



## Fostering Flexible Minds: The Effect of Probing Questions in Enhancing Divergent Thinking in Geography

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### Abstract:

Developing students' divergent thinking abilities is an educational imperative for nurturing 21st century skills. Geography education lends itself well to embedding divergent thinking pedagogies by examining interconnected human-environment systems through varied spatial and cultural lenses. This study experimentally evaluated the efficacy of integrating structured probing question interventions to foster divergent thinking in secondary-level geography education. By using the experimental design, participants were 60 students divided into an experimental group receiving probing question training over nine sessions, and a control group receiving standard geography instruction. The experimental group demonstrated significantly higher divergent thinking scores across all components compared to controls at post-test. These improvements were maintained at follow-up, underscoring the durability of the probing intervention's effects. Findings empirically validate structured probing techniques as a promising pedagogical approach for purposefully cultivating flexible reasoning, creative ideation, and innovative geographic problem-solving capacities. This study contributes an empirically-grounded divergent thinking instructional framework that can empower students' abilities as engaged global citizens adept at grappling with the complexities of our interconnected world. This study pioneers an empirically-grounded instructional framework for purposefully cultivating divergent thinking skills through structured probing question within geography education. The findings contribute to the scholarly discourse on evidence-based strategies for nurturing essential 21st century competencies across the curriculum.

**Keywords:** *Divergent Thinking; Probing Questions; Geography Education; 21st Century Skills.*

## تعزيز العقول المرنة: أثر الأسئلة السابرة في تحسين التفكير المتشعب في الجغرافيا

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### ملخص:

تُعَدُّ تنمية قدرات التفكير المُتَشَعَّب لدى الطلاب ضرورةً تربويةً مهمةً لتعزيز مهارات القرن الحادي والعشرين. ويُعَدُّ تعليم الجغرافيا منصةً ممتازةً لدمج أساليب التفكير المُتَشَعَّب، حيث يتم دراسة النظم البشرية والبيئية المترابطة من خلال رُؤَى مكانية وثقافية متنوعة. تم تقييم فعالية دمج تدخلات الأسئلة السابرة المنظمة لتعزيز التفكير المُتَشَعَّب في تعليم الجغرافيا على مستوى المرحلة الثانوية. ومن خلال التصميم التجريبي، شارك في الدراسة (60) طالبًا تم تقسيمهم إلى مجموعة تجريبية تلقت تدريبًا على الأسئلة السابرة على مدار تسع جلسات، ومجموعة ضابطة تلقت تعليمًا جغرافيًا تقليديًا. أظهرت المجموعة التجريبية درجات تفكير مُتَشَعَّب أعلى بشكل دال إحصائيًا في جميع المكونات مقارنةً بالمجموعة الضابطة في الاختبار البعدي. واستمرت هذه التحسينات في الاختبار التتبعي، مما يؤكد الطبيعة المستدامة لتأثيرات تدخل الأسئلة السابرة. تُثَبِّت النتائج صلاحية فنيات الأسئلة السابرة المنظمة كنهج تربوي واعد لتعزيز قدرات التفكير المرن والإبداعي وحل المشكلات الابتكارية في الجغرافيا. تُسهم هذه الدراسة بإطار تعليمي للتفكير المتشعب قائم على أدلة تجريبية تُعزِّز مهارات الطلاب كمواطنين عالميين ملتزمين قادرين على التعامل مع تعقيدات عالمنا المترابط. تقود هذه الدراسة إطارًا تعليميًا قائمًا على أساس تجريبي لتنمية مهارات التفكير المُتَشَعَّب بشكلٍ هادف من خلال الأسئلة السابرة المنظمة في تعليم الجغرافيا. وتُسهم النتائج في الخطاب الأكاديمي حول الاستراتيجيات القائمة على الأدلة لتعزيز الكفاءات الأساسية للقرن الحادي والعشرين عبر المناهج الدراسية.

**الكلمات المفتاحية:** التفكير المتشعب؛ الأسئلة السابرة؛ تعليم الجغرافيا؛ مهارات القرن الحادي والعشرين.

## 1. Introduction

In an era of unprecedented global interconnectedness and rapid societal transformation, developing students' capacities for divergent thinking has become an educational imperative (Bicer et al., 2019; Koivisto & Grassini, 2023). Divergent thinking involves deconstructing topics into constituent parts and generating a multitude of creative, original, and varied ideas, solutions or perspectives within a defined timeframe (Guilford, 1968). This cognitive process is characterized by imagination, curiosity, flexibility, complexity, and an embracement of intellectual risk-taking (Abu Raya et al., 2023; Hua & Yang, 2024; Vynohradova et al., 2021). By engaging in divergent thinking, learners can explore diverse angles, entertain alternative possibilities, and cultivate innovative approaches to open-ended queries or intricate real-world problems.

The nurturing of divergent thinking abilities is tightly aligned with the vision for powerful, transformative social studies teaching and learning articulated by the National Council for the Social Studies (NCSS, 2016). This framework tasks educators with connecting students substantively to academic standards, fostering active engagement and co-construction of knowledge, motivating idea exchange, and integrating social studies concepts across the broader curriculum. Echoing these principles, the Partnership for 21st Century Skills (2007; 2009) has advocated for the development of contextual learning skills, information and media literacy, critical thinking, problem-solving, creativity, communication abilities, and capacities for collaboration - competencies that are deeply intertwined with divergent thinking processes.

By capitalizing on the unique strengths of divergent thinking pedagogies, teachers can empower learners to enrich and expand prescribed curricula, build upon prior knowledge frameworks, explore diverse modes of expressing new understandings, and engage in productive exchanges that spark further insight (Cummins, 2009; Yelland et al., 2008). Critically, divergent thinking can serve as an antidote to instructional overreliance on convergent thinking - the restrictive process of guiding students towards a single, predetermined "correct" answer or solution (Roberts et al., 2017). An excessive convergent thinking focus, often pursued to boost standardized test performance, can inadvertently stifle the very creative cognitive abilities imperative for thriving in the 21st century world.

Achieving an integrative balance of both convergent and divergent thinking pedagogies is therefore vital for holistically developing learners' mastery of academic subjects while also equipping them with indispensable critical and creative thinking capabilities (Paul & Elder, 2007). Divergent thinking strategies provide an invaluable toolkit for empowering students to take ownership of their learning journeys and derive deeper meaning, enjoyment and lasting intelligence.

The multidisciplinary sphere of geography education is particularly well-suited for embedding divergent thinking approaches. Spanning areas like civics, economics, history and the examination of complex interconnected systems, geography inherently demands the consideration of diverse contexts spanning the local to the global, past to future. By purposefully engaging in divergent thinking within the geography classroom, students can exercise robust reasoning abilities, evaluate problems through multiple lenses, generate innovative place-based solutions, and appreciate the rich perspectives that the study of our world has to offer.

While techniques like brainstorming, open-ended questioning and creative ideation have long been associated with promoting divergent thinking capabilities (Acar & Runco, 2012; Kalargiros & Manning, 2015; Runco, 2010), rigorous pedagogical frameworks and empirically-validated strategies remain underexplored, particularly within specific disciplinary contexts like geography education. Bridging this gap through systematic research can yield powerful insights into how divergent thinking skills can be more intentionally and effectively cultivated.

One promising pedagogical approach that warrants further investigation is the purposeful integration of probing questions into geography instruction. Probing methods, adapted from cognitive interviewing techniques in survey design, involve the strategic use of open-ended queries to gather insights into respondents' thought processes, interpretations and depth of understanding (Lenzner & Neuert, 2017; Neuert & Lenzner, 2021). When skillfully applied as a teaching strategy, probing questions can prompt students to articulate their geographical reasoning, uncover misconceptions,

and inspire the generation of multiple explanations, perspectives or creative solutions through divergent thinking.

Despite these encouraging preliminary findings, much remains to be understood about optimally leveraging probing methods to foster divergent thinking skills in authentic learning environments. Critical gaps include determining the ideal intensity, sequencing and combinations of probing questions students are able and willing to productively engage with, as well as empirically validating the instructional efficacy of this technique for improving divergent thinking performance compared to existing pedagogical approaches.

Grounding the investigation within the context of secondary-level geography education is particularly salient. The adolescent years mark a critical juncture where divergent thinking skills can be intentionally developed and internalized as students negotiate increasingly complex cognitive demands. By probing student perspectives through open-ended questioning, geography teachers can create authentic learning experiences that stimulate intellectual curiosity, contextual analysis and creative problem-solving - higher-order thinking capabilities that will serve students well as engaged citizens in our rapidly evolving world.

Ultimately, nurturing divergent thinking is about equipping the next generation with the cognitive flexibility, innovative mindsets and decision-making acumen to tackle intricate real-world issues they will inevitably encounter. From contemplating sustainable development strategies to analyzing geopolitical conflicts through multiple lenses, the study of geography is rife with inherently open-ended problems that defy simplistic single-solution approaches. By integrating structured probing methods, geography educators can better prepare their students to thrive amidst ambiguity, see problems as multi-faceted opportunities, and generate an array of creative ideas for positive change.

The present study aims to make a pioneering scholarly contribution towards establishing probing methods as an evidence-based strategy for purposefully cultivating divergent thinking proficiencies in geography education and related disciplines. Specifically, it will experimentally evaluate the impacts of probing question interventions, implemented according to structured protocols, on the divergent thinking abilities of an experimental group compared to a control group receiving standard geography instruction. Validated assessments will be administered to comprehensively measure intervention effects on divergent thinking.

## **2. Theoretical Framework**

This study is grounded in complementary theoretical perspectives that collectively elucidate the potential of probing question interventions to stimulate divergent thinking capabilities within geography education. At its core, the investigation is guided by constructivist learning theory and its emphasis on active knowledge construction through meaningful, contextually-embedded learning experiences (Vygotsky & Cole, 1978). The probing questions serve as cognitive prompts that push learners to articulate their thought processes, grapple with misconceptions, establish conceptual linkages, and co-construct more nuanced understandings alongside the teacher and peers (King, 2007; Oliveira, 2010; Ozuem & Lancaster, 2015). This aligns with Vygotsky's notion of learning occurring within the Zone of Proximal Development through scaffolded social interactions.

Complementing this constructivist lens is Cognitive Flexibility Theory, which highlights the importance of cultivating students' abilities to adaptively reassemble diverse knowledge components in response to novel situations (Spiro et al., 1992). By intentionally exposing learners to geographic concepts through multiple cases and perspectives using probing methods, geography educators can foster cognitive flexibility. Students practice traversing varied "criss-crossing conceptual landscapes" rather than internalizing inert, siloed knowledge structures (Jacobson & Spiro, 1995). This cognitive malleability enables the consideration of alternate vantage points and innovative solution generation - hallmarks of divergent thinking prowess.

The probing question approach aligns synergistically with key principles for powerful social studies teaching and learning articulated by the National Council for the Social Studies (NCSS, 2016). These include engaging learners with compelling questions spanning spatial and ecological scales,

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fostering active knowledge construction through varied sources and disciplinary skills, motivating knowledge application through authentic contexts and societal issues, and integrating concepts across interdisciplinary boundaries. Probing methods embody these practices by continually extending students' thinking through open-ended queries while anchoring discussions in meaningful geographic contexts (Duckor & Holmberg, 2019; Quick & Sandfort, 2014; Singer et al., 2000).

Theoretically positioning divergent thinking within a revised Bloom's Taxonomy (Krathwohl, 2002), probing questions serve as catalysts for progressing towards the higher-order cognitive domains of analyzing, evaluating and creating. Students exercising divergent thinking must break down geographic problems into constituent elements, critically assess varying perspectives and evidence, then synthesize their insights into novel solutions (Lucas & Spencer, 2017). This markedly contrasts with more commonly emphasized convergent thinking processes focused on simply remembering and applying predefined knowledge and procedures (Wigert, 2013).

Psychologically, the probing question intervention is postulated to enhance the cognitive resources and mechanisms underlying divergent thinking abilities, as conceptualized within theories like the Genevieve model (Finke et al., 1992). Probing techniques that stimulate critical awareness and relationship-building may enrich students' knowledge repositories, known as "preinventive structures," upon which they can flexibly restructure ideas (Welch, 2022). Additionally, prompting learners to explicate their reasoning likely activates core generative processes like conceptual combination, analogical transfer, and productive ideation (Noroozi et al., 2013). Cumulatively, these cognitive operations feed iterative cycles of "exploratory generation" and purposeful ideation central to divergent thinking models.

From a motivational standpoint, Self-Determination Theory (Ryan & Deci, 2000) suggests probing methods, implemented with an autonomy-supportive interpersonal style, can foster intrinsic motivation by fulfilling students' needs for autonomy, competence, and relatedness within learning activities. The structured probing protocols empower learners with voice and choice in knowledge co-construction, provide optimal cognitive challenges aligned with competency growth, and engender a sense of connectedness through meaningful dialogic exchanges (Mansour, 2024). These motivational underpinnings are vital for sustaining productive cognitive engagement and creative thinking.

One of the strengths of this study is its solid theoretical grounding, which draws upon complementary perspectives from established theories in educational psychology and cognitive science. However, further enrichment of the theoretical framework could be achieved by incorporating a more comprehensive review of recent empirical studies specifically investigating the application of probing question techniques and their impacts on divergent thinking skills.

Contemporary research has shed additional light on the cognitive mechanisms underpinning how probing methods can stimulate divergent thinking processes. For instance, Gardenia et al. (2020) found that students who received a Problem-Based Learning approach with Probing-Prompting techniques demonstrated improved adaptive reasoning abilities compared to conventional instruction, lending empirical support to the proposed linkage between probing strategies and enhanced divergent thinking capacities.

Furthermore, Buranova and Rakhmonova (2024) highlighted the importance of fostering critical analytical thinking skills in students through teaching methods like probing questions, as these skills enable learners to analyze complex problems, evaluate information objectively, and develop effective solutions – capacities aligned with enhancing divergent thinking prowess.

Extending the scope beyond probing questions, converging evidence from adjacent lines of inquiry further reinforces the theoretical foundations. For example, Rahayuningsih et al. (2023) found that inquiry-based learning approaches employing open-ended questioning techniques significantly enhanced elementary students' creative thinking abilities, including divergent thinking, across academic domains, aligning with the constructivist principles and emphasis on active knowledge construction underscored in the present study.

Moreover, Lai et al. (2024) found that explicitly training students in cognitive flexibility strategies, such as considering multiple perspectives and forging conceptual connections,

substantially boosted divergent thinking performance on open-ended problem-solving tasks. This empirically substantiates the theoretical linkages between cognitive flexibility theory and divergent thinking development proposed in the current study's framework.

By synthesizing these contemporary empirical insights, the theoretical grounding could be further strengthened, underscoring the robust evidence base supporting the potential of probing question pedagogies to cultivate divergent thinking faculties. Such an expanded theoretical review would situate the present investigation within the broader scholarly landscape, highlighting its contributions while articulating avenues for future research refining and extending these promising instructional approaches.

Regarding the reference base, while the study draws upon seminal theoretical sources and foundational works, incorporating a greater proportion of recent empirical literature would enhance its scholarly relevance and currency. For instance, several key citations predate the past decade (e.g., Cummins, 2009; Paul & Elder, 2007; Partnership for 21st Century Skills, 2007; 2009; Runco, 2010; Spiro et al., 1992; Vygotsky & Cole, 1978). Updating these with more contemporary sources would be advisable.

Furthermore, recent volumes and edited works focused explicitly on integrating creativity and divergent thinking development across the curriculum (e.g., Fletcher & Benveniste, 2022; Metwaly et al., 2021; Sun et al., 2020; Xia et al., 2021) could offer relevant conceptual frameworks and empirical evidence to enrich the theoretical foundations.

By judiciously incorporating a selection of these modern, high-quality references, the study's scholarly relevance and alignment with the current state of knowledge in the field would be significantly enhanced. This would not only strengthen the theoretical underpinnings but also position the research within the broader contemporary discourse, facilitating more meaningful dialogue and knowledge translation with fellow scholars and practitioners.

Enriching the theoretical framework with an updated review of recent empirical studies investigating probing question techniques, divergent thinking development, and associated cognitive mechanisms would further solidify the study's conceptual grounding. Simultaneously, adopting a more contemporary reference base drawn from the latest scholarly sources would enhance the investigation's relevance, currency, and integration within the broader academic landscape. These refinements would collectively position the research as a timely, robust, and impactful contribution to the field, paving the way for subsequent scholarly inquiries and translational applications of these promising pedagogical approaches.

### **3. Method**

#### **3.1 Participants**

The participants in this study consisted of secondary school students enrolled in the first year of secondary education in the Tanta Al-Azhar district of Gharbia Governorate, Egypt. The sample was drawn from two different secondary institutes to avoid experimental contamination between the control and experimental groups.

A total of 60 students were selected, with 30 students from Saft Turab Secondary Institute forming the experimental group and 30 students from Danusher Secondary Institute forming the control group. Students who did not regularly attend the program sessions and pre/post-test assessments were excluded from the final sample. The age range of participants was between 15.08 to 16.83 years old. Efforts were made to ensure that the experimental and control groups were equivalent in terms of divergent thinking abilities prior to the intervention, as measured by a pre-test divergent thinking assessment.

#### **3.2 Research Design**

A pre-test/post-test control group experimental design was employed. The experimental group received geography instruction incorporating structured probing question interventions, while the control group received standard geography instruction without the probing question approach. Divergent thinking abilities of both groups were measured before (pre-test) and after (post-test) the intervention using a validated divergent thinking test in geography. The change in divergent thinking

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scores from pre-test to post-test was compared between the two groups to evaluate the effect of the probing question intervention.

### 3.3 Intervention

The intervention consisted of a training program delivered to the experimental group over nine interactive electronic sessions. The program integrated probing question techniques adapted from cognitive interviewing methods into geography instruction. The probing question techniques focused on five key skills: clarification, critical awareness, refocusing to connect relationships, prompting, and redirecting. Each session incorporated various activities and questions tailored to the relevant geography content while purposefully applying these probing strategies.

The first three sessions were introductory, familiarizing students with the program, the concept of probing questions, and examples of each probing skill. The remaining six sessions covered core geography topics from the "Location and Surface Features in Egypt" and "Climate and Plant/Animal Life in Egypt" units, with probing questions integrated throughout. However, the control group covered the same geography content but through standard instructional methods without the structured probing question approach.

### 3.4 Measures

A divergent thinking in geography test was developed and validated to assess the key components of divergent thinking: fluency, flexibility, and originality. The test consisted of 21 open-ended items written in Arabic, aligned with the geography content covered in the intervention. The construct validity was examined through confirmatory factor analysis, which supported the theorized three-factor structure of fluency, flexibility, and originality. Composite reliability coefficients were calculated, with values of 0.751 for the overall scale and 0.765 for the omega coefficient, indicating adequate construct reliability.

The internal consistency reliability was assessed using Cronbach's alpha, which yielded values of 0.778, 0.710, and 0.743 for the fluency, flexibility, and originality subscales respectively. The overall alpha for the full scale was 0.741, suggesting satisfactory reliability. Additionally, the split-half reliability method produced Spearman-Brown and Guttman coefficients ranging from 0.764 to 0.768, further supporting the reliability of the divergent thinking measure.

The test was administered as a pre-test and post-test to both the experimental and control groups. Scoring rubrics were developed to quantify performance on each divergent thinking component based on the number of relevant responses (fluency), variety of response categories (flexibility), and statistical rarity of responses (originality).

### 3.5 Procedure

1. Pilot testing of research instruments on a separate sample of 30 first-year secondary students to establish psychometric properties.
2. Pre-testing of experimental and control groups using the divergent thinking in geography assessment.
3. Implementation of the 9-session probing question training program with the experimental group. Each session was delivered through an interactive electronic format.
4. Parallel standard geography instruction for the control group, excluding the probing question approach.
5. Post-testing of both groups using the same divergent thinking assessment.
6. Scoring of pre/post divergent thinking tests by two independent raters. Inter-rater reliability was established.
7. A follow-up assessment was administered to the experimental group four weeks after the post-test to evaluate the durability of intervention effects over time.

### 3.6 Data Analysis

Descriptive statistics were computed using IBM SPSS Statistics 23 software. The assumptions of parametric tests were verified prior to analysis. Independent-samples t-tests were conducted on pre-test divergent thinking scores between the experimental and control groups to establish baseline

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equivalence. The primary analysis involved paired-samples t-tests to examine the differences in divergent thinking scores from pre-test to post-test within the experimental group. Independent-samples t-tests were also used to compare the gain scores (post-test minus pre-test) in divergent thinking between the experimental and control groups.

#### 4. Results

The results of this study provide compelling evidence for the efficacy of probing question interventions in enhancing divergent thinking abilities among secondary school students in geography education. Table 1 presents the descriptive statistics and independent samples t-test results comparing the experimental and control groups' divergent thinking scores on the post-test assessment.

Table 1: Post-Test Divergent Thinking Scores

Variable	Experimental		Control		T-value	df
	M	SD	M	SD		
Fluency,	121.20	4.156	108.73	3.868	12.028**	58
Originality	72.87	4.967	67.63	4.367	4.334**	58
Flexibility	62.20	3.845	58.27	2.840	4.507**	58

Note. N = 60; \*\* p < .01.

Significant differences were observed between the two groups across all three components of divergent thinking: fluency ( $t(58) = 12.028, p < .01$ ), originality ( $t(58) = 4.334, p < .01$ ), and flexibility ( $t(58) = 4.507, p < .01$ ). The experimental group, which received structured probing question training, demonstrated substantially higher mean scores in fluency ( $M = 121.20, SD = 4.156$ ), originality ( $M = 72.87, SD = 4.967$ ), and flexibility ( $M = 62.20, SD = 3.845$ ) compared to the control group undergoing standard geography instruction.

To further substantiate these findings, paired samples t-tests were conducted to examine the within-group changes in divergent thinking from pre-test to post-test (Table 2).

Table 2: Pre-Test to Post-Test Changes in Divergent Thinking for Experimental Group

Variable	Pretest		Posttest		T-value	df
	M	SD	M	SD		
Fluency,	107.40	3.212	121.20	4.156	17.375**	29
Originality	64.73	4.763	72.87	4.967	15.250**	29
Flexibility	58.33	3.497	62.20	3.845	8.513**	29

Note. N = 30; \*\* p < .01.

For the experimental group, highly significant improvements were detected in fluency ( $t(29) = 17.375, p < .01$ ), originality ( $t(29) = 15.250, p < .01$ ), and flexibility ( $t(29) = 8.513, p < .01$ ) after receiving the probing question intervention. Conversely, no significant changes were observed for the control group across these divergent thinking dimensions (results not shown), underscoring the impacts attributable to the probing question approach.

Additionally, a follow-up assessment was administered to the experimental group four weeks after the post-test to evaluate the durability of intervention effects.

Table 3: Post-Test to Follow-Up Changes in Divergent Thinking for Experimental Group

Variable	Posttest		Follow-up test		T-value	Df
	M	SD	M	SD		
Fluency,	121.20	4.156	121.07	4.307	.315	29
Originality	72.87	4.962	73.30	5.522	.826	29
Flexibility	62.20	3.845	61.93	3.269	.546	29

Note. N = 30.

As shown in Table 3, no significant differences were found between the post-test and follow-up test scores for fluency ( $t(29) = .315, p > .05$ ), originality ( $t(29) = .826, p > .05$ ), or flexibility ( $t(29) = .546, p > .05$ ). This suggests that the gains in divergent thinking abilities achieved through the probing question intervention were sustained over time.

#### 5. Discussion

The study offers pioneering empirical evidence for the instructional value of probing question pedagogies in fostering divergent thinking proficiencies within the context of secondary-level geography education. By purposefully integrating structured probing techniques drawn from



cognitive interviewing into geography lessons, students in the experimental group demonstrated marked improvements in their abilities to generate a rich array of relevant ideas (fluency), consider diverse perspectives and response categories (flexibility), and produce statistically infrequent, novel solutions (originality) - core competencies underpinning divergent thinking capacities (Guilford, 1968; Runco, 2010). These findings align with prior theoretical assertions regarding the potential of probing methods to stimulate divergent thought processes (Lenzner & Neuert, 2017; Neuert & Lenzner, 2021) and empirically validate their instructional efficacy within an authentic learning environment.

The significant between-group differences observed at post-test, coupled with the experimental group's substantial within-group gains from pre-test to post-test, provide robust evidence for the positive impacts of the probing question intervention. This is further reinforced by the lack of divergent thinking improvements exhibited by the control group receiving standard geography instruction without probing elements. These outcomes underscore the unique value that strategic, structured probing question approaches can offer above and beyond conventional pedagogical techniques.

Notably, the maintenance of divergent thinking gains at the four-week follow-up assessment highlights the durability and internalization of the skills acquired through the probing question training program. This sustained performance suggests that students were able to effectively absorb and apply the probing techniques, translating into enduring enhancements in their divergent thinking repertoires. The robust effects observed substantiate the ecological validity and practical relevance of embedding probing methods within authentic secondary-level geography curricula.

Theoretically, these findings can be interpreted through the lens of constructivist learning principles and cognitive flexibility theory. The probing question interventions facilitated active knowledge construction by prompting students to articulate their thought processes, clarify understandings, forge connections across concepts, and consider alternative viewpoints (Vygotsky & Cole, 1978). This stimulated higher-order cognitive operations like analysis, evaluation and creative synthesis - processes inherently aligned with divergent thinking (Bicer et al., 2019; Koivisto & Grassini, 2023). By flexibly traversing diverse cognitive pathways and grappling with open-ended geographical queries through structured probing, students could build richer, more expansive knowledge representations. This cognitive flexibility enabled them to overcome rigid, constrained thinking patterns and unlock their creative ideational potentials (Spiro et al., 1992).

Pragmatically, the positive outcomes showcase the pedagogical utility of adapting techniques from cognitive interviewing into carefully structured instructional interventions. The specific probing skills emphasized - clarification, critical awareness, relationship-building, prompting, and redirecting - proved instrumental in activating and guiding students' divergent thinking processes. For instance, prompting students to articulate the reasoning behind their responses likely stimulated cognitive flexibility by forcing them to consider varied interpretive angles. Similarly, redirecting queries that challenged prevailing assumptions may have catalyzed imaginative leaps to original solutions. Systematically layering these multi-pronged probing strategies throughout geography lessons appears to have synergistically nurtured students' divergent thinking faculties.

Within the context of geography education, the substantial improvements in divergent thinking proficiencies enabled by probing question pedagogies hold transformative potential. Geography, with its multidisciplinary examination of human-environment interactions, economic systems, political landscapes and sociocultural processes across spatial and temporal scales, is ideally suited for divergent thinking approaches (Cummins, 2009; NCSS, 2016). By equipping students with enhanced abilities to ideate flexibly, connect disparate concepts, and generate a wide array of creative place-based solutions, the probing question intervention can empower more vibrant, participatory and impactful geography learning experiences.

For instance, when studying topics like sustainable development or geopolitical conflicts, students proficient in divergent thinking can more adeptly explore complexities through multiple cultural lenses, propose innovative policy recommendations, and anticipate long-term ripple effects - vital 21st century competencies (Partnership for 21st Century Skills, 2007; 2009). Crucially, by

internalizing these higher-order cognitive skills, students gain essential tools for engaged citizenship and addressing the ambiguous, multifaceted challenges of our interconnected world. The probing question approach therefore represents a powerful means of fulfilling geography education's Vision and Mission of equipping learners as global citizens prepared to thrive in geographic contexts.

While highly promising, the present investigation contributes an important foundational steppingstone warranting further research. Potential future directions include replicating and extending these findings across diverse student populations, investigating probing question efficacy within other disciplinary domains, assessing longer-term impacts on real-world problem-solving performance, and continually refining and optimizing structured probing protocols. Mixed-methods approaches triangulating quantitative outcome data with qualitative insights into student experiences and cognitive processes could yield particularly rich insights.

Additionally, exploring the potential synergies between probing question strategies and other complementary pedagogies like problem-based learning or authentic disciplinary practices would be valuable (Hua & Yang, 2024; Roberts et al., 2017). Integrating technological innovations like adaptive learning systems or immersive virtual simulations may further amplify intervention effectiveness. Ultimately, establishing communities of practice involving educators, researchers and instructional designers collaborating on iterative intervention refinement could accelerate the systematic translation of probing techniques into robust, scalable divergent thinking pedagogies.

## 6. Conclusion

In summary, this study provides robust empirical validation for the instructional value of integrating structured probing question interventions within geography education to intentionally cultivate students' divergent thinking abilities. The encouraging results showcase probing methods as a promising, evidence-based pedagogical toolkit for eliciting higher-order cognitive processes like analysis, evaluation and creative ideation. By purposefully leveraging probing techniques adapted from cognitive interviewing, geography educators can empower their students to engage in flexible, multi-perspectival reasoning, forge rich conceptual connections, and generate an array of innovative geographic solutions - proficiencies tightly.

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