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The Effect of Kahoot-Assisted Collaborative Problem Solving on Students' Mathematical Habits of Mind

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ABSTRACT

This study aimed to determine the effect of the Collaborative Problem Solving (CPS) model, supported by the interactive platform Kahoot, on students' Mathematical Habits of Mind (MHoM) regarding the topic of polynomials. A quantitative approach was employed using a quasi-experimental method with a non-equivalent control group design. The sample was selected via cluster sampling: Class XI IPA A-1 at MAN 1 Medan served as the experimental group (36 students) and was taught using the Kahoot-assisted CPS model, while Class XI IPA A-3 (36 students) served as the control group and was taught using conventional instruction. Data were collected using a validated MHoM questionnaire, supplemented by observation sheets administered solely to the experimental group over four sessions. Hypothesis testing using the Mann-Whitney U test on N-Gain data yielded a significance value of 0.020 ($p < 0.05$), indicating that the Kahoot-assisted CPS model resulted in a significantly greater improvement compared to conventional instruction. However, the calculated effect size fell into the small category ($r = 0.262$), suggesting a limited practical impact. Observations across the four sessions also revealed a consistent upward trend, rising from 50% to 93%. Given that the intervention spanned only four sessions, these results are quite promising. Thus, the Kahoot-assisted CPS model can serve as an alternative instructional strategy for developing students' MHoM.

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1. INTRODUCTION

Mathematical Habits of Mind (MHOM) represent the distinctive thinking patterns employed by mathematicians when addressing problems with unknown solutions; these encompass the ability to explore ideas, recognize patterns, engage in reflective thinking, generalize, represent ideas, and persist in problem-solving [4], [15], [18], [29]. MHOM is not merely a cognitive ability, but rather a positive, automatic, and recurring behavioral

pattern that serves as a framework guiding students to act more wisely in problem-solving. [31].

In mathematics learning, MHOM serves as an affective aspect that complements cognitive abilities and forms the foundation for reasoning, reflective thinking, and independent thinking skills [7], [23]. This habit encourages students to develop non-routine problem-solving and higher-order thinking skills, while also fostering self-confidence, perseverance, and a critical mindset that are valuable in various contexts [5], [20].

In particular, previous research indicates that the mathematical habits of mind (MHoM) of Indonesian students remain unsatisfactory. It has been found that the average MHoM achievement of junior high school students falls within the low-to-moderate range, particularly regarding the indicators of generalization and pattern discovery [31]. Students' mathematical thinking habits show a positive correlation but remain at a suboptimal level, particularly regarding perseverance and the ability to reflect on thought processes [2]. These findings align with diagnostic test results from Grade 11 students at MAN 1 Medan, which revealed low reasoning and problem-solving skills, a tendency toward passivity, and a lack of confidence in sharing solution strategies. It should be emphasized that low mathematics scores in international assessments like PISA primarily reflect general mathematical literacy and reasoning abilities; they cannot serve as direct evidence of the state of students' mathematical thinking habits, even though the two are interrelated.

Globally, the development of MHOM has become a primary focus in modern mathematics education due to its positive correlation with students' academic achievement and mathematical literacy [2]. However, the situation in Indonesia is concerning. PISA 2022 results placed Indonesia's mathematics score at 366, well below the OECD average of 472, with the majority of students failing to reach Level 2, a benchmark requiring reasoning skills and the ability to solve non-routine problems [24]. This indicates that mathematics instruction in Indonesia has not yet been optimal in fostering habits of deep mathematical thinking.

To address this situation, a learning approach that fosters collaborative thinking is essential. One alternative is the Collaborative Problem Solving (CPS) model, which integrates problem-solving with cooperation through the exchange of ideas, strategy formulation, and solution evaluation [10], [27], [28]. This model supports the development of MHoM through idea exploration, pattern recognition, representation, and persistence in problem-solving [1].

Using Kahoot as a supporting medium offers added value that is not achieved when CPS is implemented in isolation. First, Kahoot boosts student engagement and motivation through immediate feedback, fostering greater enthusiasm for participation in group discussions [17], [26]. Second, ranking and point systems encourage a healthy competitive spirit that reinforces the attribute of persistence. Third, presenting problems in an engaging format helps students grasp the problem context prior to discussion, thereby making the exploration phase more effective than in CPS instruction without interactive media [6], [30]. The Kahoot-supported CPS stages align with MHOM indicators: the Engagement and Exploration stages encourage idea exploration; the Transformation stage facilitates the exchange of strategies and pattern discovery; the Solution and Presentation stage fosters

verification and representation skills; and the Reflection stage strengthens the ability to generalize understanding [2], [3]. Polynomials were selected as the subject matter because the topic inherently requires recognizing patterns in coefficients and exponents, generalizing solution forms, and systematically representing the relationships between terms.

Although previous studies have examined the role of Kahoot in enhancing motivation and the role of collaboration in developing thinking skills, research specifically investigating the impact of the Kahoot-assisted CPS model on students' MHOM regarding polynomial topics remains very limited. Therefore, this study was designed to address this gap by proposing the following hypothesis:

"Research Hypothesis: The Collaborative Problem Solving learning model supported by the interactive medium Kahoot results in a greater improvement in students' MHoM compared to conventional learning."

This role also serves as the outcome of innovative learning models such as Problem-Based Learning (PBL) or the Missouri Mathematics Project (MMP), which shift the focus of learning from memorizing procedures to a deep understanding of concepts, while simultaneously serving as a bridge to strengthen students' mathematical connections and higher-order reasoning [1], [11], [14]. This underscores the importance of MHoM for success in mathematics learning.

To address this need, one applicable solution is the Collaborative Problem Solving (CPS) model, which integrates problem-solving and collaboration among learners through activities such as the exchange of ideas, strategy formulation, and solution evaluation [13], [27], [28]. This process fosters learners' MHoM through idea exploration, pattern recognition, representation, and persistence in problem-solving [1]. The CPS model, supported by Kahoot, enhances engagement and active learning by presenting compelling problems and providing immediate feedback, while aligning its stages with the established MHoM indicators [17], [25].

This relevance is reinforced by previous research showing that Kahoot can enhance motivation and active learning, while collaborative activities provide students with opportunities to exchange ideas and develop mathematical thinking skills through group interaction [2], [6], [20], [27], [30]. However, studies combining Collaborative Problem Solving facilitated by the interactive Kahoot platform with Mathematical Habits of Mind remain limited, particularly at the high school level. This gap forms the basis of this study to examine the effect of Collaborative Problem Solving facilitated by the interactive Kahoot platform on students' Mathematical Habits of Mind in the context of polynomial material.

This study introduces a novel approach by combining the CPS model with Kahoot interactive media within a structured learning sequence, aligning each stage of CPS with the specific MHOM indicators targeted for development. Furthermore, the study focuses on the topic of polynomials, a subject rich in mathematical patterns and relationships, making it an ideal context for fostering MHOM. Accordingly, this research aims to examine the impact of the Collaborative Problem Solving learning model, supported by Kahoot interactive media, on the Mathematical Habits of Mind of Grade XI Science students at MAN 1 Medan regarding the topic of polynomials.

The results of this study are expected to make both theoretical and practical contributions. Theoretically, this research enriches the mathematics education literature by presenting a conceptual framework and empirical evidence regarding the integration of the CPS model and Kahoot as an effective strategy for developing students' MHOM. Practically, these findings offer an alternative instructional strategy that mathematics teachers can implement to enhance student engagement and thinking skills, thereby ultimately improving the quality of mathematics instruction in schools.

2. METHOD

Research Design

This study employs a quantitative approach using a quasi-experimental method with a non-equivalent control group design [23]. The experimental class received instruction based on the Collaborative Problem Solving (CPS) model supported by the interactive medium Kahoot, while the control class received conventional instruction. The independent variable is Kahoot-assisted CPS instruction, and the dependent variable is Mathematical Habits of Mind (MHoM). The research design is presented in Table 1.

Table1 . Research Design

Class	***Pretest***	**Treatment**	***Posttest***
Experimental	O_1	X_1	O_2
Control	O_1	X_2	O_2

Description:

O_1 = *Pretest: Mathematical Habits of Mind* Questionnaire

O_2 = *Posttest: Mathematical Habits of Mind* Questionnaire

X_1 = *Collaborative Problem-Solving* Model Using the Kahoot Interactive Media

X_2 = Learning Using Conventional Models/Methods

Population and Sample

This study was conducted at MAN 1 Medan during the odd semester of the 2026/2027 academic year. The study population consisted of all Grade XI Science (IPA) students at MAN 1 Medan totaling 206 students distributed across six classes. The sample was selected using the cluster sampling technique, taking into account that the classes were already naturally formed [23]. Three classes were chosen: Class XI IPA A-2 served as the instrument trial class (34 students), Class XI IPA A-1 as the experimental class (36 students), and Class XI IPA A-3 as the control class (36 students). The assignment of the experimental and control classes was based on the equivalence of initial ability characteristics, confirmed through prerequisite scores and MHoM pretest results.

In this study, the sampling method employed was cluster sampling, wherein entire existing classes were included in their entirety, without individual randomization [23]. The steps for assigning the experimental and control groups were as follows:

1. Selection of candidate classes: Three classes were randomly selected from the six available classes, specifically, XI IPA A-2, XI IPA A-1, and XI IPA A-3. Class XI IPA A-2 (34 students) was designated for the instrument pilot test.
2. Assessment of initial equivalence: The remaining two classes (XI IPA A-1 and XI IPA A-3) were then assessed for initial ability equivalence based on report card grades from the previous semester and recommendations from the subject teacher. The equivalence test results indicated no statistically significant differences regarding these two indicators.
3. Group assignment: The experimental and control classes were determined through a simple draw. The draw designated Class XI IPA A-1 (36 students) as the experimental group and Class XI IPA A-3 (36 students) as the control group.
4. Confirmation of initial equivalence (pretest): Prior to the intervention, both classes were administered the MHoM questionnaire as a pretest. The results of the initial difference test are presented in Table 2.

Table 2. Results of the MHoM Pretest Equivalence Test

Aspect	Eksperimental Class (n = 36)	Control Class (n = 36)	Statistical Test	Mark p	Information
Rata-rata Pretest	56,22	60,14	Uji Mann-Whitney U	0,078	Tidak Berbeda Nyata (p > 0,05)

The results confirm that, although the control group's mean was slightly higher, there was no statistically significant difference in baseline MHoM conditions between the two groups prior to the intervention.

Research Instrument

The main instrument was a four-point Likert-scale MHoM questionnaire designed based on eight aspects identified by Cuoco and operationalized into six indicators: exploration of mathematical ideas, reflective thinking, generalization, pattern and relationship recognition, mathematical representation, and persistence [10].

The data sources consisted of primary data comprising students' responses to the MHoM questionnaire and observations made during instruction, and secondary data, consisting of students' academic grades. Data collection was conducted in three stages: preparation, implementation, and conclusion. The research instruments included the MHoM questionnaire (a 4-point Likert scale with 20 items measuring six indicators) and an observation sheet to monitor MHoM development during the learning process. An observation sheet was used as a supporting instrument to monitor these six indicators during instruction in the experimental class.

Validity and Reliability of the Instruments

The research instrument was first tested for validity and reliability to ensure its suitability for measuring Mathematical Habits of Mind. Validity included expert assessment by three validators regarding the alignment of items with indicators, clarity of language, and student comprehensibility, as well as empirical validity through Pearson's product-moment

correlation. An item was deemed valid if the calculated r was ≥ the table r at the 5% significance level. Reliability was calculated using Cronbach's alpha, and the instrument was deemed reliable if the coefficient was > 0.60 [25]. The results of this test can be seen in the following table:

Table 3. Validity and Reliability Test Results for the MHoM Instrument

Test	Result	Information
Content Validity	Average Aiken's V Score = 0,87	Very good
Item Validity	20 of 20 item are valid (r-count = 0,348-0,726 > r-table = 0,339	All Items are Valid
Reliability (Cronbach's Alpha)	coeficient = 0,842	High/Very Reliable

The intervention was conducted over four learning sessions, each lasting 2 x 45 minutes. Kahoot was integrated into each stage of the CPS model, covering: (1) pattern recognition in polynomial operations, (2) polynomial multiplication and algebraic identities, (3) polynomial division and the remainder theorem, and (4) polynomial applications in problem-solving.

Observations were conducted solely in the experimental class over the course of four instructional sessions. Two observers, mathematics teachers not directly involved in the study, were responsible for completing observation sheets containing a list of MHoM indicators. Inter-rater reliability was assessed prior to the study using data from a pilot test of the instrument in a different class, yielding an agreement coefficient of 0.89 (categorized as very high). This ensured consistency and objectivity in the observers' assessments throughout the instructional process.

The study was conducted in adherence to ethical research principles; the initial step involved obtaining formal authorization from the university, followed by securing permission from the target school. Furthermore, students' real names or identities were excluded from the report, and the data were used exclusively for research purposes.

Data Collection Procedure

Data collection was conducted in three stages: preparation, implementation, and conclusion. The preparation stage involved coordination with mathematics teachers, the development of the Merdeka Curriculum Teaching Module, and the development and testing of the instrument's validity and reliability. The implementation stage began with an MHoM pretest in both classes, followed by the application of CPS assisted by Kahoot in the experimental class and conventional learning in the control class, and concluded with a posttest using the same instrument. The final stage included data processing and analysis, drawing conclusions, and preparing the research report.

Data Analysis

Data analysis included descriptive statistics, the Shapiro-Wilk normality test, and Levene's test of homogeneity at a significance level of 0.05. Hypothesis testing used the Independent Samples t-test if the data were normally distributed and the Mann-Whitney U

test if the data did not meet the assumption of normality. These tests aim to determine differences in MHoM between the experimental and control classes after the treatment. The magnitude of the effect is determined through an effect size based on the Z-value from the hypothesis test, referring to Cohen's (1988) criteria.

3. RESULTS AND DISCUSSION

3.1. Results

Data Description and Prerequisite Tests for Analysis

The study was conducted on 11th-grade students at MAN 1 Medan, with 11th-grade Science Class A-1 serving as the experimental class and 11th-grade Science Class A-3 as the control class. The Mathematical Habits of Mind (MHoM) questionnaire was administered as a pretest before the intervention and as a posttest after the intervention. Descriptive statistics for the pretest and posttest data of both classes are presented in Table 4.

Table 4. Descriptive statistics for MHoM questionnaire pretest and posttest scores

Data	Class	N	Min	Max	Average	Elementary School
Pretest	Experiment	36	43	69	56.22	5.499
	Control	36	44	75	60.14	6.275
Posttest	Experiment	36	45	80	63.89	7.218
	Control	36	48	77	63.22	6.569

The data in Table 4 show that, prior to the treatment, the mean pretest score of the control group was higher than that of the experimental group by a margin of 3.92 points. Following the treatment, the mean posttest score of the experimental group was slightly higher than that of the control group, with a difference of 0.67 points. The absolute gain for the experimental group was 7.67 points, whereas the control group showed a gain of only 3.08 points.

Since the initial proficiency levels of the two groups were not equivalent, the analysis was not performed directly on the raw posttest scores. Instead, N-Gain scores were calculated for each student to normalize the improvement relative to the available scope for improvement:

$$N - Gain = \frac{Skor\ Postest - Skor\ Pretest}{Skor\ Maksimum - Skor\ Pretest} \quad (1)$$

Justification for using N-Gain on the MHoM questionnaire: Although MHoM is measured using a Likert scale, the resulting total scores constitute interval data that can be aggregated. N-Gain was selected because it allows for a fair comparison of improvement among students with varying initial scores students with high pretest scores have less room for improvement compared to those with low pretest scores. Without normalization, raw improvement figures can be misleading. N-Gain also facilitates standardized interpretation based on Hake's (1998) categories: ≥ 0.7 = High; 0.3–0.7 = Medium; < 0.3 = Low.

Normality and homogeneity tests were conducted on the pretest, posttest, and N-Gain scores; the results are presented in Table 5.

Table 5. Normality and homogeneity test results

Data	Class	Sig. Shapiro-Wilk	Sig. Levene	Notes
Pretest	Experiment	0.624	0.619	Normal, Homogeneous
	Control	0.866		Normal, Homogeneous
Posttest	Experiment	0.409	0.596	Normal, Homogeneous
	Control	0.835		Normal, Homogeneous
N-Gain	Experiment	0.036	0.423	Abnormal, Homogeneous
	Control	0.003		Abnormal, Homogeneous

Given the unequal nature of the group designs, Analysis of Covariance (ANCOVA) was considered as an alternative, using posttest scores as the dependent variable and pretest scores as the covariate. However, a key assumption of ANCOVA, namely, the normal distribution of residuals, was not met, as neither the N-Gain nor the posttest data followed a normal distribution. Consequently, ANCOVA was deemed unsuitable. Instead, a more appropriate and robust approach for this scenario is the non-parametric Mann-Whitney U test applied to N-Gain scores, which directly compares the normalized gains between the two groups.

N-Gain Data and Hypothesis Testing

Table 6. Descriptive Statistics of MHoM N-Gain Scores

Class	N	Min (%)	Max (%)	Mean (%)	SD	Category
Experiment	36	3.23	100	33.96	23.71	Moderate
Control	36	-100	61.11	13.70	32.35	Low

The average N-Gain for the experimental group was 33.96% (moderate category), whereas the control group's average was 13.70% (low category). The 20.26% difference in the average gain demonstrates the relative superiority of the Kahoot-assisted CPS model over conventional instruction. Notably, the minimum N-Gain score in the control group was −100, indicating that some students in that group experienced a decline in MHoM scores from the pretest to the posttest. This decline can be attributed to the fact that MHoM is not a construct that improves automatically; without interventions fostering consistent thinking habits, scores may drop due to fatigue, shifts in motivation, or a lack of reinforcement during instruction. In contrast, all students in the experimental group showed score increases, resulting in more uniform variation in gains (SD = 23.71) compared to the control group (SD = 32.35).

Table 7. Mann-Whitney U test results for MHoM N-Gain scores

Class	Mean Rank	Sum of Ranks	Mann-Whitney U	Sig. (2-tailed)
Experiment	42.22	1,520	442	0.020
Control	30.78	1108		

The significance value was 0.020 (< 0.05); thus, H_0 was rejected, and H_1 was accepted. There was a significant difference in the increase in MHoM between the experimental and control groups. The obtained effect size was r = 0.262 (95% CI [0.034;

0.467]), which falls into the small category according to Cohen's (1988) criteria. This implies that, despite the statistically significant difference, the magnitude of the treatment's practical impact was limited.

Achievement of Mathematical Habits of Mind Indicators

An analysis of indicator achievement was conducted to identify the aspects of Mathematical Habits of Mind that showed the most improvement and those that still need to be enhanced in the experimental class, using posttest data. The results of the analysis for each MHoM indicator are presented in Table 6.

Table 8. Achievement of MHoM Indicators in the Experimental Class

Indicator	Number of Items	Average	Percentage	Notes
Exploration of Mathematical Ideas	3	3.04	76%	Achieved
Reflective Thinking	3	3.24	81%	Highly Achieved
Generalization	2	2.97	74%	Achieved
Identifying Patterns and Relationships	3	3.18	79%	Achieved
Mathematical Representation	3	3.10	77%	Achieved
Persistence (Diligence)	6	3.33	83%	Highly Achieved
Total Average	20	3.19	79%	Achieved

The data in Table 8 show that persistence is the MHoM indicator with the highest level of achievement, followed by Reflective Thinking, both of which fall into the "highly achieved" category. This indicates that students in the experimental class demonstrate good persistence in solving mathematical problems and are able to reevaluate their thought processes. Conversely, generalization was the aspect with the lowest level of achievement, although it still fell within the "achieved" category, indicating that the ability to draw general conclusions from a pattern remains relatively more challenging for students. Overall, MHoM achievement fell within the "achieved" category, suggesting that the implementation of Collaborative Problem Solving aided by Kahoot shows a positive trend in supporting the development of various aspects of students' mathematical thinking habits.

Development of MHoM Based on Observation Results

Observations were conducted during four sessions in the experimental class to monitor students' MHoM development throughout the learning process. A summary of the observation results is presented in Table 9 and Figure 1.

Table 9. MHoM Observation Scores for Each Session

Session	MHoM Indicators					
	Exploration of Mathematical Ideas	Reflective Thinking	Generalization	Finding Patterns and Relationships	Mathematical Representation	Persistence (Diligence)
1	25%	75%	50%	25%	50%	75%
2	62.5%	75%	62.5%	75%	75%	75%
3	75%	75%	75%	75%	75%	75%
4	87.5%	100%	100%	75%	100%	100%

The average observation score showed an increase from 50% in the first session to 93% in the fourth session. It is important to emphasize that, since observations were conducted only on the experimental group, this increase cannot be considered independent evidence of the treatment's effect without comparative data from a control group. This trend merely illustrates the progression of student behavior during Kahoot-assisted CPS instruction and should be interpreted with caution.

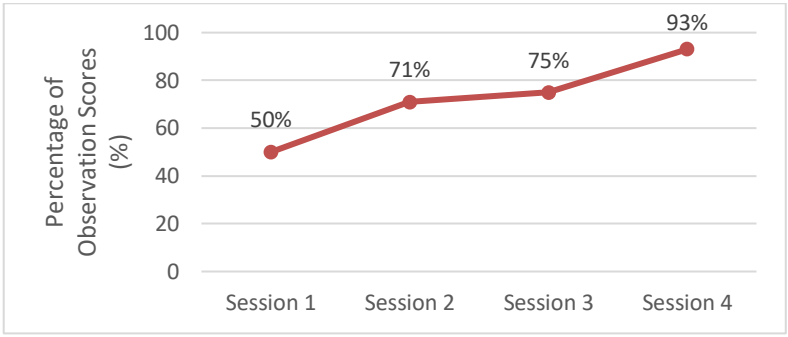


Figure 1. Graph of the Development of Students' MHoM Observation Scores

Figure 1 shows that the observation scores for the Mathematical Habits of Mind of students in the experimental class increased in every session. The greater increase in the early sessions indicates the development of MHoM as the Collaborative Problem Solving stages, supported by Kahoot, were implemented. In subsequent sessions, the increase occurred more gradually, indicating increasingly stable development throughout the learning process. In the final session, the observation scores increased again, reaching the "very high" category. This finding reinforces the quantitative results that the gradual implementation of Collaborative Problem Solving supported by Kahoot can foster the development of students' Mathematical Habits of Mind.

3.2. Discussion

The research results indicate that the group of students participating in the Kahoot-assisted Collaborative Problem Solving (CPS) learning model achieved a significantly greater improvement in MHoM compared to the group receiving conventional instruction. The Mann-Whitney U test results yielded a significance value of 0.020 (< 0.05), indicating that the difference in improvement is statistically significant. However, the obtained effect size of r = 0.262 (95% CI [0.034; 0.467]) falls into the small category according to Cohen's (1988) criteria.

The small effect size can be attributed to several underlying reasons: First, MHoM is not a cognitive ability that can be altered in a short period; rather, it is a habitual pattern of thinking that requires continuous repetition, reinforcement, and internalization [31]. With only four instructional sessions, this habit-formation process was still in its early stages, resulting in a limited measurable impact. Second, MHoM scores were based on student self-reports, which are susceptible to social desirability bias and inter-individual differences in perception; these factors tend to increase variance and reduce the detected effect size. Third, pretest scores that were already above the baseline floor limited the scope for improvement,

thereby resulting in smaller observable relative changes. The statistical significance achieved despite the small effect size indicates consistency in the direction of change across students, rather than the magnitude of the change itself.

The CPS model and the Kahoot medium contribute through distinct yet complementary pathways. The CPS structure serves as the primary framework shaping the thinking process: the engagement and exploration stages encourage students to explore ideas independently prior to discussion; the transformation stage facilitates the exchange of strategies and pattern discovery; the solution and presentation stage fosters verification and representation skills; while the reflection stage strengthens generalization capabilities [2], [3]. This aligns with the findings of Hikmah & Siswono (2020), indicating that a collaborative, problem-based structure enhances active participation and the exchange of ideas among students [28].

Separately, Kahoot offers unique contributions not derived from the CPS structure alone: First, Kahoot enhances affective engagement through appealing visual design, immediate feedback, and a points/ranking system that fosters a healthy competitive spirit, aspects difficult to achieve in conventional group discussions [17], [26]. Second, the Kahoot quiz at the start of each session serves as a trigger that simultaneously activates prior knowledge, allowing the exploration phase of CPS to begin on a stronger foundation. Third, the concluding quiz provides instant conceptual reinforcement that bolsters indicators of perseverance and reflection, as students immediately gauge their understanding and are motivated to correct errors [6], [30].

However, it must be clearly acknowledged that this research design cannot isolate the pure effect of Kahoot from that of CPS. Since both interventions were administered simultaneously to a single group, it is impossible to determine the specific proportion of improvement attributable to the CPS structure, the Kahoot medium, or the synergy between the two. The observed improvement is most likely the result of an interaction between them, wherein Kahoot boosted engagement, leading students to participate more actively in the CPS stages, which, in turn, fostered MHoM.

The findings of this study align with the research of Xu et al. (2023), who conducted a meta-analysis and found that problem-based collaborative learning significantly enhances critical thinking skills and mathematical habits of mind. However, effect sizes varied depending on the duration and intensity of the intervention [27]. Specifically regarding MHoM, Yustinah et al. (2023) reported that instruction emphasizing reflection and collaboration resulted in an MHoM improvement with an average N-Gain of 31.8% [31], a figure very close to the 33.96% observed in the present study. Similarly, Sofitri & Nugraheni (2024) found that an approach combining cognitive challenges with socio-affective support was effective in enhancing MHoM; however, achieving the generalization indicator remained the greatest challenge across most studies [22].

Compared to studies focusing solely on the use of Kahoot, Maulidah et al. (2020) reported significant improvements in motivation and conceptual understanding, though without directly measuring MHoM [15]. While Arifin (2025) found Kahoot most effective for engagement and persistence, it was less impactful on abstract reasoning skills such as generalization [17]. This explains why, in the present study, the indicators showing the

greatest improvement were persistence and reflective thinking, whereas generalization remained low, an aspect that inherently requires a depth of reasoning that interactive media alone cannot provide.

The generalization indicator reached the lowest percentage at 74%; while still within the "achieved" category, it lagged behind other indicators. This is understandable, as generalization the ability to draw general conclusions from specific patterns or cases is a higher-order thinking process requiring three prerequisites: pattern recognition, verification of the pattern across various cases, and the abstraction of relationships into a broader form [2]. In this study, students were assisted in recognizing patterns through the exploration and transformation stages of CPS; however, practice in testing these patterns against a variety of cases was limited due to time constraints. Furthermore, the topic of polynomials requires the generalization of abstract algebraic forms, whereas students are accustomed to working with concrete numbers. Without continuous reinforcement through guiding questions such as "Does this pattern hold true for all cases?" or "What is the general form of this pattern?", students tend to stop at pattern recognition without proceeding to generalization [8].

This study has several limitations that must be acknowledged and considered when interpreting the results. First, the assignment of experimental and control groups was not based on individual randomization but rather on pre-existing classes; consequently, the design remains susceptible to unobserved differences in initial characteristics, even though equivalence tests indicated that the groups were comparable at the outset. Second, the intervention was implemented over only four learning sessions—a relatively short duration, given that the formation of thinking habits requires an internalization process that unfolds over a longer, sustained period. Third, the study was conducted at a single school (MAN 1 Medan), meaning that generalizing the findings to schools with different characteristics requires caution. Fourth, MHoM measurement relied on a self-report questionnaire dependent on students' perceptions and honesty, factors potentially influenced by social desirability bias. Fifth, observational data regarding MHoM development were collected solely from the experimental group without a comparison group; thus, the observed upward trend cannot be independently confirmed as a direct result of the intervention. Finally, because the study design combined the CPS model with Kahoot media, the effects of the individual components could not be disentangled; consequently, it is impossible to determine the specific contribution of CPS alone, Kahoot alone, or the synergy between the two.

To address the aforementioned limitations, future research is advised to employ a factorial or multi-group design that simultaneously compares four conditions: (1) CPS alone, (2) Kahoot alone, (3) CPS combined with Kahoot, and (4) conventional instruction. This design would enable researchers to isolate the distinct effects of each intervention and examine potential interaction effects between them. Furthermore, future studies should consider extending the duration of the intervention, supplementing questionnaires with interviews or hands-on problem-solving tasks, and including a broader range of schools and settings to enhance the generalizability of the findings. Placing specific emphasis on generalization indicators supported by structured guiding questions is also recommended to foster optimal development in this particularly challenging aspect.

4. CONCLUSION

This study aims to examine the effect of the Collaborative Problem Solving learning model, supported by the interactive Medium Kahoot, on students' Mathematical Habits of Mind regarding the topic of polynomials. The results indicate that the improvement in Mathematical Habits of Mind among students taught using this model was significantly higher than that of students receiving conventional instruction; the average improvement fell into the "moderate" category, whereas the conventional group fell into the "low" category. Indicators of perseverance and reflective thinking showed the greatest development, while the aspect of generalization still requires further strengthening. Theoretically, these findings contribute to the mathematics education literature by providing empirical evidence that integrating a collaborative approach with interactive digital media creates an effective framework for fostering students' Mathematical Habits of Mind. Practically, these results offer an alternative instructional strategy for classroom implementation and provide a basis for schools to design learning programs that meaningfully combine collaboration with the use of technology.

Students participating in CPS instruction supported by Kahoot demonstrated a significantly greater improvement in MHoM compared to the comparison group. This is evidenced by a significance value of 0.020 (< 0.05), with an average N-Gain of 33.96% (moderate category) for the experimental group and 13.70% (low category) for the control group. Although this improvement was statistically significant, the effect size was small (r = 0.262, 95% CI [0.034; 0.467]), indicating a limited practical impact. An analysis of indicator achievement revealed that perseverance and reflective thinking showed the most improvement, whereas generalization remained an area requiring further strengthening.

The primary limitations of this study include the relatively short duration of the treatment, comprising only four sessions and the non-randomized design utilizing pre-existing classes. Future research is advised to implement interventions of longer duration, involve larger samples from diverse schools, and employ a research design capable of isolating the distinct effects of the CPS model and Kahoot media.

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