# Enhancing creativity in secondary school mathematics: A quasi-experimental, mixed methods study in Vietnam

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This paper presents an experimental design aimed at enhancing creativity in mathematics among secondary school students. The quasi-experimental research was conducted at two urban secondary schools and one rural school in Hanoi and Nam Dinh provinces, Vietnam, involving 229 grade 6 students and three teachers. The study found that creativity-enriched mathematics instruction, grounded in the principles of realistic mathematics education, such as the use of practical contexts, cultivation of students' experiences, provision of self-initiated and collaborative learning opportunities, and didactic orientation, can foster the development of creative competencies in mathematics. Moreover, the research demonstrates the feasibility and effectiveness of implementing creativity-enriched instruction in various school settings. These findings can help raise awareness among educators and inspire them to modify their teaching methods to promote the development of students' creative competencies, which are increasingly critical in the era of the fourth industrial revolution.

## Introduction

In an increasingly interconnected and volatile world, education systems face constant pressure to equip students with the competencies necessary to navigate complex challenges. The most sought-after qualities in today's labour market have been extended from purely technical knowledge to include more generic, transferrable skills, such as communication, teamwork, critical thinking, creativity, problem solving, and leadership. Among these, creativity holds a particularly important position as 21st-century citizens are increasingly expected to contribute to the creation of new knowledge and new solutions (Fielding & Murcia, 2022; Suyitno & Suyitno, 2018).

Although creativity was traditionally attributed to the world of art and literature (Ayllón et al., 2016), mathematics as a subject lends itself naturally to the development of creativity for students (Sheffield, 2017). It does so by involving students in the process of solving problems, reasoning critically, developing procedural fluency, and demonstrating conceptual understanding (Davis et al., 2014). However, currently, mathematics teaching is still dominated by many ineffective models and approaches. There has, for example, been criticism over pedagogies that focus primarily on showing students to use superficial rote learning strategies, imitate given procedures, memorise facts, and handle simple procedures (Lithner, 2017). Hiebert (2003), for example, observed that students are most engaged in learning facts and simple procedures rather than seeking solutions to more advanced and more cognitively demanding mathematical problems. There has also been disapproval of the inadequacy of mathematics school textbooks in equipping students with such important competencies as problem solving or critical reasoning. This is regardless of the fact that textbooks are one main influencing factor for innovating mathematics instruction (Rezat & Straesser, 2013). On examining over 5,700 secondary mathematics tasks in mathematics textbooks from twelve countries, Jäder et al. (2020) found that the majority of these tasks only demand students to solve mathematical problems using readily supplied templates while the problem-solving competency is scarcely covered. The significance of shifting to mathematics education that can foster creativity among students is highlighted by the presently ineffective practices of teaching mathematics in general school education.

In Vietnam, mathematics as a subject plays a key role and serves as a gatekeeper in high-stakes examinations that decide students' eligibility to graduate from high school or enter a university. As a country that faces a multitude of socio-economic challenges, Vietnam has surprised international education experts with its students' mathematics performance in the *Programme for International Student Assessment* (PISA), which surpasses the OECD average and outranks the performance of students from many other established education systems (Thien et al., 2016). Asadullah et al. (2020) referred to this as "an education paradox" when noting the impressive achievements of Vietnamese socially disadvantaged students. However, in contrast with such achievements in international assessments, the country's concrete educational outcomes have not been well aligned. Several issues require attention, including gender gaps (Le et al., 2023), as well as pedagogical practices characterised by an excessive emphasis on theoretical aspects and a preference for rote learning and memorisation (Le et al., 2022). In relation to educational outcomes of Vietnamese graduates, the World Bank in its 2014 report "Skilling up Vietnam: Preparing the workforce for a modern market economy" (Bodewig & Badiani-Magnusson, 2014) showed the persistence of skills gaps in the country, both in terms of job-specific technical and transferrable skills. The World Bank report called for strategic skills development in Vietnam, which necessarily involves fostering the development of cognitive skills (such as problem solving and critical thinking) and behaviour skills (such as teamwork and communication) (Bodewig & Badiani-Magnusson, 2014). This paper argues that creativity-oriented instruction could and should be made accessible in mathematics lessons to foster essential 21st-century skills for students.

This paper reports part of the findings from a research project conducted to develop mathematical creativity for students in Vietnamese secondary schools. This paper particularly reports the experimental phase of the study, in which creativity-enriched mathematics instruction was implemented at three secondary schools in Hanoi and Nam Dinh, Vietnam. The paper first reviews the construct of creative thinking capability and the development of creative thinking in mathematics instruction to set the context for the study. The paper then outlines the research design, including the research sites, the experimental procedure, and the approach to evaluating the outcomes and effectiveness of the intervention. The findings and discussions of the findings are then provided, from which implications are given in pedagogical terms.

## Literature review

### Creativity in mathematics

Creativity is a latent construct that has been examined in different contexts of use and domains. Therefore, apart from a shared agreement that this construct is multidimensional, there exist wide variations in the definitions and interpretations of creative competence. For example, researchers hold different opinions about the domains that constitute creativity, such as:

- originality, appropriateness, and effectiveness (Carreira & Amaral, 2018);
- novelty, aesthetics, utility, and authenticity (Kharkhurin, 2014);
- originality, value, surprise, and aesthetics (Acar et al., 2017);
- authenticity, inconsistency, potentiality, and discovery (Runco & Beghetto, 2019).

Runco and Beghetto (2019) noted that the different conceptualisations of creativity are due to an individual-social perspective dichotomy in the literature. The individual perspective (for example, adopted by Runco, 1995) treats creativity as cognitive, subjective, individual processes and mechanisms. In contrast, the social perspective (for example, practised by Glăveanu, 2014) considers that creativity is bound by social norms, positions, and practices and does not exist without social recognition. Runco and Beghetto (2019) refuted this dichotomy, arguing that initially, creativity is personal attributions that may or may not be subject to social interpretations by external audiences. In case an individual's primary novelty interacts with external audiences, both individual and social attributions involve the construction of originality. This unified definition of creativity by Runco and Beghetto (2019) has useful implications for the design and implementation of creativity-enriched mathematics instruction in this study.

Moving on to mathematical creativity, according to Haylock (1997), whether seen as a thinking process or a product, mathematical creativity involves overcoming fixations and practising divergent thinking. Fixations can be in the form of *content-universe fixation* (restricting one's thinking to a limited number of familiar possibilities) or *algorithmic fixation* (repeatedly adhering to an algorithm that was initially successful in previous situations but is no longer appropriate or optimal for others). Overcoming fixations requires one to be open to a wide range of possibilities and refraining from stereotypes that are conditioned by previous experience. In the meantime, divergent thinking is manifested when one can provide multiple responses to an open-ended question.

Mathematics tasks and measurement tools developed to assess divergent thinking in mathematics commonly tap into criteria such as fluency, flexibility, originality, and elaboration (Koestler, 1964). A student's mathematical fluency is commonly calculated as their total number of correct responses to a mathematical item divided by the maximum number of correct responses by a student in the investigative population; their mathematical flexibility is calculated as the total number of response categories to an item divided by the maximum number of response categories by a student in the investigative population; and their originality score is calculated as their frequency of producing uncommon responses compared to that of all students in the investigative population (Gruntowicz, 2020). According to Haylock (1997), since flexibility facilitates the generation of different ideas when one solves a mathematical problem, it is more useful than the quality of fluency in indicating creative thinking. Tabach and Levenson (2018) made the same observation, commenting that representations of flexible thinking are more subtle and hence less straightforward to be measured than fluency. As for elaboration, Sitorus (2016) argued that through the process of expanding an idea with details, one can clarify and expand their thinking and eventually have a better understanding of concepts, which is not only facilitative but also indicative of creativity. It should be noted that many researchers expand the attributes of mathematical creativity in their assessment tools. Lin and Cho (2011), for example, through a confirmative factor analysis that produces a well-fitting factor structure of creativity, proposed the *Creative Problem-Solving Attributes Inventory* with six predictors, namely divergent thinking, convergent thinking, motivation, environment, and domain-general knowledge and skills, and domain-specific knowledge and skills. The complex nature of the instruments, however, can make it challenging to operationalise in classroom assessments.

## Creativity-enriched mathematics instruction

There are strong pedagogical implications as mathematics instruction is shifting away from the "genius" view of creativity. The "genius" view believes that creativity is a special, rare quality of exceptionally talented individuals and is not likely to be much influenced by instruction (Silver, 1997, p. 75). In stark contrast with this view, many educational researchers now support the view that "creativity is closely related to deep, flexible knowledge in content domains; is often associated with long periods of work and reflection rather than rapid, exceptional insight; and is susceptible to instructional and experiential influences" (Silver, 1997, p. 75). This latter view suggests that creativity-related classroom instruction can and should benefit a much wider student population than just a small number of gifted and exceptional learners (Sheffield, 2017).

To develop creative competence alongside mathematical thinking for students, creativity-enriched mathematics instruction has been implemented in different forms. Inquiry-based teaching, for example, has been used to encourage opportunities for formulating and solving problems beyond mathematics problems in prescribed textbooks and from that, develop for students a conceptual understanding of the subject matter. Problem solving and problem posing are considered a mediator that helps students think creatively (Vale et al., 2018). Inquiry-based teaching was recommended and testified early on by many scholars such as Ayllón et al. (2016) and Yuanita et al. (2018).

Realistic mathematics education (RME) is a more inclusive pedagogical approach used to develop mathematical creativity for students. RME is characterised by teaching and learning activities that cultivate student experiences and active learning, promote discussions, build connections between concepts and topics, and translate concrete realities into abstract mathematical models and concepts (Hasbi, et al, 2019). More importantly, RME believes the key to successful mathematics instruction is to build mathematical belief for students, helping them believe in themselves as mathematically able and believe in mathematical teaching and learning (Makonye, 2014). This guiding motivation of RME is supported by empirical studies that have established a positive correlation between students' mathematical beliefs and mathematics performance (Revina & Leung, 2019). Many researchers and educators (for example, Drijvers et al., 2019; Sitorus, 2016; Yuanita et al., 2018) have argued that RME is one of the most effective pedagogies to develop for students their mathematical creativity.

Studies that investigate the contribution of RME to students' mathematical creativity typically employ either a quasi-experimental or a descriptive-explorative qualitative approach. The scale of RME implementation is quite far-ranging as seen in the various RME narratives reported in the book edited by van den Heuvel-Panhuizen (2020). A good number of quasi-experimental RME publications are from the Indonesian school context as this country has been promoting RME for over ten years in a majority of its provinces. For example, Ismunandar et al. (2020) trialled RME with 33 Grade 7 students using one group-paired design whereas Yuanita et al. (2018) experimented with RME instruction on 426 secondary school students using non-equivalent pre- and post-test control groups. In both studies, the research team calculated the N-Gain score and found intermediate gains in students' creative thinking or mathematical belief. Ismunandar et al. (2020) reminded that the effectiveness of RME can vary significantly depending on course objectives, student population, and learning environment. It is argued that RME essentially starts with teachers being able to identify, design, and implement creativity-fostering activities. This highlights the importance of motivating, training, and supporting teachers in relevant aspects of RME.

### Creativity-enriched mathematics instruction in Vietnamese secondary schools

Secondary school education in Vietnam is for students from Grade 6 to 9, typically aged between 11 and 15 years old. According to Do (2017), mathematics teachers in the Vietnamese school typically use one highly structured sequence in teaching: first explaining and illustrating mathematical concepts, then giving drills (often decontextualised), and finally assigning a lot of enrichment exercises for homework. It is further noted that teacher talking time occupies 90% while the remainder is reserved for individual (8%) and group work (2%). The observation by Do (2017) reflected not just the pedagogy used in the Vietnamese mathematics class but also a system-level issue in Vietnamese school education. Such a pedagogy for the teaching of school subjects in general and mathematics, in particular, is unlikely to equip important 21st-century skills for students, including creative competence.

RME was first introduced in mathematics education in Vietnam in the mid-2000s (Do et al., 2021). However, the approach was not adequately promoted until MOET enforced the *New General Education Curriculum* in 2018, meaning it is still popular among only a small circle of mathematics teachers. Do et al. (2021) observed a bottom-up undertaking of RME, noting that school principals and policymakers tend to be less informed of the approach than mathematics teachers. So far, only several researchers have examined the use of RME in mathematics classes in Vietnam. For example, Bui et al. (2021) experimented with RME-based instruction for Grade 7 mathematics at a Vietnamese secondary school. They found a positive contribution of RME to students' problem-solving skills. Other than that, there is scarce scholarly literature that defines, empirically validates, or measures the development of mathematical creativity in Vietnamese schools. Some limited literature briefly addresses mathematical creativity when discussing the benefits of problem solving. For example, Tran et al. (2016) analysed 234 survey responses, 27 in-depth interviews, and 208 lesson plans and found that the development of creativity in the Vietnamese school remains limited. This again raises the importance of identifying and trialling activities that can support the development of mathematical creativity for Vietnamese school students.

## Method

### Research design

This paper reports the experimental phase of a study conducted to develop and enhance creative competence for Vietnamese school students via creativity-enriched mathematics instruction. The main task of the experimental phase was to trial creativity-enriched activities that could be used in mathematics classes. This phase is characterised by quasi-experimental research, particularly the non-equivalent groups design, due to the difficulty in randomly assigning students into treatment and control groups. The research team was mindful that for a study using the non-equivalent groups design, there is a possibility of confounding variables beyond control that can affect the study's internal validity. Therefore, significant efforts were taken to reduce bias in selecting research sites and research participants. The research was carried out in Vietnamese, and the research tools were translated into English for the purpose of including illustrative quotations and presenting appendices as references. Ethics approval for this study was granted by the Vietnam National Institute of Educational Sciences.

### Research sites and participants

The research sites comprised two metropolitan secondary schools in Hanoi City and one suburban school based in Nam Dinh Province. Our study selected schools from different localities to see if creativity-enriched mathematics instruction could be implemented with students from different school settings. For each participating school, two classes were selected, both taught by the same teachers but one received creativity-enriched mathematical instruction while the other received conventional instruction. The experiment was conducted between March and June 2020, during a period when Vietnamese schools were still open and unaffected by the Covid-19 pandemic, thanks to prevention policies implemented by the Vietnamese government. The participating schools and student numbers (given in brackets) are provided in Table 1.

Table 1: Research sites and sampling (N=229)

| Location | School names (anonymised) | Treatment group | Control group |
|---|---|---|---|
| Hanoi | A Secondary School | Class 6A1 (41) | Class 6A2 (38) |
| | B Secondary School | Class 6A (41) | Class 6C (40) |
| Nam Dinh | C Secondary School | Class 6A (34) | Class 6B (35) |

### Intervention procedure

Drawing on the literature and the particular context of mathematics teaching in Vietnamese secondary schools, the study developed a battery of tasks for use in the experimental mathematics classes. The study aimed for creativity-enriched teaching and learning activities that were grounded on the principles of RME, for example,

- using practical contexts and cultivating students' diverse, rich experiences;
- being problem-based to stimulate students' curiosity and offer problem-solving, problem-posing, and redefinition opportunities;
- offering self-initiated and collaborative learning opportunities;
- using project-based activities where students actively solve authentic problems and make their own decisions;
- being didactically oriented to promote student interactions.

As for mathematics tasks, the study aimed for those that could invite a range of possible responses or repeated redefinition of the elements of a situation, as informed by the work by Haylock (1997), Leikin (2009), Peressini and Knuth (2000), and Vale et al. (2018). The study targeted tasks that could encourage divergent thinking and fixation overcoming rather than challenging-and-speedy task types. The procedure, activities, and assessment tools were consulted with a team of two senior research fellows working at the Vietnam National Institute of Educational Sciences, two mathematics educators, and four classroom teachers before being implemented. Prior to the intervention, surveys and interviews were conducted with teachers and students from five localities to collect information about their perception of and familiarity with creativity-enriched mathematics instruction. Pre- and post- mathematics tests were also administered to ensure similar mathematical ability between the treatment and control groups. The three teachers participating in the project were provided with an intensive two-week training workshop to ensure their thorough understanding of the pedagogical procedure and materials. The intervention comprised 6 lessons spanning over 21 contact hours. Within the scope of this paper, only the intervention and post-intervention outcomes are reported. A summary of the instruments used is given in Table 2.

Table 2: Research instrumentation

| Procedure | Instruments | Sampling |
|---|---|---|
| Pre-intervention | Teacher survey<br>Student survey<br>Teacher interviews (Appendix 4)<br>Student interviews<br>Mathematics tests (Appendix 5) | 123 responses received<br>213 responses received<br>3 teachers<br>6 students |
| Intervention | Lesson plans (Appendix 3)<br>Creativity rating scale (Appendix 1)<br>Teacher observation (Appendix 2)<br>Student observation<br>Mathematics tests (Appendix 5) | |
| Post-intervention | Teacher interviews (Appendix 4)<br>Student interviews | 3 teachers<br>6 students |

### Data analysis

Two types of data were collected and analysed from the intervention. Qualitative data referred to teachers' and students' thoughts on the intervention, including written records of observations during interventions and post-intervention interviews. Qualitative data were analysed manually for themes related to the implementation of creativity-enriched mathematics instruction. Meanwhile, quantitative data referred to student performance in formative and summative mathematics tests and were analysed using *SPSS*. The following statistical tests were performed on the quantitative data:

- Independent sample t-test to confirm statistical evidence in the creativity competence acquired by students in the treatment groups compared with the control groups
- Dependent sample t-test to confirm statistical evidence in the creativity competence acquired by students in the treatment groups before and after the intervention
- Effect size ES (SMD) = $\dfrac{\overline{X}_{TN} - \overline{X}_{DC}}{S_{DC}}.100\%$

  (in which
  $\overline{X_{TN}}$ is the mean of the treatment group, $\overline{X_{DC}}$ is the mean of the control group, and $S_{DC}$ is the standard deviation of the control group). Interpretations of effect sizes were based on Hopkins et al. (2009) as below:

| Effect sizes | > 1.0 | 0.80 – 1.00 | 0.50 – 0.79 | 0.20 – 0.49 | < 0.20 |
|---|---|---|---|---|---|
| Magnitude of effect | Very large | Large | Moderate | Small | Trivial |

## Findings

### Quantitative findings

Table 3 presents the mathematics test results of students in the control and treatment groups at the three participating schools before and after the intervention. It can be seen that after the intervention, students in the treatment groups had higher mathematical gain scores compared with those in the control groups at all the participating schools. The mean score difference between the treatment and control groups was around 1.11 for A Secondary School and C Secondary School and was higher at 1.5 for B Secondary School. It can also be noted that for both pre- and post- mathematics test results, C Secondary School recorded lower statistics compared with the remaining two. At this suburban school, the mean test result recorded for the treatment group after the intervention was 5.74, lower than the mean score of 6.07 for A Secondary School and 6.85 for B Secondary School. The effect size statistics ES (SMD) recorded was moderate at 0.56 and 0.51 for A Secondary School and C Secondary School respectively and was large at 0.89 at B Secondary School.

Table 3: Mathematics test results

| Schools | Group types | N | Pre-intervention | | | Post-intervention | | |
|---|---|---|---|---|---|---|---|---|
| | | | M | SD | SE | M | SD | SE |
| A Secondary School | Treatment | 41 | 4.93 | 2.296 | 0.359 | 6.07 | 1.903 | 0.297 |
| | Control | 38 | 4.92 | 2.148 | 0.349 | 4.95 | 1.999 | 0.324 |
| B Secondary School | Treatment | 41 | 5.20 | 2.315 | 0.362 | 6.85 | 1.424 | 0.222 |
| | Control | 40 | 5.03 | 2.527 | 0.399 | 5.35 | 1.688 | 0.267 |
| C Secondary School | Treatment | 34 | 4.24 | 2.388 | 0.409 | 5.74 | 1.399 | 0.240 |
| | Control | 35 | 4.46 | 2.318 | 0.392 | 4.63 | 2.157 | 0.365 |

Table 4 presents the independent samples t-test statistics before the intervention for each participating school. Levene’s tests obtained a value of F = 0.144 (sig = 0.705 > 0.05) at A Secondary School, F = 0.000 (sig = 0.998 > 0.05) at C Secondary School, and F = 0.269 (sig = 0.606 > 0.05) at B Secondary School. This shows the data had similar variances between the control and treatment groups at the three schools.

Table 4: Pre-intervention independent samples t-test

| Schools | Equal variances | Levene’s test for equality of variances | | t-test for equality of means | | | | |
|---|---|---|---|---|---|---|---|---|
| | | F | Sig. | t | df | Sig. (2-tailed) | Mean diff. | Std. error diff. |
| A Secondary School | Assumed | 0.144 | 0.705 | 0.012 | 77 | 0.991 | 0.006 | 0.501 |
| | Not assumed | | | 0.012 | 76.991 | 0.991 | 0.006 | 0.500 |
| B Secondary School | Assumed | 0.269 | 0.606 | 0.316 | 79 | 0.753 | 0.170 | 0.538 |
| | Not assumed | | | 0.316 | 78.021 | 0.753 | 0.170 | 0.539 |
| C Secondary School | Assumed | 0.000 | 0.998 | -0.392 | 67 | 0.697 | -0.222 | 0.566 |
| | Not assumed | | | -0.391 | 66.768 | 0.697 | -0.222 | 0.567 |

Table 5 presents the post-intervention independent samples t-test statistics following the intervention at the three schools. It shows a significant difference in mathematical gain scores between the treatment and control groups, with F = 0.226 (sig = 0.012 < 0.05), 7.426 (sig = 0.014 < 0.05), and 0.789 (sig = 0.000 < 0.05) at A Secondary School, C Secondary School, and B Secondary School respectively. The finding suggests that creativity-enriched instruction contributed more to students' mathematical ability compared with conventional instruction.

Table 5: Post-intervention independent samples t-test

| Schools | Equal variances | Levene's test for equality of variances | | t-test for equality of means | | | | |
|---|---|---|---|---|---|---|---|---|
| | | F | Sig. | t | df | Sig. (2-tailed) | Mean diff. | Std. error diff. |
| A Secondary School | Assumed | 0.226 | 0.636 | 2.564 | 77 | 0.012 | 1.126 | 0.439 |
| | Not assumed | | | 2.560 | 77.788 | 0.012 | 1.126 | 0.440 |
| B Secondary School | Assumed | 0.789 | 0.377 | 4.338 | 79 | 0.000 | 1.504 | 0.347 |
| | Not assumed | | | 4.328 | 76.165 | 0.000 | 1.504 | 0.347 |
| C Secondary School | Assumed | 7.426 | 0.008 | 2.520 | 67 | 0.014 | 1.107 | 0.439 |
| | Not assumed | | | 2.536 | 58.526 | 0.014 | 1.107 | 0.439 |

Table 6 shows the number of students who produced more than one solution to mathematics problems in the pre- and post-intervention mathematics tests. As reviewed in the literature, the ability to generate different ideas or solutions is a display of "flexibility" – one useful dimension of the creativity construct. Numbers in Table 6 were extracted from students' responses to the mathematics tests. Before the intervention, few students in both the treatment and control groups could produce more than one answer to a mathematics problem. Following the intervention, improvements were recorded regarding the ability to solve a mathematics problem using different solutions by students in the treatment groups. The most remarkable improvement could be noted for the treatment group at A Secondary School, with 34 out of 41 students producing multiple solutions to a mathematics problem. The problem-based activities regularly used in the intervention were likely to have facilitated and encouraged students to be flexible and overcome fixation in their thinking. In contrast, a modest figure with 5 out of 34 treatment students from C Secondary School could present more than one solution to the mathematics problems in the post-intervention mathematics tests. Its proportion (14.7%) came at a third and a fifth of the figures recorded for B Secondary School (39%) and A Secondary School (83%) correspondingly.

Table 6: Number of students giving more than one solution to mathematics questions

| Schools | Pre-intervention | | | | Post-intervention | | | |
|---|---|---|---|---|---|---|---|---|
| | Treatment | | Control | | Treatment | | Control | |
| | N | % | N | % | N | % | N | % |
| A Secondary School | 2 | 4.9 | 1 | 2.6 | 34 | 83 | 1 | 2.6 |
| B Secondary School | 1 | 2.4 | 0 | 0 | 16 | 39 | 10 | 25 |
| C Secondary School | 0 | 0 | 0 | 0 | 5 | 14.7 | 0 | 0 |

## Qualitative findings

Having experienced teaching both traditional and creativity-enriched instruction, all three teachers in charge favoured the latter and agreed that students were most motivated and learnt best through problem-based and realistic situations. The teachers explained that realistic mathematics problems allowed students to take the initiative in identifying the problem to be solved, planning how to solve it using different sources of information, and presenting their solutions, as illustrated in the following excerpt:

> The class [the treatment group] were excited whenever I assigned them to groups to work on a real-life maths problem. When we worked on the "Getting to School" Activity [details in Appendix 3], all the students participated and discussed so enthusiastically how to estimate the distance from their home to school. They came up with many creative ideas. They also discussed many interesting ways to illustrate and scale their answer on A0-sized paper [sample work in Figure 1]. (Teacher 1, A Secondary School)

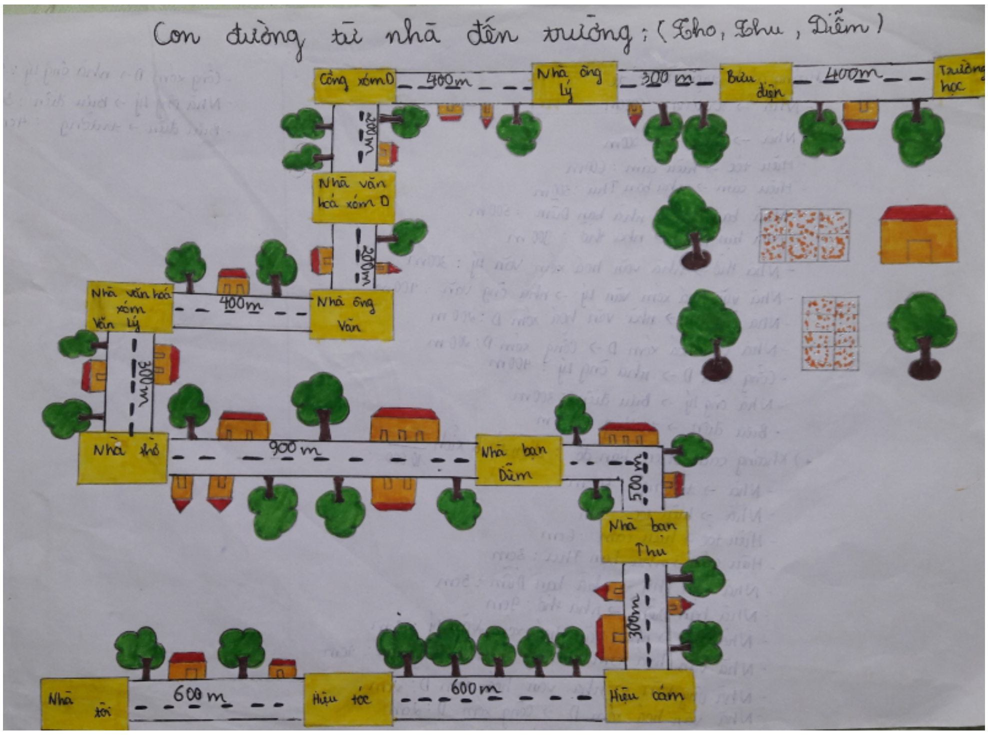


Figure 1: Sample student work for "Getting to school" activity

The teachers not only saw the display of creativity in group performance but also from individual students. As part of the intervention, each teacher selected two students from the treatment group as cases that they observed throughout the intervention period. The observation was done using the observation checklist with creativity indicators in Appendix 2. All the teachers noted a clear progression in these cases' mathematical creativity. As shared by one teacher:

> This student, Minh [pseudonym], is quite a competent student. He can tell quite quickly how to solve a maths problem. However, he is rather shy to raise or defend his ideas and is often reluctant to try other ways to find the answer. Before [the intervention], I rated him as Level 1 [referring to the Creativity Rating Scale in Appendix 1]. He scored an 8 [out of 10] on the first maths test. When participating in the activities [the treatment], Minh engaged more with other friends. He also sought more ways to solve maths problems. In the "Getting to School" activity, he was the one to suggest his groupmates using a Hanoi local map to calculate the distance to school. I gave him a 10 in the latest test. I also rated him as Level 2 or 3 after the activity. (Teacher 2, B Secondary School)

From a student's point of view, mathematics lessons enriched with realistic, creativity-oriented activities benefitted their learning in multiple ways. Before the treatment, two students from each treatment class were interviewed on what they perceived creativity to be like and how their classes were usually taught. Following the treatment, these students were interviewed again to see how they perceived their creative competence and learning growth. The students were able to articulate quite clearly a renewed perception of mathematical creativity and how the intervention contributed to their learning. Their remarks on the treatment activities largely resembled the teachers' reflections, as seen in the following excerpt:

> Before, I was only familiar with listening to my teachers and doing a lot of practice in my workbook. I often kept doing a lot of practice until I knew how to apply fluently a formula my teachers gave me. Now I often calculate different possibilities and solutions first before deciding on which is the best option to go with. (Student 4, C Secondary School)

It can be seen from above that the teachers had quite an extended view of creativity when treating it not purely in terms of cognitive resourcefulness. They extended the indicators of creativity to include other aspects, such as positive mathematical belief, confidence, and motivation. When it came to assessments, teachers tended to search for the display of divergent thinking in students' work.

At the same time, the teachers acknowledged that it was a challenging task. The teacher at C Secondary School revealed that the project-based, didactic approaches used in the intervention had rarely been used at the school. She commented that the first few lessons were devoted to transitioning students to experiential and student-centred learning. The lack of familiarity among C Secondary School teachers and students with non-conventional pedagogies could have been accountable for a lower score gain when the creativity-enriched instruction was implemented compared with the score gains reported at the other two schools.

## Discussions

This study supports a general agreement in the literature that provided with a facilitative learning environment and encouraged to solve a problem using different solutions, students are more likely to develop and display mathematical creativity. This facilitative learning environment refers to activities that deliberately and explicitly provide opportunities for discovery and intrinsic motivation (Baer & Garrett, 2010; Vale et al., 2018). In our study, the activities used in the intervention display those qualities. They also entailed a shift from an instrumentalist point of view that focused only on mathematical content and embraces passive reception of knowledge to a learner-centred point of view that encourages students to explore their own learning. The study refutes a common stereotype among Vietnamese educators that creativity is a topic only for gifted students and that Vietnamese students lack creativity. Instead, through teachers' and students' ability to articulate aspects of creative competence, our study demonstrates that students think and create new knowledge in their own space of flexibility.

The study, at the same time, acknowledges some major challenges and their implications for expanding the implementation of mathematical creativity in Vietnamese schools. Firstly, while teachers embraced mathematical creativity, they may not have a sound understanding of the construct to support and monitor students experiencing the creative learning environment. The case of the suburban school C Secondary School demonstrates a challenge in transitioning to creativity-enriched instruction when the student cohort was not ready for that and thus required more teacher support. This reflects a common observation by Wahyudi et al. (2017) that teachers tend to be more familiar with transmitting knowledge than facilitating student-centred and active learning as they are often not trained to use inquiry-based learning or exploit real-world problems as cases for learning.

Secondly, it is challenging to fit the assessment of divergent thinking into the broader curricular and pedagogical ecology of Vietnamese school settings that favours standardised testing. Recent attempts to update textbooks and curricula are deemed superficial due to a lack of a solid theoretical framework to support teaching and assessment of mathematical creativity (Nguyen et al., 2023). Beghetto and Kaufman (2014) warned that focusing on divergent thinking can lead creativity to be treated simply as "a curricular add-on" that is "completely irrelevant to the academic curriculum" (p. 56). This is similar to a remark by Baer and Garrett (2010) that "it is hard to see how listing 100 interesting and unusual ways to use egg cartons will help Johnny improve his scores on state-mandated achievement tests" (p. 11).

These challenges have implications for the long-term commitment in terms of teacher training, curriculum, assessments, and empowerment for classroom teachers in Vietnam. Ismunandar et al. (2020) has reminded that course objectives, student population, and learning environment should be taken into consideration when implementing non-conventional pedagogies.

## Conclusion

Our article adds empirical evidence regarding the contribution of creativity-enriched instruction to students' mathematical creativity. It revisits the construct of mathematical creativity as well as the characteristics of creativity-enriched pedagogical approaches. From that, we propose teaching activities to be implemented in Vietnamese secondary school settings to develop and enhance mathematical creativity for Vietnamese school students, particularly those grounded on the principles of RME. Using a quasi-experimental research design, the study implemented creativity-enriched mathematics lessons at three secondary schools with the participation of three teachers and 229 Grade 6 students. The findings demonstrate the feasibility and effectiveness of creativity-enriched in different school settings. Our study reiterates a remark by Mann (2006) that "changes in classroom practices and curricular materials are necessary" and "will only be effective if creativity in mathematics is allowed to be part of the educational experience" (p. 237). Creativity-enriched mathematics instruction, particularly when grounded on the principles of RME, frees students from closed problems with predetermined answers and transforms learning into personally meaningful experiences, thus nurturing creative mindsets.

This study offers some forms (in Appendix 2) for observing creativity-enriched mathematics instruction in secondary school settings. The forms aimed to be exhaustive to cover different aspects of classroom instruction. However, this study admits a limitation in using those forms reliably, due to the typical large class sizes in Vietnamese secondary schools. While each teacher selected only two students from the treatment group to observe throughout the intervention period, they may have experienced challenges in following in a quality manner the detailed list of 28 items in Appendix 2 while simultaneously attending to other students in their class. Future quasi-experimental studies on creativity-enriched classroom instruction that consider using these forms can modify them to ensure the ease of use and the reliability of the findings.

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## Appendix 1: Creativity rating scale (teacher version)

| Criteria | Level 1 | Level 2 | Level 3 |
|---|---|---|---|
| identify the specific task or question to be solved | identify part of the task or question to be solved in some detail | identify part of the task or question to be solved in detail | fully identify the task or question to be solved in detail |
| propose appropriate hypotheses for solving the question or task | propose one appropriate hypothesis for solving the question or task | propose several appropriate hypotheses for solving the question or task | propose and elaborate several appropriate hypotheses for solving the question or task |
| propose an appropriate plan to solve the question or task | propose an appropriate plan by considering an option to solve the question or task | propose an appropriate plan with several possible options to solve the question or task | propose and plan in detail several possible options to solve the question or task |
| implement the plan in an effective and creative manner | implement part of the plan to solve the question or task in an effective manner | implement all the options in the plan to solve the question or task in an effective manner | implement all the options in the plan to solve the question or task using available resources/ skills/ understan-ding in an accurate, effective, and scientific manner |
| report implementation of the plan in a creative and scientific manner | collect, analyse, and interpret results though lacking completeness and clarity | collect, analyse, and interpret results clearly and completely | collect, analyse, and interpret results in a clear, logic, creative, and scientific way that shows conceptual understanding of the matter |
| present the solutions in a creative and scientific manner | present the solutions in full and with clarity | present the solutions in full and with clarity using suitable charts/ tables/ other forms of visual aids | present the solutions in a clear, complete, and scientific manner using suitable charts/ tables/ concept maps/ other forms of visual aids |
| use the checklist to self-assess the solutions | use self-evaluation forms/ checklists/ criteria to evaluate the solutions produced | use self-evaluation forms/ checklists/ criteria to evaluate the solutions produced and provide some justifications for the self-evaluation | use self-evaluation forms/ checklists/ criteria to evaluate the solutions produced in a fluent manner; provide justifications for the self-evaluation |

## Appendix 2: Observation form (teacher version)

*Evaluation form for group performance*

School: ..........................................................................Class: ........................................................................
Group: ..........................................................................Date of observation: .............................................
Lesson:..........................................................................................................................................................

| Criteria | Achievement of creative competence | | | | Comments |
|---|---|---|---|---|---|
| | Level 0 (0-4 marks) | Level 1 (5-6 marks) | Level 2 (7-8 marks) | Level 3 (9-10 marks) | |
| identify the specific task or question that needs to be solved | | | | | |
| propose hypotheses appropriate for solving the question or task | | | | | |
| propose a plan appropriate to solve the question or task | | | | | |
| implement the plan in an effective and creative manner | | | | | |
| report implementation of the plan in a creative and scientific manner | | | | | |
| present the solutions in a creative and scientific manner | | | | | |
| use the checklist to self-assess the solutions | | | | | |

Aspect(s) for which students display the most of their creativity: ..........................................................
.........................................................................................................................................................
.........................................................................................................................................................
Aspect(s) for which students display the least of their creativity: ..........................................................
.........................................................................................................................................................
.........................................................................................................................................................

*Observation form for individual student performance*

School: ..........................................................................Class: ........................................................................
Student name: ...............................................................Date of observation: .............................................
Lesson:..........................................................................................................................................................

Which of the following behaviours were displayed by the student? Please tick all that apply.

| | | |
|---|---|---|
| 1 | Identifying the problem to be solved in a specific situation | ☐ |
| 2 | Asking questions to understand clearly the problem to be solved | ☐ |
| 3 | Approaching the problem to be solved from different perspectives | ☐ |
| 4 | Proposing different hypotheses to solve the problem | ☐ |
| 5 | Drawing a plan to solve the problem in a quick and efficient manner | ☐ |
| 6 | Taking initiative and confidently engaging in solving the problem | ☐ |
| 7 | Selecting suitable method(s) to solve the problem from a range of available methods and mathematical topics (with/ without teacher support) | ☐ |

| | | |
|---|---|---|
| 8 | Improving the method suggested by the teacher to solve the problem | ☐ |
| 9 | Selecting and using available resources, facilities, and time to solve the problem in an effective manner | ☐ |
| 10 | Finding a solution to the problem while not necessarily following conventional approaches/ formulas | ☐ |
| 11 | Finding ways to handle issues arising while solving the problem | ☐ |
| 12 | Justifying a solution that is different from and more efficient than conventional solutions | ☐ |
| 13 | Understanding the mathematical concept(s) beyond the practical problem | ☐ |
| 14 | Uncovering new knowledge that is not covered in the main textbooks | ☐ |
| 15 | Applying the newly acquired knowledge to solve other problems | ☐ |
| 16 | Presenting the solution(s) to others in a way that shows a thorough, creative understanding of the matter | ☐ |
| 17 | Justifying and defending personal or group opinions on the matter | ☐ |
| 18 | Self-evaluating the solution produced by oneself or produced as a group | ☐ |

Other comments/ notes:

................................................................................................................................................................

................................................................................................................................................................

## Appendix 3: Sample intervention

*"Getting to School" activity*

| | |
|---|---|
| Grade | 6 |
| Learning outcomes | By the end of the activities, students are expected to be able to<br>• understand the concept of ratios<br>• scale the distance between two locations on a map<br>• work collaboratively<br>• present solutions orally (using diagrams/ charts/ posters) |
| Materials | Local maps |
| Procedure | • 45 mins planning (15ms in-class instruction, 15ms in-class group discussion, 15ms in-class group presentation of their plan)<br>• 1–week implementation in groups: Individual students in each group identify the distance from their home to school. They can do so in different ways, for example, by asking their parents, estimating by themselves using the travel time, or looking up on a map. The whole group collates the information from individual group members and sketches a map of ways to school.<br>• 45–75 mins group presentation in class using posters/ charts/ maps to illustrate their works |
| Assessments | Teacher evaluation using Creativity rating scale (Appendix 1), Observation Form (Appendix 2), and summative/ formative mathematics tests (Appendix 5)<br>Student self-evaluation using Creativity Rating Scale, Observation Form |
| Reflection | Interviews with teachers and students |

## Appendix 4: Interview protocol (sample teacher version)

1. What do you think are the indicators of creative thinking in mathematics?
2. In classes that you teach, do students display those examples of creativity?
3. Are there many students in classes that you teach who can display those examples of creativity? Are there any students in classes that you teach who can display all those examples?
4. What teaching approaches/ pedagogies do you think can develop or enhance mathematical creativity for students?
5. In class do you use activities or mathematical problems that:
   a. stimulate students' curiosity? Do students enjoy those activities?
   b. engage students in discussions and debates to solve a problem? Do students enjoy participating in those activities? Do they manage to reach a consensus for their solution?
   c. encourage different solutions? Are there many students who can give different solutions?
   d. use mathematical formulas or concepts to solve practical, real-life problems? Are students taught to relate concepts to practical problems? If yes, how is that done?
   e. are in the form of a project? If yes, can you give an example of an activity and tell the outcome?
6. How often do you use the activities above?
7. How do you assess students' learning if the above activities are used? Do you reward answers or solutions that are creative?
8. How likely are you to implement the activities above in the future? What may hinder or encourage you to do so?

## Appendix 5: Sample mathematics tests

*Formative test (15 minutes)*

1. Between 7 p.m. and 10 p.m. this evening, Ha plans to spend 1/6 of an hour helping her mom with the clean-up, 3/4 of an hour on her homework, and 1 hour and 30 minutes on her favourite book. She plans to spend the remaining time watching her favourite music show on TV. The show lasts 30 minutes. Will Ha have enough time to watch the full show? List possible solutions for your answer.

2. Nam, Huy, Mai, and Binh are sharing their lunch. There are five apples to share. List all possible ways to share the five apples equally between the four friends.

*Summative test (45 minutes)*

1. A bookstore is offering a sale of 15% off storewide. Four friends are interested in a Maths book priced at 60,000 dongs. They come up with different prices after the discount: Binh says 9,000 dongs; Mai says 69,000 dongs; Huy thinks it's 51,000 dongs; Hoa argues that the book costs only 4,500 dongs with the sale. Who says the correct amount? Explain your answer in different ways.

2. A group of students decided to visit Dai Lai Lake by bike. They started at 6:30 a.m. and planned to arrive at 10:00 a.m. After riding for 1 hour and 30 minutes, they stopped for a 20-minute break. During the break, they calculated that they had travelled 21 km. They looked at a 1:200000 scale map and saw that Dai Lai Lake was marked 9.5 cm away on the map. After the break, the group continued to travel at the same speed. Would they get to the lake by 10:00 a.m.? Explain your answer.

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