female students. The question indicates that male students have better creative skills than female students.

Gender differences for each domain. Table 4 shows that female students outperform male students in number and algebra domains. Meanwhile, male students surpass female students in geometry and statistics; this is supported by previous research showing that male students can perform better in visual-spatial abilities [37, 38]. It also can be seen in Figure 1 that when students need to use visual representation ability to solve problems, most male students can outperform females. It also applies to statistics, where many visual representations are used, i.e., diagrams and graphics. However, although male students' scores in statistics and geometry are higher than female students, there is no significant statistical difference between male and female students. Therefore, this research confirms previous re-

search that showed no significant difference between males and females in visual abilities [39].

On the other hand, the characteristics of female students who are good at using language authors [40, 41] are essential in mathematics [42], especially in numbers and algebra. In the algebra domain, students will need skills, such as using

symbols, variables, or other mathematical language, to manipulate real-life mathematics problems and solve them to get answers. Therefore, it is no wonder female students can perform better in algebra. From Figure 2, we also find that while male students better understand visual representation than female students when the information is given in writing (sentences), female students can perform better than male students. Female students tend to grasp the information in writing or text more easily than male students [43].

In general, from a topic point of view, geometry is the most challenging topic for students. Most students needed help answering the HOTS question on this topic. As shown in Figure 1, the question is straightforward, but most of the students incorrectly answer the question. It may be caused by the need for students to understand the facts and concepts of line and angle. In geometry, there are a lot of terms and concepts that must be understood by students, not only memorized. On the other hand, statistics and probability domains are the most manageable topics for students; this can be caused by the fact that statistics and probability are more realistic than others.

CONCLUSIONS

HOTS is essential for adapting to and facing challenges in the 21st century. Therefore, developing students' HOTS in the teaching and learning process, including mathematics, is crucial. Furthermore, this study explores the HOTS profile of students in mathematics. The results show that HOTS-level mathematics students are generally in a low category. However, the analysis showed no significant difference in HOTS between male and female students in general or at each level. Meanwhile, when viewed from the mathematics domain, there is a substantial difference between male and female students only in the algebra domain. The study also showed that the HOTS question on geometry is the hardest for students to solve.

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Conflicts of Interest

The authors declare no conflict of interest regarding the publication of this manuscript.

Author Contributions

Nyoman Sridana: Conceptualization, writing – review, supervision; Muhamad Syahidul Qirom: Conceptualization, writing - original draft, editing, and visualization; Muhammad Turmuzi: Writing – review and methodology.

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