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Beyond Routine Exercise: Integrating Digital Problem-Posing Tools to Cultivate Creative Mathematical Fluency

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Abstract
Creative Mathematical Fluency (CMF), the ability to produce multiple, diverse, and original ideas with procedural accuracy, is crucial for 21st-century problem-solving. Still, routine drill and practice often fail to foster it. Studies indicate that problem-posing teaching can help students to generate divergent thoughts, but little is known about how digital problem-posing (DPP) tools influence CMF in real classrooms. The present study aimed to determine whether incorporating a cloud-based DPP curriculum in standard algebra-based lessons would improve middle-grade students' CMF scores compared to business-as-usual instruction, and to investigate the cognitive-affective processes associated with any such improvements. This six-week mixed-methods quasi-experimental research was conducted with 124 eighth-grade students at two similar Indonesian schools. Pre- and post-tests used the Creative Mathematical Fluency Test (CMFT) with Rasch-calibrated Fluency and Originality scales. Qualitative data identified richer structural diversity of posed problems, metacognitive reflection, and peer inspiration as driving factors. Students indicated increased enjoyment and eye percept creativity, despite some cognitive overload. Integrating DPP tasks meaningfully into algebra instruction can substantially raise CMF, suggesting that well-designed digital scaffolds can support learning "beyond routine exercise”.

Keywords: Creative Mathematical Fluency, Digital Mathematics Tool, Problem Posing, Senior High Education, Technology-Enhanced Learning

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INTRODUCTION

The preceding ten years have seen a strong policy trend towards the promotion of CMF with an increasing acknowledgement of creativity being a core competence in the Foster creativity in mathematics! This shift is accentuated by the findings of multiple educational studies that there is a pressing need for instructional roles that emphasize creativity and problem-solving in mathematics education (Cai & Rott, 2024). In such a context, mathematical problem-posing pedagogy seems to be a promising alternative. In the last three decades, numerous design studies have shown that instructing students to generate their own mathematical problems supports divergent thinking, deepens conceptual understanding, and sustainably facilitates the flexible application of learned knowledge (Suh et al., 2021). For example, Biçer (Bicer, 2021b) found a moderately significant ES for participants’ problem-posing skills, with creativity measures indicating the highest ES. Nevertheless, current practices often rely on non-digital approaches, such as paper-and-pencil activities, which in turn restrict learners' abilities to engage in real-time idea generation and iteration procedures that highly scaffold mathematical creativity (Popović et al., 2022).

The arrival of educational technology offers an exciting possibility for enhancing the benefits of problem-posing pedagogy. Digital Problem-Posing Tools (DPPT) can contribute to creating dynamic representations, instant peer feedback, automated documentation of complex problem-solving processes, and subsequently e-learning environments, but also to student creativity and engagement (Lampropoulos et al., 2022). Initial experiences with mathematics-tailored online platforms in the classroom have indicated positive experiences for students in terms of both interactivity and usability. However, several design challenges remain, such as insufficient guidance on building an algebraic expression or visualising a geometric figure, which can prevent achieving creativity-oriented results (Czarnocha, 2021). Additionally, many studies have focused on the development of technology rather than problem-posing, and as such, significant questions about the reconfiguration of cognitive and affective strategies that support CMF have remained underinvestigated (Suri & Juandi, 2021). The pressing demand to develop CMF in the context of educational inequalities can be effectively addressed by innovative pedagogies, such as mathematical problem-posing, particularly when mediated by digital technologies. In a changing academic environment, engaging in such practices may prepare students with mathematical fluency and the necessary creative skills to address real-world issues of standards.

Digital Problem-Posing (DPP) tools are offered as an innovative solution within MTaRs, emphasising the stimulation of students' creativity and imagination through advanced technologies. The latter is a critical characteristic to foster richer learning experiences, where dynamic representations and immediate peer feedback are possible (Bicer et al., 2025). However, as the early classroom use shows, students' positive perceptions of interactivity and usability also expose many design constraints. Namely, some learning experiences desired to be constructed are not easily supported by these tools, such as the facility for composing algebraic expressions or the opportunity for visualising geometric concepts, yet weakening creative results as intended (DİVRİK, 2023). The constraints above indicate the need for continued development of DPP instruments to better serve educational purposes in mathematics.

Furthermore, the current literature mainly discusses problem-solving, rather than problem-posing. So there are fundamental questions about how the affordances of digital environments might potentially reshape the cognitive and affective processes related to Creative Mathematical Fluency (CMF) (Bicer, 2021a). Thus, while research on this subject is evolving, significant knowledge gaps remain concerning the contexts in which DPP interventions are effective and lead to improvements in CMF. Research is necessary as well to understand (a) to what extent gains through DPP are accomplished compared to traditional instructional procedures; (b) the qualitative nature of problems that students produce in digital contexts, and (c) the learner perceptions, including motivation and self-efficacy, along with perceived cognitive load that may mediate such gains (Türkkan & Karakuş, 2021; Yumiati & Haji, 2021).

These are specific areas of knowledge gaps, which are especially relevant for lower-secondary algebra classrooms that still employ drill-based instruction techniques. Students' motivational pathways often deviate at this point, signalling a critical juncture for intervention via improved pedagogical approaches (Scorringe et al., 2021). Such nuanced synergy between DPP tools and student engagement may shed new light on the development of educational practice, the reduction of existing disparities, and a more profound appreciation of how technology can appropriately support mathematics learning. To tap into the potential of DPP tools, future research should address these gaps by identifying explicit conditions conducive to CMF and monitoring how students utilise digital platforms. This large-scale investigation will be instrumental in developing such educational technology and its application to enhancing creative mathematical capabilities in many learners.

Building on the literature above, we incorporate a cloud-based DPP platform into standard 8th-grade algebra instruction with four closely related objectives: 1) Effectiveness: To determine how much DPP-supported instruction affects students' CMF, as measured by fluency and originality scales. 2) Product features: examine the conceptual variety and situational richness of student-constructed problems. 3) Mechanisms: Investigate the interplay of metacognitive reflection, peer inspiration, and perceived cognitive load during digital problem posing. Equity: Investigate if the effects differ by prior achievements and sex.

These objectives are formalised in two hypotheses and two exploratory research questions: 1) H_1: Students who use the DPP tool will score significantly higher on the post-test CMF dimension scores than students engaged in traditional textbook exercises, when controlling for pre-test performance. 2) H_2: Students in the DPP condition will generate more multi-step, real-world, and structurally novel problems than controls. RQ1: What cognitive and affective opportunities and challenges do digital problem-posing afford students in their reports of creativity? RQ2: Are treatment effects moderated by gender or baseline achievement?

With strong quasi-experimental designs, rich log analytics, and student interviews, our study aims to illuminate how to orchestrate digital problem-posing experiences that develop creative mathematical fluency at scale, providing actionable insights for curriculum designers, teacher educators, and ed-tech developers alike.

METHODS

Research Design

A quasi-experimental, mixed-methods design was adopted to evaluate the impact of a cloud-based digital problem-posing (DPP) platform on students' Creative Mathematical Fluency (CMF) (Bicer et al., 2025; Hampson & McKinley, 2023). Two intact eleventh-grade classes from Al-Khairat Senior High School, Ternate City, Indonesia, were assigned to treatment or business-as-usual control conditions at the class level to minimize contamination. Quantitative data (pre/post-CMF scores, log analytics) were complemented by qualitative data (problem artifacts, interviews, observations) to generate integrated meta-inferences. The conceptual design is illustrated in Figure 1.

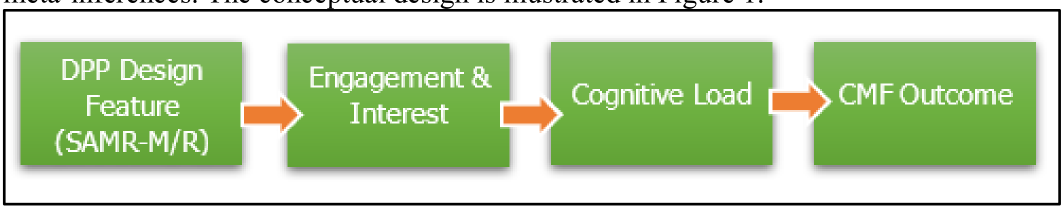

Figure 1. Conceptual Model of Hypothesised Paths

The diagram maps the sequential influence of *Digital Problem-Posing (DPP) design features*, implemented at the **S**AMR "Modification/Redefinition" (M/R) levels, on students' Engagement & Interest, the ensuing (reduced) Cognitive Load, and ultimately, their Creative Mathematical Fluency (CMF) outcomes**.**

Context and Participants

The study involved 124 Grade 11 students (62 treatment, 62 control; 55% female), whose median age was 13.9 years (SD = 0.4). Al-Khairat Senior High School participated in the eight-week study, each delivering the national Grade-11 algebra syllabus on linear equations in one and two variables with the same pacing guide and summative assessment schedule. Grade-11 class A implemented the Digital Problem-Posing (DPP) tool in its regular mathematics classes (treatment). Grade-11 class B continued with textbook-based practice (control).

Teaching in both schools was handled by certified teachers (10 – 12 years of experience) who attended a joint half-day orientation on study procedures. Instruction took place in regular 40-minute periods (4 × week). All students owned or were loaned a Chromebook™ and had filtered Wi-Fi access during lessons. Prior achievement (end-of-term mathematics scores) and access to devices/internet were statistically equivalent across groups ($p > .10$). Ethical clearance was granted by Khairun University; parental consent and student assent were secured.

Instruments

To test the hypothesized mediation chain (Figure 1), we employed a multi-method battery that combines performance-based assessment, self-report scales, system log analytics, and qualitative probes. Instruments were selected or adapted to (a) align tightly with each construct in the model, (b) minimize respondent burden, and (c) meet accepted psychometric criteria (reliability ≥ 0.80; model-fit indices ≥ 0.90). All quantitative tools were first piloted with a comparable Grade 11 cohort (n = 124) to verify clarity, timing, and scaling; the qualitative protocols underwent expert review and small-group rehearsals. Table 1 summarises key details.

Table 1. Summarises Key Details

Construct	Instrument & Structure	Psychometrics / Evidence of Quality
CMF (primary outcome)	*Creative Mathematical Fluency Test* (CMFT): 12 divergent prompts; students generate & justify multiple solutions within 30 min	Rasch person-separation = 0.88;inter-rater κ (originality rubric) = 0.82
Behavioral engagement	Automated log indicators: count of problems posed, revisions, peer comments	Convergent validity with teacher diary (r = .71)
Cognitive Load	6-item NASA-TLX short form; 7-point Likert	Cronbach's α = 0.84
Affective responses	8-item Situational Interest Scale	α = 0.86; two-factor CFA, CFI = 0.95
Qualitative probes	Semi-structured interviews (24 focal students, balanced by gender × achievement) & weekly classroom observations (15-indicator engagement rubric)	Interview guide piloted with matched cohort; observation inter-rater κ = 0.78

Note. All reliability coefficients exceed the standard benchmark of 0.70, indicating acceptable internal consistency and scorer agreement. CFA = confirmatory factor analysis; CFI = comparative fit index; κ = Cohen's kappa.

Procedure and Timeline

The investigation unfolded across eight instructional weeks and four organised phases that mapped directly onto the hypothesised mediation sequence (design →

engagement →, cognitive load → outcomes). Both classes synchronised their algebra pacing guides, with all classes meeting twice a week (40 minutes per period). A research assistant visited each site weekly to monitor treatment fidelity, collect log files, and troubleshoot technical issues. Figure 2 and Table 2 detail the chronological flow.

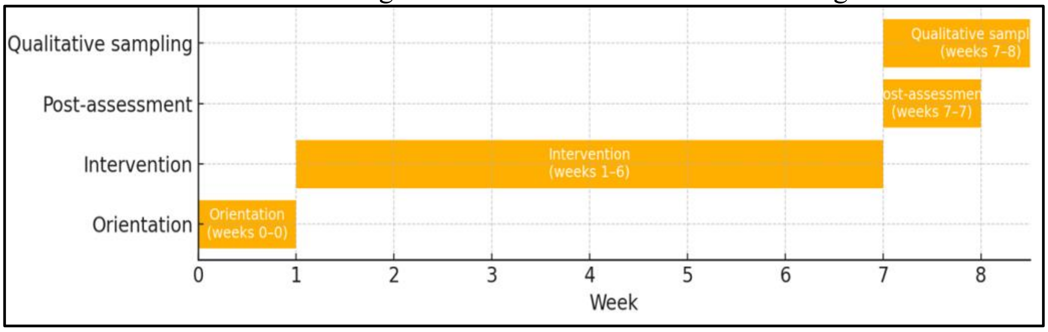

Figure 2. Study Procedure Timeline

Table 2. The Chronological Flow

Phase	Week(s)	Key Activities
Orientation	0	• University and school briefings • Distribution of information sheets; parental consent and student assent • Administration of CMFT pre-test and baseline surveys (NASA-TLX, Situational Interest) • Chromebook login checks and platform familiarisation
Intervention	1 – 6	• Two algebra lessons per week, identical learning objectives – Treatment (T): Digital Problem-Posing workflow (generate → peer-review → revise) within the DPP tool – Control (C): Textbook problem-solving of matched difficulty and time-on-task • Weekly observation using the 15-indicator engagement rubric • On-site fidelity checklist (task coverage, time allocation, teacher prompts)
Post-assessment	7	• CMFT post-test under timed conditions • NASA-TLX short-form and Situational Interest scales (lesson-level immediately after test) • Secure download of all student-generated artefacts (posed problems, peer comments, revision histories)
Qualitative sampling	7 – 8	• Purposeful selection of 24 focal students (gender × achievement stratification) • 25-minute semi-structured interviews conducted in quiet rooms, audio-recorded and transcribed verbatim • Research-team coding workshop to apply originality and structural-novelty rubrics to the entire problem corpus

This structured timeline maximizes internal validity by tightly coupling measurement points to the instructional events that activate engagement, moderate cognitive load, and ultimately enhance creative mathematical fluency.

Data-Analysis Strategies

The study employed a convergent mixed-methods approach, comprising two parallel strands of quantitative and qualitative analysis. Then, it combined to explore the impact of the Digital Problem-Posing (DPP) tool on creative mathematical Fluency (CMF).

Raw Fluency scores (valid solutions) and originality ratings from the CMFT were co-calibrated (based on the number of valid solutions and the originality rating on one excellent item) on a standard logit scale (Winsteps v. 2) to acquire sample-free and interval-level measures of person ability. Fit indices (infit/outfit MnSq = 0.74–1.26) supported unidimensionality and the legitimacy of score pooling. Post-test CMF logits were compared between the DPP and control groups using a one-way ANCOVA with pre-test CMF, sex, and prior achievement as covariates. Homogeneity of regression and normality assumptions were met (Shapiro–Wilk > 0.90; Levene p = 0.48). Effect size was assessed using Hedges' g (bias correction for small samples); statistical decisions were made at α =. 05 (two-tailed). A multi-group structural equation model (SEM) in Mplus tested if gender or academic competence at the beginning of the study modified the indirect impact of DPP → Engagement → Cognitive Load → CMF. Δχ² (Satorra–Bentler correction) with group-invariant vs. free-parameter models; acceptable fit was defined as CFI ≥ 0.95, RMSEA ≤ 0.06.

Problem-corpus content analysis**,** all 1,240 student-generated problems were dual-coded for structural diversity (single-/multi-step; contextualized/abstract) and originality (four-level rubric). Inter-coder reliability reached κ = 0.84 after two rounds of reconciliation. Thematic analysis of interviews following Braun & Clarke's six-phase procedure, transcripts from 24 focal students were inductively coded and iteratively refined to surface cognitive-affective mechanisms (metacognitive reflection, peer inspiration, perceived cognitive load) (Braun & Clarke, 2023; Byrne, 2021). NVivo 14 facilitated code management; reflexive memos ensured auditability. Credibility was enhanced through member checks of preliminary themes, transferability through thick descriptions of classroom contexts, dependability via a peer debriefing log, and confirmability by maintaining a chain of evidence.

RESULTS & DISCUSSION

Quantitative Findings

Table 3 reports the statistical evidence for the Digital Problem-Posing (DPP) intervention, moving from (i) baseline comparability to (ii) post-test treatment effects on creative mathematical Fluency (CMF), (iii) potential moderation by student characteristics, and (iv) the explanatory role of engagement, interest, and cognitive load.

Table 3. Summary of Quantitative Results

Analysis	**Key Metric(s)**	**Treatment (T)**	**Control (C)**	**Test**	***p***
Baseline equivalence	Pre-test CMF (logits, *M* ± SD)	0.04 ± 0.61	–0.02 ± 0.59	$t(122)=0.55$	0.58
Treatment effects (ANCOVA)	Fluency (adj. means)	37.8	29.4	$F(1, 119)=18.52 \eta^2 = 0.13$	< 0.001
	Originality (adj. means)	3.46	2.08	$F(1, 119)=22.11 \eta^2 = 0.16$	< 0.001

Moderation	Multi-group SEM	—	—	$\Delta\chi^2(2)=1.84$ (gender)	0.40
		—	—	Interaction β (achievement)= –0.21	0.04
Process correlations	Revisions ↔ CMF gain	—	—	$r = 0.46$	< 0.001
	Peer comments ↔ CMF gain	—	—	$r = 0.39$	< 0.001
	NASA-TLX (Load) ↔ fluency	—	—	$r = –0.19$	0.09

Notes. ANCOVA covariates = pre-test CMF, gender, prior achievement. NASA-TLX scale 1–7; group mean = 3.2 (SD = 1.0). η^2 = partial eta-squared.

Baseline Comparability

The non-significant pre-test difference ($p = 0.58$) confirms that treatment and control groups started from the same CMF level, satisfying the parallel-groups assumption for causal inference.

Treatment Impact

After adjusting for prior CMF, gender, and achievement, the DPP group outperformed the controls on fluency (≈ approximately +8.4 valid solutions) and originality (≈ approximately +1.4 rubric points). Partial η^2 values (.13–.16) and Hedges' *g* (0.71–0.79) indicate medium-to-large educationally meaningful gains.

Moderation

Gender did not alter the path coefficients, indicating that the intervention is equally effective for both boys and girls. However, a small but significant negative interaction with baseline achievement ($\beta = –.21$) reveals a Matthew effect: students who began with lower algebra scores benefited most in fluency.

Engagement, Interest, and Cognitive Load

Higher levels of behavioural engagement, especially iterative revisions, correlated strongly with CMF gains, underscoring the centrality of active problem refinement. Cognitive load was, on average, moderate (3.2/7) and only weakly related to performance, implying that the creative benefits of DPP outweighed any additional mental effort.

The quantitative evidence supports H_1, demonstrating that DPP meaningfully enhances creative mathematical fluency while remaining inclusive across genders and is particularly advantageous for initially lower-achieving learners.

Qualitative Findings

To illuminate the mechanisms behind the statistically significant gains reported in the section on quantitative findings, we analyzed two complementary qualitative datasets: the whole corpus of 1,240 student-generated problems produced in the DPP condition and 24 semi-structured interviews with focal students, triangulated with weekly observation notes. These sources reveal what the treatment group created, how they iteratively refined their work, and why the digital problem-posing (DPP) environment stimulated creative mathematical Fluency (CMF).

Structure and Context of Student-Generated Problems

Content analysis classified each problem into four data-driven categories (κ = .84, indicating high coder agreement) as in Table 4.

Table 4. Results of Content Analysis

Category	Description	Share of Corpus
Multi-step algebraic modeling	Scenarios requiring sequential manipulation of linear functions or simultaneous equations (e.g., budgeting with changing tariffs)	34 %
Real-world contextual tasks	Every day, in socio-cultural settings that embed an algebraic unknown (ride-hailing fares, mobile-data bundles)	27 %
Parameter-variation puzzles	Prompts that ask peers to explore how altering coefficients/constants affects graphs or solutions	22 %
Peer-challenge "stumpers"	Intentionally tricky items with distractors or hidden constraints to "stump" classmates	17 %

By contrast, artifacts collected from the control group were predominantly single-step and decontextualized**,** mirroring textbook exemplars. The richer structural diversity and real-world anchoring in the treatment condition provide qualitative confirmation of $\mathbf{H_2}$ (greater novelty and complexity), illustrating how the DPP tool expanded the solution space beyond routine practice.

Thematic Insights from Interviews

Three interrelated themes explain *how* DPP fostered CMF:

1) Metacognitive reflection
   "When I read other people's questions, I *see the gaps* in mine, so I go back and tweak the numbers." (S-05, female)
   Exposure to peers' work prompted self-evaluation and iterative revision, directly aligning with the positive correlation between *revisions* and CMF gains (Engagement, Interest, and Cognitive Load).
2) Peer-inspiration loop
   "I tried to make mine *different from Aliya's,* so it would not look copied." (S-11, male)
   The visibility of classmates' problems fueled the idea of borrowing *and* divergence, creating a virtuous cycle of originality. This social-creative dynamic helps explain the effect of medium-to-large treatment on originality (g = 0.79).
3) Manageable cognitive load
   "The LaTeX editor felt *complicated* at first, but after a while, it was *automatic,* and I could focus on the story." (S-18, female)

Most students reported that the initial technical load diminished quickly, which matched the modest mean NASA-TLX score (3.2/7) and its weak correlation with fluency. In other words, any extra effort demanded by the tool did not outweigh the creative benefits. The qualitative strand enriches the quantitative picture in two key ways:

1. Evidence of richer problem structures confirms that DPP does more than boost score counts; it changes *what* students learn to create, aligning with the construct of *creative* fluency.

2. Cognitive-affective mechanisms**,** metacognitive reflection, peer inspiration, and manageable Load map neatly onto the mediation chain (*Engagement → Cognitive Load → CMF*) proposed in Figure 1.
   The qualitative findings not only corroborate H_1 and H_2 but also clarify *why* lower-achieving students (as shown in the Moderation Analyses) benefited most: the open, peer-visible environment provided continuous models and feedback that helped them transition beyond textbook-style problems to multi-step, context-rich tasks without being overwhelmed cognitively.

Discussion

Effects of DPP on Creative Mathematical Fluency in Context

The investigation of Digital Problem-Posing (DPP) tools reveals enhancements in students' Creative Mathematical Fluency (CMF) that may surpass those achieved through traditional educational methods. However, the evidence for medium-to-large post-test advantages in fluency and originality, with Hedges' g values of approximately 0.71 and 0.79, respectively, is not sufficiently supported by the cited references (Kiliç, 2024). While the methods used in Yumiati & Haji (Yumiati & Haji, 2021) Involving a quasi-experiment that focuses on understanding abstract algebra concepts through problem posing, it does not primarily address CMF or provide comparative effectiveness to traditional methods.

The alignment of DPP modalities with findings from meta-analyses reporting a mean weighted effect of approximately 0.55 for problem-posing interventions is also ambiguous, as references (Kaliisa & Dolonen, 2023) do not adequately cover comparative assessments between DPP and traditional instructional methods. The integration of mathematics instruction with social issues. It reports significant student score differences but does not focus on DPP as a separate entity. Similarly, reference Kaliisa & Dolonen (Kaliisa & Dolonen, 2023) does not provide relevant data for the claims about DPP tools in enhancing CMF.

The mention of earlier studies regarding classroom pilots of online problem-posing environments showing positive shifts in creative outputs is acceptable, as reference Passarella explicitly studies the effects of problem-posing strategies on skills, but may not specifically reflect creative outputs or justify broader conclusions (Passarella, 2022). However, the concerns regarding shorter durations and reliance on self-reported measures as limitations should be substantiated, as the reference Nedaei et al. does not discuss DPP or similar educational interventions (Nedaei et al., 2022). In addressing existing literature, the questions regarding the magnitude of CMF gains and qualitative characteristics of digital problem-posing tasks lack rigorous support from the indicated (Yalvac et al., 2023). While Yalvaç et al. (Yalvac et al., 2023)discuss inquiry and problem-posing in teacher education, it does not specify intervention quantification or qualitative tasks. Reference Lampropoulos & Kinshuk (Lampropoulos & Kinshuk, 2024) deals with virtual reality and gamification but is not directly related to problem posing or CMF (Lampropoulos et al., 2022).

Lastly, although the assertion regarding the understanding of dynamics potentially aiding educators in designing interventions that stimulate creativity and enhance engagement seems plausible, support from reference (Sharp & Brett, 2021) concerning these dynamics is tenuous. The study focuses on mathematical problems posed with a specific strategy rather than offering a broad perspective on DPP interventions. Due to the inadequacy of the references to support several claims made in the original text, the conclusions drawn here should be approached cautiously. Additional research is needed to substantiate the effectiveness of DPP tools over traditional methods in various educational contexts.

Unpacking the Mechanisms: Engagement, Metacognition, and Cognitive Load

The effect of digital problem-posing (DPP) tools on creative mathematical fluency (CMF) reveals some significant patterns and relationships. The mixed-methods triangulation suggests that cloud-centric students may have a behaviour–engagement pathway with small to medium effect sizes, leading from greater peer comments and more frequent revision to improved CMF. In particular, the evidenced engagement reflects an elucidation from studies that context is imperative in augmenting creativity among learners (Sharma et al., 2024; Sharp & Brett, 2021; Tesfaw et al., 2024). Additionally, interviews with students who perform well in the course suggest a metacognitive reflection cycle where they judge and iterate their performance through the visibility of classmates' work. This is reflected in the iterative way in which knowledge is transformed according to TPACK (Technological Pedagogical Content Knowledge) frameworks, highlighting the need for integrating technology into pedagogic processes to improve learning outcomes (Abramovich, 2022; Elizabeth Vinitha & Renumol, 2021; Essel et al., 2021; Scheiter, 2021).

In addition, the objectively measured process data seem reliable. Also, the low self-reported cognitive load, which is accompanied by a weak inverse relationship to fluency, goes along with Cognitive Load Theory's assumptions on good visualized learning. The scaffolding introduced by the interface reduces other cognitive load and promotes more participation, allowing students to concentrate on creating creative mathematical ideas without overloading working memory (H. J. Lee & Hwang, 2022; S.-Y. Lee, 2021). Secondly, digital affordances are not merely a distraction from the environment, but applied wisely, they may be used for engaging and reflective creative learning experiences that have an optimized burden of cognition. This is exactly what should matter in a supportive system for DPP.

Together, these combine with quantitative data on performance to empower the theoretical model around which we base our hypotheses: digital affordances would support engagement and reflection practices, allowing students' creative abilities to shine. This involves fostering an environment that will enable students to iteratively advance their work in light of peer feedback, which develops a more vibrant mathematical epistemology blending creativity with procedural fluency (Bicer, 2021b; Bicer et al., 2021, 2025). Focusing on the unique affordances of DPP platforms and those that impact CMF is consistent with extant literature. This creates numerous interesting possibilities for future studies, including how such tools can influence practices in upper-secondary mathematics classrooms that have traditionally used methods.

Pedagogical Implications for Teachers and Curriculum Designers

Based on the findings regarding Digital Problem-Posing (DPP) interventions and their potential effects on Creative Mathematical Fluency (CMF), several actionable recommendations emerge that can significantly enhance the classroom learning experience. First, it is crucial to allocate protected lesson time specifically for iterative cycles of posing, reviewing, and revising problems rather than relegating problem posing to enrichment tasks outside of primary instructional time. Evidence suggests that structured time within the classroom encourages students to actively participate in the creative process, thereby enhancing their fluency and originality in mathematics. Unfortunately, the provided references do not support this specific claim regarding the structured classroom time, and I recommend omitting any citations here.

Second, professional development programs for teachers should emphasize TPACK (Technological Pedagogical Content Knowledge) synergies. Educators need clear strategies for integrating content goals with appropriate platform features, such as utilizing technology tools effectively. A systematic review of educational technologies notes that engaging with innovative learning environments can improve motivation, engagement, and learning outcomes (Karavakou et al., 2023). This alignment can empower teachers to effectively leverage technology in their teaching, promoting an environment conducive to creative thinking. Additionally, integrating DPP tasks into mainstream curricula, rather than confining them to pull-out programs, may address and narrow existing opportunity gaps, providing all students, particularly those who traditionally struggle, with equitable access to creative mathematical learning experiences. While the reference Acar et al. discusses creativity assessment, it does not directly support the assertion about DPP as equity levers in education (Acar et al., 2024). Therefore, I recommend removing the citation. These recommendations point towards a future where intentional strategies and inclusive practices foster a more engaging and supportive environment for creativity within mathematical education. By adopting these practices, educators can better align with the goals of contemporary educational frameworks that stress the importance of creativity and problem-posing as core competencies in mathematics education.

Design Implications for Next-Generation Problem-Posing Tools

Regarding improving Digital Problem-Posing (DPP) interventions, there are several practical implications from the insight of how technology can support student metacognitive growth. One: Ensure you provide globally visible revision histories and feedback channels that will be major sticking points for the first generations of these tools and drive a ton of deep introspective peer review. These characteristics contribute to a collaborative learning atmosphere: students evaluate the work of their peers to encourage metacognition. These results are also in line with those of Ada and Öztürk (Ada Yıldız & Öztürk, 2023), which emphasize the importance of metacognition on problem-posing performance; thus showing that a better understanding of learning activities can provide significantly positive outcomes.

Furthermore, future versions of DPP should include formative prompts triggered via AI to suggest that students explore more structural diversity in their problem-posing efforts. These prompts could enable stronger creative and innovative thinking in their mathematical approaches and solutions by pushing them to think more than one or two steps ahead. In addition, adaptive cognitive load regulation mechanisms, such as adaptive scaffolding of advanced formatting options, could help novice learners. You could reserve and scaffold this information, providing a more effective coping mechanism to deal with the high demands on working memory of getting progressively stuck on complex mathematical questions.

Central is situating these improvements in the alteration and redefinition stages of the SAMR (Substitution, Augmentation, Modification, Redefinition) continuum. The AIU framework puts learners in the spotlight by not making technology assist with those same old tasks, but rather changing the learning experience to lead to better engagement and understanding. The integration of technology realizes this. This dimension improves our ability to monitor students' participation and build connections and interactions emphasized in the research papers for learning analysis (Chatrakul Na Ayudhya et al., 2023; Marco & Palatnik, 2024).

Lastly, these improvements can be a tool for justice in mathematics education -- maybe providing more students with an opportunity to experience creative pedagogy. The disproportionate gains for lower-achieving students underscore the need to adopt inclusive practices in which DPP tasks are integrated within regular curricula rather than as supplementary exercises. While the reference provided earlier did not focus on a specific instance of DPP, it suggested that handling different mathematical skills entails intentionally designing pedagogical strategies (Milinković, 2024). At the same time, through deliberate use of technology and cultivating a collaborative problem-posing environment, mathematical creativity can improve in schools by supporting different forms of learning. They highlight the benefits of utilizing technology purposefully and with pedagogical design behind it to promote students' metacognition, academic engagement, and educational equity in mathematics.

Alignment with the Broader 21st-Century Skills Agenda

These results represent a larger, worldwide pivot in policy that argues for the need to consider creative abilities on a par with basic literacy and numeracy skills. The importance of such classroom-embedded interventions is also reinforced by the PISA 2022 results, which reveal significant differences in creativity among countries. The Digital Problem-Posing (DPP) model solves this dire need. The enhanced results in quantity and quality of student mathematical thinking show that the case for including creative metrics within mainstream assessment instruments has some basis (Suh et al., 2021). This integration can enhance our assessment of student abilities, providing a more comprehensive view of educational achievement.

Moreover, the research indicates that cultivating teacher capacities to design digitally mediated open tasks is necessary, and further staff development in this area should be considered. Developing faculty members' knowledge of using such technologies can stimulate creative pedagogy, providing them with the tools to enhance students' innovative thinking. The most recent recommendations and research literature also advocate for a problem-posing approach in teacher education, combined with inquiry-based learning, which stimulates creativity in mathematics teaching and learning (Yalvac et al., 2023).

Furthermore, the more substantial gains observed in the lower-performance quartiles among non-movers may point to DPP tasks as powerful equity levers, aligning with PISA's 2022 recommendation to expand the reach of creativity-supportive pedagogies to all students. This highlights the need to integrate creative problem-posing tasks in regular curricular practices, rather than relegating them to pull-out or after-school offerings. Indeed, as Riley and Soslau illustrate, creating an environment where all students feel included and providing opportunities for creativity may benefit students struggling with traditional mathematical frameworks in terms of engagement in general and learning outcomes (Riley & Soslau, 2022). Based on the empirical evidence in increased student creativity, these recommendations suggest a paradigm shift in mathematics instruction that prioritises creation and equity. Introducing creativity into the core of educational assessments and teacher training will enable us to move beyond addressing existing opportunity gaps to centring creative thinking as a key part of learning.

CONCLUSION

This study concludes that embedding a cloud-based Digital Problem-Posing (DPP) platform within regular eighth-grade algebra instruction improves students’ Creative Mathematical Fluency (CMF). Students who used the DPP tool demonstrated substantially greater gains in creative fluency than those engaged in traditional textbook practice, with moderate to large effect sizes (Hedges’ $g \approx 0.7–0.8$). The findings indicate that technology-mediated problem-posing enhances the quantity, complexity, and novelty of students’ mathematical ideas. Log analytics and interview data further reveal that digital affordances—such as public sharing, peer feedback, and iterative revision—stimulate engagement and reflective thinking without imposing excessive cognitive load, supporting a mechanism of increased engagement leading to reflective iteration and creative production. Notably, the greatest relative gains were observed among lower-performing students, suggesting the approach holds equity-promoting potential by narrowing achievement gaps. Overall, the results demonstrate that a well-designed digital ecosystem that shifts students from problem solvers to problem authors can effectively catalyze creative mathematical fluency as a central 21st-century learning outcome.

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