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HYBRID LEARNING ENVIRONMENT AND THE RELATIONSHIP WITH CREATIVE THINKING IN MATHEMATICS AMONG MALAYSIAN SECONDARY SCHOOL STUDENTS

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Abstract. *Hybrid learning environments (HLE), which combine traditional face-to-face instruction with online components, have gained significant prominence in modern education, particularly following the COVID-19 pandemic. In response to this shift, the Malaysian Ministry of Education launched the Program Perintis Sekolah Hybrid (PPSH) in 2020. This study investigates the level of HLE and creative thinking in the selected PPSH schools. In addition, the relationship between HLE and creative thinking in mathematics was also studied. Data was collected from 384 secondary school students using an adopted and validated instrument namely Hybrid Learning and Creative Thinking in Mathematics (HLCTM). The findings demonstrate a statistically significant positive correlation ($r = 0.544$, $p < 0.01$) between HLEs and creative thinking, highlighting that well-structured hybrid environments foster creativity by integrating pedagogical, social, and technical design elements. This study contributes to the growing literature on hybrid learning by providing actionable insights for educators and policymakers to optimize its implementation, particularly in mathematics education.*

Keywords: *hybrid learning environment, creative thinking, mathematics education, secondary school, SCORE model*

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Introduction

The fields of Science, Technology, Engineering, and Mathematics (STEM) are fundamental in driving innovation, economic growth, and societal advancement in the 21st century. STEM education has become a cornerstone of global education systems, preparing students to address complex real-world challenges, develop critical problem-solving skills, and engage with emerging technologies (Iskandar et al., 2020). As the demand for STEM professionals grows, education systems worldwide must evolve to foster not only technical proficiency but also higher-order cognitive skills such as creativity, adaptability, and critical thinking (Razali et al., 2022).

Mathematics, as a core component of STEM, plays a crucial role in building foundational skills that enable students to analyse, reason, and solve problems effectively. However, traditional approaches to teaching mathematics often fail to nurture students' creative thinking, which is essential for innovation and the application of mathematical knowledge to diverse scenarios (Idris et al., 2023). Creative thinking in mathematics refers to the learner's ability to approach mathematical problems through imaginative, flexible, and innovative strategies. It encompasses the generation of multiple solutions, the application of knowledge to unfamiliar situations, and the ability to see patterns and relationships that may not be immediately obvious.

According to Khalid et al. (2020), creativity is the process of having original ideas that have value and is further divided into two concepts: creativity and innovation. Creativity is putting imagination to work, while innovation is putting new ideas into practice. This form of thinking is essential in nurturing higher-order problem-solving skills and fostering a deeper engagement with mathematical concepts. As education shifts toward 21st-century competencies, creative thinking in mathematics is increasingly recognized as a core element in preparing students for complex, real-world challenges (Ibrahim, Isa, & Embong, 2023).

In response to these demands, the Program Perintis Sekolah Hybrid (PPSH), or Hybrid School Pioneer Program, was launched in 2020 by the Malaysian Ministry of Education. Under this initiative, 110 schools were selected as pioneer hybrid schools, serving as a transformative step toward advancing digitalisation and Information and Communication Technology (ICT) in education (Povera, 2022). This program not only promotes technological innovation but also aims to cultivate creative thinking skills among students by exposing them to diverse learning environments.

This study seeks to address existing gaps by examining the relationship between hybrid learning environments and students' creative thinking in mathematics among secondary school students. As PPSH has only recently been implemented in selected schools, research on its execution and effectiveness remains limited. Therefore, this study aims to explore the extent of hybrid learning practices and students' creative thinking levels within PPSH schools, specifically from the students' perspective. By conducting a detailed analysis, the research aspires to generate actionable insights for educators and policymakers, ultimately contributing to the effective optimisation of hybrid learning in preparing students for the demands of a dynamic and interconnected world.

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Literature Review

Hybrid Learning in Mathematics Education

A hybrid learning environment can involve a combination of in-person classroom instruction and online resources, activities, or assessments. The advent of Hybrid Learning Environments (HLEs) offers a transformative approach to addressing challenges in mathematics education. By integrating traditional face-to-face instruction with online learning components, HLEs provide a flexible and engaging learning environment that caters to diverse learning needs (Nurwahyuni et al., 2022). The pedagogical, social, and technical dimensions of HLE enhance students' access to resources, encourage collaboration, and support self-paced exploration (Krishnan et al., 2023). These features create an ideal platform for implementing innovative instructional strategies to foster creativity and deep understanding in mathematics.

In mathematics education, a hybrid learning environment often involves a combination of in-person instruction and online resources, activities, or assessments. Hybrid learning has become increasingly prominent, especially following the COVID-19 pandemic. Its flexibility allows for personalized learning experiences, where adaptive tools and differentiated pacing support learners' cognitive and emotional needs.

Creative Thinking in Mathematics

Creative thinking in mathematics involves the ability to generate novel ideas, explore multiple solutions, and approach problems from different perspectives (Setiawan et al., 2023). Creative thinking in mathematics refers to a learner's ability to approach mathematical problems through imaginative, flexible, and innovative strategies. It encompasses the generation of multiple solutions, the application of knowledge to unfamiliar situations, and the ability to see patterns and relationships that may not be immediately obvious. According to Khalid et al (2020), creativity is the process of having original ideas that have value and is further divided into two concepts such as creativity and innovation.

Creativity is putting imagination to work, meanwhile, innovation is putting new ideas into practice (Khalid et al., 2020). This form of thinking is essential in nurturing higher-order problem-solving skills and fostering a deeper engagement with mathematical concepts. As education shifts toward 21st-century competencies, creative thinking in mathematics is increasingly recognized as a core element in preparing students for complex, real-world challenges (Ibrahim, Isa & Embong, 2023). In the context of STEM education, fostering creativity in mathematics not only enhances students' cognitive abilities but also prepares them for the interdisciplinary demands of STEM careers.

To measure creative thinking, researchers have developed a variety of instruments that assess key cognitive traits such as fluency, flexibility, originality, and elaboration. One of the most established tools is the Torrance Tests of Creative Thinking (TTCT), developed by E. Paul Torrance (1971), which has been widely used in educational research across disciplines. The TTCT evaluates divergent thinking through tasks that encourage idea generation and problem-solving beyond conventional approaches. Though not subject-specific, the test has been adapted in mathematics education to identify students' creative potential in tackling open-ended or non-routine problems.

Building on the need for domain-specific tools, Lehmkuhl et al. (2021) introduced the SCORE model, a self-assessment instrument designed to measure creativity in the context of K–12

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computing education. While originally intended for computing, the SCORE model provides a structured framework to assess creativity across educational contexts by focusing on dimensions such as self-assessment, creativity processes, originality, reflection, and evaluation. Its design emphasizes learner awareness of their creative processes, which makes it adaptable to mathematical settings where students are expected to explore multiple problem-solving strategies. The use of models like TTCT and SCORE reflects a growing emphasis on both assessing and cultivating creative thinking as a measurable and essential learning outcome in mathematics education.

Hybrid Learning and Creative Thinking

In mathematics education, it is necessary to understand the relationship between hybrid learning environment and creative thinking. This relationship is a multifaceted topic that has garnered significant attention in educational research. Research indicates that hybrid learning environments can promote creative thinking by offering varied instructional strategies that cater to different learning styles. For instance, the integration of technology in hybrid settings allows for interactive and collaborative learning experiences, which have been linked to improved creativity among students. Studies suggest that hybrid environments, through varied instructional strategies, can promote creative thinking by catering to diverse learning styles. For example, hybrid learning can integrate interactive, inquiry-based activities that engage students in non-linear, imaginative thinking (Pukdeewut et al., 2013).

Hybrid learning environments has been shown to foster an environment conducive to creative thinking including in mathematics. This is primarily due to the flexibility and diverse learning opportunities it provides, which can enhance students' engagement and motivation, critical components for creativity. These environments create opportunities for interactive learning, collaborative engagement, and innovative pedagogical strategies, all of which can stimulate creativity (Dragicevic et al., 2020). One significant advantage of hybrid learning is its ability to incorporate multimedia tools, such as videos and animations, to engage students in imaginative problem-solving. For example, a study demonstrated that hybrid project-based learning, supported by animated videos, improved students' creative thinking in geography (Nurwahyuni et al., 2022). The multimedia tools allowed students to visualise abstract concepts, encouraging them to explore ideas more deeply and approach problems innovatively.

The pedagogical approaches employed in hybrid learning environments can further enhance creative thinking. Hybrid learning environments often provide flexibility in how students engage with mathematics. Besides, online components can allow for personalized learning experiences, adaptive learning platforms, or the ability to work at one's own pace. This flexibility can positively impact mathematics attitudes by catering to individual learning styles, preferences, and needs. Furthermore, the use of digital tools in hybrid learning can stimulate students' cognitive abilities, specifically in enhancing students' concentration and creativity (Rong et al., 2022)

Moreover, the social dynamics of hybrid learning environments play a crucial role in fostering creativity. A study found that perceived social support, which is often enhanced in collaborative hybrid learning settings, is positively correlated with creative thinking skills (Barutcu, 2023). This aligns with the findings of Chan and Yuen (2014), who argue that environmental factors, including social support and collaborative opportunities, significantly influence teachers' ability to foster creativity in their students. The collaborative nature of hybrid learning encourages students to engage in group work, which has been shown to improve creative outcomes by

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allowing for the exchange of diverse ideas and perspectives (Barutcu, 2023; Chan & Yuen, 2014).

On the other hand, Problem-Based Learning (PBL) and inquiry-based strategies, which are often utilised in hybrid settings, have been shown to cultivate an atmosphere that encourages exploration and innovation since PBL models, when integrated into hybrid environments, provide students with opportunities to work together on complex tasks. These tasks require problem-solving and idea generation, which are essential for creativity. Research by Erdem and Adiguzel (2019) indicates that creative thinking is nurtured in environments that promote inquiry and problem-solving. Hybrid learning environments further amplify these benefits by offering access to diverse online resources and tools, enabling students to visualize mathematical problems, experiment with simulations, and collaboratively solve challenges. This combination of collaborative inquiry and digital support creates a fertile ground for developing both mathematical proficiency and creativity, equipping students with the skills needed to tackle real-world problems effectively.

This is supported by the work of Nuankaew et al. (2023), which suggests that collaborative learning environments are essential for developing creative problem-solving skills. The combination of these pedagogical strategies within a hybrid framework can create a rich learning environment that stimulates creative thought. Festiawan et al. (2024) found that students participating in hybrid PBL not only improved their creative thinking but also experienced higher motivation. They added that the structured nature of PBL, combined with the flexibility of hybrid learning, creates a conducive environment for experimentation and innovation. Aside from PBL, it was also found that hybrid Project-Based Learning (PjBL) significantly enhance students' creative thinking abilities. This model encourages innovative thinking and self-regulated learning, leading to high levels of creativity among students (Zakiah & Fajriadi, 2020).

In addition to collaborative methods, the use of dialogue-based pedagogies, such as the dialogue-embedded Synectic model, has been shown to be effective in hybrid settings. This model, as described by Sahoo et al. (2023), involves guided discussions that encourage students to approach problems from diverse perspectives. By promoting metaphorical thinking, this approach helps students break away from conventional thought patterns and develop original ideas. The hybrid format enhances this process by providing both in-person discussions and digital platforms for asynchronous reflection, offering a balance that supports deeper cognitive engagement.

Another important factor in hybrid learning is technology preparedness. Students equipped with the necessary digital skills and access to technological tools are better positioned to engage in creative problem-solving. Fideli and Aliazas (2022) found that students with higher levels of technological readiness were more likely to collaborate effectively and produce innovative solutions in mixed learning environments. This finding underscores the importance of bridging digital divides and ensuring equal access to resources to maximise the benefits of hybrid learning.

While these discoveries are encouraging, hybrid learning is also confronted with substantial obstacles. Inadequate teacher training and unequal access to digital tools were identified by Dragicevic et al. (2020) as significant obstacles to effective implementation. Balancing the online and offline components of hybrid learning to create an optimal environment for fostering

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creativity is another challenge that requires careful consideration. Furthermore, while individual studies highlight the potential of hybrid learning to enhance creative thinking, there is limited research exploring its broader application across various disciplines and age groups.

This study explores the relationship between HLE and creative thinking in mathematics among secondary school students, focusing on how the pedagogical design, social design, and technical design elements of hybrid environments correlate with students' creativity in mathematics for instance fluency, flexibility, originality, and elaboration in problem-solving. By examining this relationship, the study aims to provide insights into optimizing hybrid learning environments to enhance creative capacities in mathematics education, contributing to the broader goal of advancing STEM education in the digital age.

Challenges and Gaps in Hybrid Learning for Creativity

Despite its potential, the understanding of hybrid learning's impact on creative thinking, particularly among secondary school students, remains limited. While research highlights its ability to engage learners and improve critical thinking, the mechanisms that specifically foster creativity are not well understood (Sahoo et al., 2023). Challenges such as technological preparedness, teacher readiness, and the design of effective learning activities further complicate the successful implementation of hybrid models (Dragicevic et al., 2020; Fideli & Aliazas, 2022).

These gaps underscore the need for systematic research to explore how hybrid learning environments influence the creative capacities of secondary students, particularly in relation to creative personality and curiosity, skills expansion, knowledge and skills expansion, fluency, flexibility, originality, and elaboration. These are key dimensions of creativity as identified by SCORE and similar models (Lehmkuhl et al., 2021).

While individual studies highlight positive outcomes, there is limited research that systematically explores the broader application of hybrid models across disciplines and age groups. Hence, this study seeks to address existing gaps by examining the level of hybrid learning environments among secondary school students, the level of their creative thinking in mathematics and also the relationship between hybrid learning environments and students' creative thinking in mathematics.

Research Objectives

The main objectives of the study are to explore the extent of hybrid learning practices and students' creative thinking levels within PPSH schools and to study the relationship between hybrid learning environments (HLE) and creative thinking in mathematics. The specific objectives of the research are:

1. To examine the level of hybrid learning environments from the perspective of secondary school students.
2. To assess the level of creative thinking in mathematics among secondary school students who participate in hybrid learning environments.
3. To investigate the relationship between hybrid learning environments and the creative thinking in mathematics among secondary school students.

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Research Method

The study employs a quantitative research design using a self-reported of survey questionnaire. The survey questionnaire namely Hybrid Learning and Creative Thinking in Mathematics (HLCTM). 19 items were used for the study measure hybrid learning environment was adapted and adopted from (Lu, 2021). On the other hand, 30 items that was used to measure creative thinking in mathematics was adapted and adopted from Lehmkuhl et al. (2021). This questionnaire or instrument has three sections. Section A contains the part of demographic information of respondents, i.e. school, class, gender and age. Meanwhile, in section B and C, the questionnaires used five Likert Scale agreement to measure hybrid learning environment and creative thinking in mathematics respectively. This questionnaire was interpreted as Strongly Disagree (1), Disagree (2), Neutral (3), Agree (4), and Strongly Agree (5).

Although the instruments used in this study were adopted and adapted from well-established sources, content validation was conducted to ensure their appropriateness for the specific research context. A panel of seven experts representing diverse fields such as mathematics education, pedagogy, curriculum and instruction, and educational assessment was consulted to evaluate the content validity of the instrument items. Their feedback helped refine the wording, structure, and alignment of items with the intended constructs.

Following expert validation, a pilot study was conducted in a secondary school with similar characteristics to the actual study site. A total of 42 students took part to help test the clarity, reliability, and ease of use of the instrument. The internal consistency of the scales was examined using Cronbach's alpha. The results indicated high reliability, with $\alpha = 0.91$ for the creative thinking and $\alpha = 0.92$ for the hybrid learning, demonstrating excellent internal consistency for both constructs.

To minimize potential bias in both the pilot and full-scale study, several measures were taken. Anonymity and confidentiality were assured to encourage honest responses. Besides, standardized instructions were clearly explained to all participants to ensure consistent understanding. Participants were also informed that there were no right or wrong answers, thereby emphasizing the importance of sharing their genuine perceptions and experiences. Furthermore, the use of previously validated instruments with high reliability coefficients contributed to reducing measurement error and enhancing the credibility of the findings. In addition, a diverse panel of experts helped ensure that the instrument was free from disciplinary and cultural bias, making it suitable for students from various backgrounds.

Following the successful completion of the pilot study, minor revisions were made based on participant feedback and item analysis. The final version of the instrument was then used in the actual data collection phase. The actual data collection was carried out involving 402 secondary school students who have participated in the PPSH program in Selangor and Kuala Lumpur, Malaysia. The sample size was determined based on Krejcie and Morgan's (1970) sample size determination table, ensuring a representative sample for statistical analysis. The participants, aged between 13 and 17 years old, were selected using a cluster sampling technique. The participants consist of secondary school students from public schools who have participated in the PPSH program. Out of a total of 402 participants, 384 students were then selected through systematic random sampling using SPSS version 27 to ensure randomness and reduce selection bias.

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The final sample comprises students from 7 public schools, all of which share a similar demographic profile. These students have prior experience engaging in a hybrid learning environment, which combines face-to-face and online instructional methods, specifically in the context of learning mathematics. This demographic alignment ensures the study targets individuals with comparable educational backgrounds and exposure to hybrid learning methodologies, enhancing the reliability and relevance of the findings. This uniformity helped enhance the reliability, relevance, and generalizability of the findings.

Result

Demographic Information

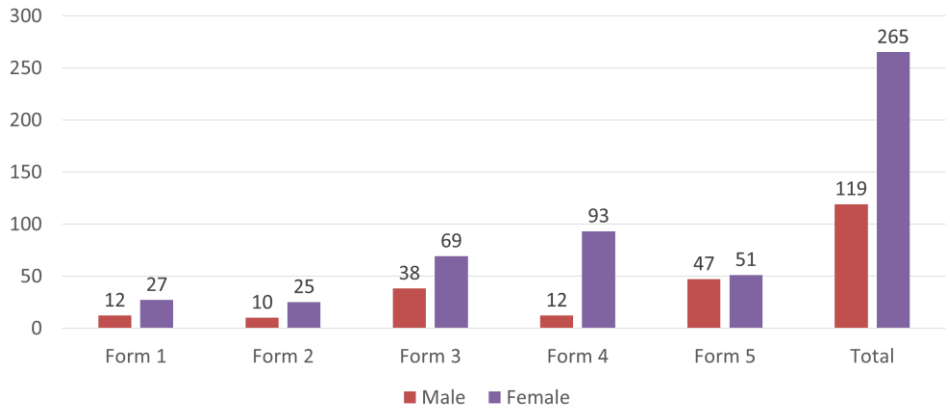

Figure 1: Demographic Information

Figure 1 shows that the total sample size is 384, 119 males (31% of the sample) and 265 females (69% of the sample). Form 3 holds the highest number of participants across all forms, with a total of 107 respondents. It accounts for 27.9% of the total sample, making it the majority form. 340 respondents (88.5% of the total sample) or the majority of the respondents in this study identify as Malay. This is consistent with the demographic composition in Malaysia, where Malays are the largest ethnic group. The Indian group forms a significant minority in this dataset, comprising 7.3% of the respondents. This group is one of the major ethnic minorities in Malaysia, and their relatively higher representation compared to other minorities in this study may suggest that the study also captures a portion of this community. The Iban (0.8%), Chinese (2.3%) and other categories groups are underrepresented compared to their actual population proportions in Malaysia.

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Level of Hybrid Learning Environment

Reliability score

Table 1: Reliability of HLE instrument

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.901	.903	19

Table 1 shows the reliability score of 0.901 for the HLE instrument indicates excellent internal consistency. This means that the 19 items used to measure pedagogical, social, and technical aspects of the hybrid learning environment are highly cohesive and consistently measure the intended constructs. A high Cronbach's Alpha suggests that students' responses to different items in the questionnaire are strongly correlated, reinforcing the tool's reliability in capturing perceptions of the hybrid learning environment. Such a robust score demonstrates the tool's suitability for educational research and its potential for providing reliable insights into students' experiences in hybrid settings.

The level of HLE perceived by secondary students

The overall mean score for the Hybrid Learning Environment (HLE) was 3.53, with a standard deviation of 0.89, as shown in Table 2 below. This score indicates that students generally perceive the hybrid learning environment positively, falling slightly above the midpoint of the scale.

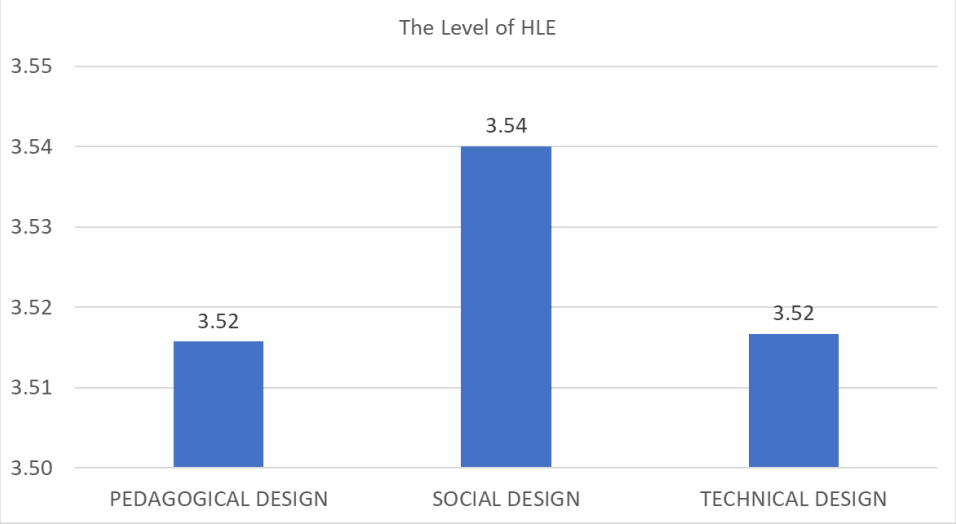

Figure 2: The level of hybrid learning environment

Figure 2 shows that the highest mean score is social design. The results suggest that the HLE provides a moderately supportive framework for learning, where pedagogical design (clarity of objectives and structured content), social design (peer interaction and teacher feedback), and technical design (accessibility and flexibility) collectively meet student needs. The relatively high standard deviation, however, indicates some variability in students' experiences, potentially reflecting differences in individual access to technology, teacher preparedness, or the effectiveness of hybrid implementation.

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The mean score highlights the effectiveness of integrating traditional face-to-face learning with digital tools, providing students with opportunities to interact with content, peers, and educators in a flexible and structured manner. However, to optimise the HLE, targeted improvements in areas such as increasing student engagement with technical tools or enhancing collaborative opportunities may further enrich the learning experience.

Table 2: Level of HLE

1. PEDAGOGICAL DESIGN	**Mean**	**Std. Deviation**
The learning objectives are clearly stated in each lesson	3.55	0.99
The organization of each lesson is easy to follow	3.50	0.83
The structure of the environment helps me focus on learning	3.53	0.90
Expectations of tasks are clearly stated	3.41	0.89
Activities are planned carefully	3.54	0.84
The content of the subject worked well in the hybrid learning environment	3.52	0.84
The presentation of the content was clear	3.56	0.91
Average Mean	**3.52**	**0.88**
2. SOCIAL DESIGN		
I communicate with other students in the subject electronically	3.26	1.00
I can ask my teacher what I do not understand	3.58	1.00
Other students respond promptly to my requests for help	3.60	0.94
The teacher gives me quick comments on my work	3.60	0.85
My classmates and I regularly evaluate each other's work	3.55	0.85
I was supported by a positive attitude from my teacher	3.65	0.88
Average Mean	**3.54**	**0.92**
3. TECHNICAL DESIGN		
I can access the learning activities at times convenient to me	3.53	0.85
The online material is available at locations suitable for me	3.40	0.82
I am allowed to work at my own speed to achieve my learning objectives	3.44	0.86
I decided how much I want to learn in a given period	3.57	0.87
I decide when I want to learn	3.59	0.92
Using hybrid learning allowed me to explore the interest of my own	3.57	0.98
Average Mean	**3.52**	**0.88**
Overall Mean	**3.53**	**0.89**

Level of creative thinking in mathematics among students

Reliability score

The reliability score of 0.925 shown in Table 3 for the creative thinking instrument similarly reflects excellent internal consistency. This score, derived from then 30 items measuring various dimensions of creative thinking (fluency, flexibility, originality, elaboration, etc.), indicates that the instrument is reliable for assessing students' creative thinking capabilities. A score above 0.9 signifies that the items effectively capture the different facets of creativity while maintaining consistency. This high reliability ensures that the tool accurately represents students' creative thinking levels and can be confidently used in academic and educational assessments.

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Table 3: Reliability of creative thinking instrument

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.925	.925	30

Level of creative thinking in mathematics

Table 4 shows the overall mean score for Creative Thinking was 3.32, with a standard deviation of 0.98, indicating a moderate level of creative thinking among students. This suggests that while students demonstrate some ability to generate ideas, adapt to challenges, and engage with tasks innovatively, there is room for further development.

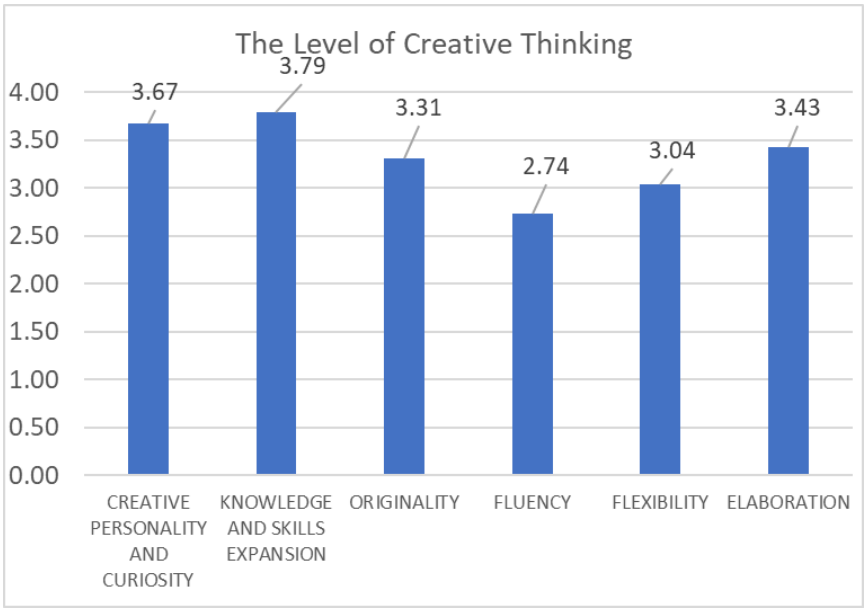

Figure 3: Students' creative thinking in mathematics

Figure 3 shows that knowledge and skills expansion score the highest, followed by creative personality and curiosity and elaboration, reflecting students' strengths in seeking new information and refining their ideas. These results highlight their ability to learn and apply details effectively in creative tasks. However, the dimension of fluency, which involves generating diverse ideas, scored the lowest. This suggests that students may need additional support in brainstorming and developing a wider range of solutions to problems.

The findings underscore the importance of building on students' strengths in elaboration and knowledge expansion while implementing strategies to improve their fluency, such as encouraging divergent thinking and open-ended problem-solving. Addressing these areas will help foster a more balanced and robust creative skill set among students.

Table 4: Level of creative thinking in mathematics among students

1. CREATIVE PERSONALITY AND CURIOSITY	Mean	Std. Deviation
I think it is important to have ideas	3.96	0.90
I have many useful ideas	3.69	0.91
I like to do new things (visit new places, meet new people, etc.)	3.78	0.98
I can complete several things during the day	3.67	0.97

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I question beliefs, customs, and traditions, for example, not to go under the stairs to avoid bad luck	3.26	1.00
Average Mean	**3.67**	**0.95**
2. KNOWLEDGE AND SKILLS EXPANSION		
I like to learn new things	3.76	1.07
I like to discuss matters by giving my opinion	3.86	0.93
I like to participate in extra-curricular activities to learn new things	3.53	1.11
I go online several times to learn new things	3.74	0.97
I learn from my mistakes	4.07	0.90
Average Mean	**3.79**	**0.99**
3. ORIGINALITY		
I like to create my own solution or method to solve mathematical problems	3.46	1.03
I try to solve mathematical problems on my own before asking someone	3.34	0.98
I like to create new patterns and not just to use the ones that already exist	3.30	0.94
I think it is important to think in many different ways to solve mathematical problems	3.33	0.98
I love imagining new mathematical concepts and solutions	3.12	1.01
Average Mean	**3.31**	**0.99**
4. FLUENCY		
I can imagine different solutions to solve a mathematical problem	2.94	0.95
I find it easy to solve mathematical problems	2.75	0.96
I am able to explain a mathematical concept to classmates	2.73	0.99
I find it easy to answer questions asked by my mathematics teacher	2.78	0.93
I can solve difficult mathematical problems effortlessly	2.49	1.00
Average Mean	**2.74**	**0.97**
5. FLEXIBILITY		
I am able to combine ideas in ways that other people have not tried	2.73	1.01
I can think of new ways to solve a mathematical problem	2.74	0.96
I like to work on creating new things instead of doing repetitive exercises	2.97	0.98
I can find the materials I need to develop an idea	3.28	0.96
If a certain resource is not available, I try to find a solution with other available resources	3.46	0.90
Average Mean	**3.04**	**0.96**
6. ELABORATION		
I care about the details when I work on mathematical problems	3.30	0.94
I like to choose nice colors and fonts when I create math-related projects	3.27	1.00
After using a fun math app, I like to talk to someone about it	3.16	0.99
When I am interested in something, I pay attention to every detail	3.59	1.06
When I do homework, I like to make it beautiful and decorated	3.81	1.06
Average Mean	**3.30**	**0.94**
Overall Mean	**3.32**	**0.98**

Relationship Between Hybrid Learning Environment and Creative Thinking in Mathematics

Table 5 presents the descriptive statistics for students' perceptions of the hybrid learning environment (HLE) and their creative thinking (CT) in mathematics. The mean score for creative thinking (MEAN_CT) was 3.3240 with a standard deviation of 0.55562, indicating a moderately high level of creative thinking among the students, with some variability in responses. Meanwhile, the mean score for students' perceptions of the hybrid learning environment (MEAN_HLE) was 3.5324 with a standard deviation of 0.56745, suggesting that, overall, students had a positive view of their hybrid learning experience.

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Table 5: Descriptive data on

Descriptive Statistics

	Mean	Std. Deviation	N
MEAN_CT	3.3240	.55562	384
MEAN_HLE	3.5324	.56745	384

Table 6: Correlation between HLE and creative thinking in mathematics

Correlations

		MEAN_CT	MEAN_HLE
MEAN_CT	Pearson Correlation	1	.544**
	Sig. (2-tailed)		.000
	N	384	384
MEAN_HLE	Pearson Correlation	.544**	1
	Sig. (2-tailed)	.000	
	N	384	384

**. Correlation is significant at the 0.01 level (2-tailed).

Table 6 reports the results of the Pearson correlation analysis, which revealed a statistically significant positive relationship between HLE and CT. The correlation coefficient was r = 0.544, with a p-value of 0.000, indicating that the relationship is significant at the 0.01 level (2-tailed). The moderate positive correlation implies that as students' perceptions of the hybrid learning environment improve, their creative thinking in mathematics also tends to increase.

This suggests that a well-designed hybrid learning environment may serve as a meaningful contributor to enhancing students' higher-order thinking, particularly creativity in mathematical problem-solving. The statistical significance of the result supports the conclusion that the relationship observed is unlikely to be due to chance, lending credibility to the assertion that improvements in the quality and implementation of hybrid learning strategies are associated with increased creative thinking in mathematics.

Discussion, Recommendation and Conclusion

Discussion

Perception of Hybrid Learning Environment (HLE)

The descriptive statistics for the Hybrid Learning Environment (HLE) reveal a mean score of 3.532 with a standard deviation of 0.5674, indicating that students generally perceive their hybrid learning environment positively. The relatively high mean suggests that students find the HLE to be supportive of their learning needs, with pedagogical, social, and technical designs contributing to a well-rounded educational experience. However, the standard deviation reflects some variability in responses, suggesting that not all students have uniformly positive experiences. This may be due to factors such as differences in teacher readiness, access to technology, or the quality of hybrid implementation.

Hybrid learning environments are known to provide flexibility and diverse instructional strategies that cater to various learning styles, enhancing student engagement and motivation. This flexibility allows students to interact with content in innovative ways, fostering critical components of creativity such as problem-solving and adaptive thinking. These findings align

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with existing research, which highlights the role of hybrid learning in promoting cognitive engagement and fostering skills that are essential for creativity (Dragicevic et al., 2020; Fideli & Aliazas, 2022).

Level of Creative Thinking in mathematics

The descriptive statistics for Creative Thinking (CT) show a mean score of 3.3240 with a standard deviation of 0.55562, indicating a moderate level of creative thinking in mathematics among students. This score suggests that while students demonstrate some ability to generate ideas, adapt to challenges, and engage with tasks innovatively, there is room for further development. The relatively low variability in responses, as indicated by the standard deviation, suggests a more consistent perception of creative thinking abilities across the student population.

Higher scores in dimensions like knowledge and skills expansion and elaboration suggest that students are adept at seeking new information and refining their ideas. However, lower scores in dimensions like fluency, which involves generating diverse solutions, highlight a need for further support in divergent thinking and brainstorming activities. These results align with findings by Festiawan et al. (2024) and Erdem and Adiguzel (2019), who suggest that structured interventions in hybrid settings can enhance students' ability to think creatively.

Correlation Between HLE and Creative Thinking in Mathematics

The Pearson correlation analysis indicates a statistically significant positive correlation between HLE and CT, with a correlation coefficient (r) of 0.544 and a p-value of 0.000. The strength of this relationship suggests a moderate positive association, indicating that as students' perceptions of the hybrid learning environment improve, their creative thinking abilities also increase. The positive direction of the correlation supports the idea that hybrid learning environments play a crucial role in fostering creativity.

The statistical significance of the correlation confirms that this relationship is unlikely to have occurred by chance. These findings align with the broader literature, which highlights the capacity of hybrid learning environments to enhance creative thinking through interactive and flexible educational strategies (Nurwahyuni et al., 2022; Rong et al., 2022). Elements such as collaborative learning, access to multimedia tools, and opportunities for self-paced exploration are critical in supporting dimensions of creativity, including fluency, originality, and elaboration.

Limitations and Recommendations for Future Research

This study provides valuable insights into the relationship between hybrid learning environments (HLE) and creative thinking among secondary school students. However, certain limitations must be acknowledged. First, the sample was limited to public school students in Selangor and Kuala Lumpur, which may restrict the generalisability of the findings. The homogeneity of the sample, in terms of demographic and educational backgrounds, means that the results may not fully represent students from private schools, rural areas, or other regions with differing access to resources or educational practices. Expanding the diversity of participants in future research could yield more comprehensive and generalisable findings.

Second, the reliance on self-reported data introduces the potential for response bias, as students may provide socially desirable answers or have difficulty accurately assessing their own creative thinking and perceptions of HLE. Additionally, the quantitative nature of the study,

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while robust for statistical analysis, may overlook nuanced experiences and individual insights. Incorporating qualitative methods, such as interviews or focus groups, could offer a richer understanding of how students experience and benefit from HLE.

Third, the study's cross-sectional design limits the ability to infer causality between HLE and creative thinking in mathematics. Although a significant positive correlation was observed, it cannot be concluded that HLE directly causes improvements in creative thinking. Longitudinal research that tracks changes in students' creativity over time would be more effective in establishing causal relationships and understanding the long-term impacts of hybrid learning environments.

Future research should aim to address these limitations by including diverse student populations, incorporating qualitative methods, and employing longitudinal designs. Exploring specific pedagogical strategies within HLE, such as the use of problem-based or project-based learning models, could further clarify which elements are most effective in fostering creativity. Additionally, examining the role of technological readiness and access would provide valuable insights into how disparities in resources influence the relationship between HLE and creative thinking. These steps could enhance the applicability and depth of future findings, offering more targeted recommendations for educators and policymakers.

Conclusion

This study aimed to investigate the relationship between hybrid learning environments (HLE) and creative thinking in mathematics among secondary school students, focusing on key dimensions such as fluency, flexibility, originality, and elaboration. The objectives were to assess the current level of implementation of HLE, evaluate students' creative thinking, and examine the relationship between the two. Data were collected from 384 secondary school students using validated instruments with excellent reliability (Cronbach's Alpha = 0.92 for HLE and 0.901 for creative thinking).

The findings revealed that students perceive the hybrid learning environment positively, with a mean score of 3.53, reflecting its effectiveness in providing a supportive and engaging framework. Pedagogical design emerged as a key strength, indicating that clear objectives and structured activities significantly contribute to students' engagement. Creative thinking was also found to be at a moderate level, with a mean score of 3.32. Students demonstrated strengths in knowledge and skills expansion and elaboration, but lower scores in fluency indicated a need for further support in generating diverse ideas.

The study established a significant positive correlation ($r = 0.544$, $p < 0.01$) between HLE and creative thinking, suggesting that improvements in hybrid learning environments are associated with enhanced creative thinking abilities in mathematics. These results align with existing research, which highlights the potential of HLE to foster creativity through interactive, flexible, and collaborative learning experiences. However, the moderate level of creativity observed indicates that while HLE is effective, there remains room for improvement in its design and implementation.

Research Implications

This study contributes to filling a gap in the literature by providing empirical insights into the impact of hybrid learning on creative thinking among Malaysian secondary school students, especially in an area that remains underexplored, particularly in the context of the recent

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implementation of the PPSH in November 2022. As PPSH is still in its early stages, these findings offer valuable information on how hybrid learning is being applied in Malaysian classrooms and how it can be further refined.

The findings also carry important implications for educational practice. To optimize the impact of hybrid learning, educators should focus on enhancing pedagogical strategies, specifically by incorporating activities that promote divergent thinking and creativity. It is equally important to ensure equitable access to technology and to prepare students to use digital tools effectively, so that all learners can fully participate and benefit from hybrid environments. Besides, this study contributes to the growing literature on hybrid learning by providing actionable insights for educators and policymakers to optimize its implementation, particularly in mathematics education.

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