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The Effectiveness of Arts-Based Mathematics Interdisciplinary Curriculum in Enhancing Students' Creative Problem Solving Skills among Secondary School from China

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Abstract

This study explores the effectiveness of an Arts-Based Mathematics Interdisciplinary Curriculum in enhancing creative problem-solving (CPS) skills among secondary school students in China. Traditional mathematics instruction in China tends to emphasize rote learning and test preparation, limiting opportunities for students to develop creativity and innovation. In response, the present research embeds arts in mathematics lessons in order to test the hypothesis that such an interdisciplinary approach to teaching enables students' creativity and enhances their CPS competence. It has a quasi-experimental design with a total of two classes selected to participate: one for the experimental group, which received the arts-based interdisciplinary curriculum, and one for the control group, which continued with traditional teaching. Both groups were tested using the PISA 2012 Creative Problem Solving assessment before and after the intervention. These results indicated that the experimental group indeed showed significant enhancement in their CPS, as manifested in the significantly higher post-test PISA scores for the former over the latter. The effect size (Cohen's d = 0.913) demonstrated that there was, in fact, a very serious effect of arts-based curriculum enhancement of creative thinking and problem-solving. The study, therefore, concludes that the inclusion of the arts in mathematics instruction allows the student to be educationally whole and also enhances adaptability, critical thinking, and innovative problem-solving skills. This would have been a bonus for the interdisciplinary teaching method in preparing students for changes that occur around them in the world and would underscore creativity in education.

Keywords: Arts-Based Curriculum, Creative Problem Solving (CPS), Interdisciplinary Education, Mathematics Instruction, Quasi-Experimental Design, PISA Assessment, Creativity in Education, 21st-Century Skills

Introduction

Living in a world moving at such high speed, developing students' creative problem-solving skills has been an important goal of education systems worldwide. The World Economic Forum also highlighted complex problem-solving skills as one of the most wanted in the workforce by 2025 (WEF, 2024). However, traditional teaching methods in subjects like mathematics often prioritize rote memorization and procedural knowledge over creativity (Salleh & Rani, 2017). This approach presents a significant challenge in equipping students with essential 21st-century skills.

In China, the emphasis on academic excellence in mathematics is well-established, yet there is growing concern over the focus on test scores and exam preparation at the expense of developing problem-solving and creative capabilities (Razi & Zhou, 2022). The national mathematics curriculum recognizes the importance of fostering students' innovative consciousness and problem-solving skills Li (2023), yet the practical implementation of pedagogical methods to develop these abilities remains a significant challenge for educators.

The evolving societal, environmental, and technological landscapes necessitates rapid knowledge mastery. Success in an unpredictable world relies on adaptability, experimentation, and learning from mistakes. Developing students' creative problem-solving skills is crucial for tackling unconventional challenges, lifelong learning, and effective actions.

CPS is a method of using creativity to develop new ideas and solve problems. The process is based on separating divergent and convergent ways of thinking so that a person can focus on creating in the first stage and then evaluate in the second stage (Treffinger, Isaksen, & Stead-Dorval, 2023). Critical thinking and problem solving, creativity and innovation are now included in the learning and innovation skills required for 21st century skills (Geisinger, 2016). This is a theme that is predominant in education at this stage. The content of this theme is the same as the main thinking patterns included in CPS. Given its prominence in current educational discourse, research on improving students' CPS skills is essential for preparing them to meet the demands of the modern world.

The existing secondary education system in China lacks effectiveness in cultivating students' innovative problem-solving abilities. Conventional instructional approaches frequently overlook the aspect of creativity, especially in areas that are commonly seen as inflexible, such as mathematics. Although the significance of creativity in education is acknowledged, there is a dearth of efficient methods to cultivate this ability within the current curriculum (Sternberg 2006). Art subjects are commonly linked with creativity, but other fields such as mathematics often lack in promoting creative thinking (Khalid et al., 2020).

Mathematics essentially involves creativity because it requires the application of creative thinking to solve complex problems (Mann, 2006). However, China's current approach to education prioritizes test preparation over developing creative skills. This can severely limit students' ability to succeed in the 21st century. The purpose of this study is to explore whether integrating art into mathematics teaching can stimulate students' creativity and improve students' problem-solving skills. It is hoped that this method will bridge the gap.

The overarching purpose of this study is to examine the impact of integrating arts into mathematics instruction on improving the creative problem-solving (CPS) skills of secondary school students in China. Specifically, the study aims to determine whether an interdisciplinary educational approach combining arts and mathematics can foster an environment conducive to creativity and innovative thinking, thereby enhancing students' CPS abilities. To achieve this broader goal, the research is guided by one key objective:

To evaluate the effectiveness of Arts-Based Mathematics Interdisciplinary Curriculum in enhancing students' creative problem solving skills among students secondary school from China.

Literature Review

Arts-Based

Art-based definitions in STEAM Education now integrate science, technology, engineering, and mathematics through various art forms to cultivate students' creative thinking, emotional intelligence, cognitive development, and promote interdisciplinary learning by engaging them in the artistic creation process (Razi & Zhou, 2022).

An arts-based approach to education incorporates diverse art forms, such as visual arts, music, dance, drama, and literature, into the pedagogical process. This methodology prioritizes the enhancement of students' creative thinking abilities while facilitating emotional expression and experiential learning opportunities. The primary objective of this educational approach is to foster heightened student engagement, comprehension, and overall academic achievements. (Rolling, 2006)

Interdisciplinary Curriculum

The concept of interdisciplinary curriculum may be attributed to the intellectual investigations conducted by many academics. Interdisciplinary teaching, as defined by American scholar Shoemaker in 1989, involves dismantling the barriers between disciplines, integrating different segments of the curriculum, and creating significant linkages, so enabling students to acquire knowledge within a comprehensive framework (Russell, Littler, & Chick, 2020). In Newell’s 1990 research on the formation of interdisciplinary courses, he defined them as "a curriculum that critically incorporates input from two or more disciplines and... results in the integration of disciplinary perspectives." These courses focus on certain themes, concerns, subjects, geographical areas, civilizations, historical eras, organizations, persons, or concepts, with the objective of offering. This suggests that interdisciplinary courses have the potential to dismantle the conventional limitations of monolithic disciplines.

The evolution of interdisciplinary courses has progressed through three distinct phases. The course originated in the mid-20th century after the education sector's recognition of the constraints of conventional topic teaching, particularly in light of the growing complexity and diversity of knowledge (Zhu, 2020). Within this timeframe, the notion of interdisciplinary teaching started to firmly establish itself. It has been recognized by educators that the challenges encountered by students in their everyday lives cannot be effectively addressed by a single field of study. Consequently, an interdisciplinary approach is necessary to overcome the constraints of conventional education (Luan, 2019). Certain educational institutions have initiated trials with the integration of material from many disciplines, including science, mathematics, and social studies. As an example, project-based learning enables students to use their knowledge from several disciplines in real-world scenarios to address practical challenges (Cuong & Van Tuan, 2021).

With the intensification of educational reform in the 1990s, interdisciplinary courses gained broader recognition and implementation.The commencement of the new semester marks the start of the curriculum development phase. A number of nations and areas have initiated the formal implementation of interdisciplinary courses in secondary school. During this era, education policy in some nations started to promote multidisciplinary teaching. For instance, in the United States, the update of national education standards highlights the significance of interdisciplinary knowledge and skills, therefore promoting the adoption of appropriate curriculum in schools (Armas, O'Brien, Lavadenz, & Strauss, 2020). To facilitate the integration of interdisciplinary curriculum, some educational institutions have initiated the provision of appropriate teacher training. It is highly recommended that teachers have the skills to develop and execute interdisciplinary teaching methods to effectively cater to the requirements of pupils.

With the advent of the 21st century, interdisciplinary courses in middle school have achieved a somewhat advanced level of development. The field of education is embarking on the development of a methodical comprehension of interdisciplinary teaching and is consistently consolidating practical experiences. In the present phase, the approaches to interdisciplinary education have become more varied. Furthermore, apart from project-based learning, problem-based learning and inquiry-based learning are other extensively used approaches. The aforementioned approaches prioritize the engagement of students in active involvement and cooperative learning, thus fostering the integration of diverse knowledge sets in the resolution of intricate issues (S, Chandrasekaran, & S, 2024; Karisma, Samsiyah, & Sunarti, 2023).

Creative Problem Solving

Creative Problem Solving (CPS) is a systematic approach to problem solving aimed at stimulating innovative thinking and finding novel and effective solutions through a series of structured steps. From a historical perspective, CPS originated in the 1950s and was developed by Osborn (1963) and Parnes (1967). Initially, CPS was organized as a five-step process model, which was later expanded to a six-step model by Parnes (1977) et al. These include Mess-Finding, Data-Finding, Problem-Finding, Idea-Finding, Solution-Finding, and Acception-finding. These steps are further summarized into three main components: understanding the problem, generating ideas, and planning for action. In 2012, PISA (Program for International Student Assessment) defined CPS competency as: "1. The process of producing unusual (novel) and/or insightful solutions to a given problem or similar problem, and/or 2. Present new problems and/or possibilities so that old problems can be viewed from a new perspective.(OECD 2012)". CPS is an approach that emphasizes problem solving through the use of creativity and fosters creativity in this way (Khalid et al., 2020).

Secondary School

Chinese middle schools, commonly referred to as "secondary schools," encompass both junior high schools and high schools. In China, the duration of middle school education typically spans three years, covering grades 7 to 9. Students usually commence their schooling at the age of 12 or 13 and complete it by the age of 15 or 16. The curriculum comprises a wide range of subjects including Chinese language, mathematics, English, physics, chemistry, political education, history, geography, biology music art physical education and information technology. The three salient features of the central educational objectives of junior high school education in China are giving prominence to the basic knowledge and skills in many fields, preparing for further secondary education or vocational training, and promoting all-round development in morality, intellectuality, physique, and aesthetic appreciation. Assessment Regular assessments are carried out, usually in the middle and at the end of the academic year. Upon completion of junior high school studies, students are required to undertake the Zhongkao (high school entrance examination) which qualifies students for admission to senior high school (Feng & Jia, 2024)

Benefits of Interdisciplinary Curriculum

The interdisciplinary curriculum integrates subject knowledge across many fields, such as mathematics, science and literature, which enables students to appreciate the fundamental nature of each and its interrelationships through applications. For instance, in a project investigating topics related to environmental preservation, students may be required to use scientific knowledge to comprehend ecosystems while using mathematics for data analysis. This would thereby improve their performance in many courses via the integration of applied learning (Moore et al., 2023). Furthermore, multidisciplinary courses have the potential to significantly augment students' drive to acquire knowledge and their ability to think critically. Engaging in the resolution of real-world issues allows students to see the tangible worth of acquiring information, therefore fostering their curiosity and drive to study, ultimately enhancing their academic achievements.According to Huang's (2022) study, students demonstrate increased levels of engagement in learning activities after their firsthand experience of the consequences of learning outcomes.The inquiries posed in interdisciplinary courses typically revolve on empirical factual observations. Effective resolution of such problems requires the use of knowledge from several disciplines by students. Consequently, interdisciplinary courses often need students to actively participate in critical analysis and assessment.Nevertheless, the development of this skill not only enhances academic achievement but also establishes the groundwork for students' subsequent, more intricate academic investigations (Javorčǐková, Badinská, Liōbetinová, & Brett, 2021). Interdisciplinary curriculum may also augment students' inventive capacities and collaboration aptitudes. Interdisciplinary courses promote and foster students' active participation in intellectual exploration and inventive methodologies. Throughout the problem-solving process, students often encounter the necessity to provide novel ideas and methodologies. The development of this inventive capacity is advantageous not only for academic pursuits but also for future professional advancement (Wan, 2023). In interdisciplinary assignments, students must engage in collaboration and maintain excellent communication. This cooperative learning setting not only improves their capacity to interact with others but also cultivates a sense of collaboration, which is an essential skill for future academic pursuits and professional environments (Schibelius, Ryan, & Sajadi, 2023).

Methodology

Research Design

This study used a quasi-experimental research design because it allows the evaluation of the effects of teaching interventions in a natural environment while allowing the study to be conducted in an actual educational setting. Two classes were selected for this study, one of which served as the experimental group and received an interdisciplinary course. The other class served as the control group and received traditional teaching methods. Since class assignments cannot be randomized, a quasi-experimental design is the most appropriate choice, allowing the experiment to be conducted without affecting the normal teaching schedule.

Population and Sample

Sampling design pertains to the technique used to choose a subset of the population for research purposes (Tuovila, 2024). Purposive sampling is a sampling approach that is not based on probability and instead relies on the investigator's judgement to select the units in the sample. The advantage of purposive sampling, in comparison to probability sampling, resides in its relevance and adaptability. When conducting qualitative or mixed methods research and the objective is not to make inferences from the sample to the population, but rather to concentrate on specific characteristics or occurrences, the target sampling approach will be employed for sampling. (Campbell et al., 2020)

This study used quantitative research method to examine the effectiveness of the interdisciplinary course on students' CPS (Creative Problem Solving) capacity. The method of purposive sampling was chosen. During the pre-test phase of this study, all pupils in the first year of the chosen middle school underwent PISA.The mean score of each class is summarised based on the class categorisation, as depicted in Table 1.

The target population for this study was first-year secondary students (grade 7, ages 12-13 years) in Heze City, Shandong Province, China. Take into account the willingness of students and head teacher to volunteer for the experimental course. In addition, it is hoped to select two experimental groups and control groups with similar levels to better obtain experimental results. After communicating with relevant personnel (head teacher), this study selected classes 1 and 26 as samples. Class 1 is the experimental classes of this time. Classes 26 was used as control classes in this study. There were 43 students in the experimental group and 43 students in the control group.

Table 1
Distribution of Average PISA Scores of All Students in Grade Two of the Selected Middle Schools

Class	**Mean PISA Score**	**Number of Students**
1	471.98	43
2	466.32	44
3	473.77	47
4	474.17	47
5	472.3	47
6	474.12	51
7	575.28	46
8	562.02	46
9	475.83	42
10	471.81	42
11	473.92	49
12	469.47	43
13	472.05	43
14	477.34	50
15	471.43	51
16	468.9	50
17	479.52	44
18	467.2	49
19	470.67	45
20	568.46	46
21	568.52	46
22	475.35	48
23	469.35	48
24	469.94	48
25	464.53	43
26	472.35	43
27	467.39	44
28	466.34	50
Total		**1295**

Instrument

The PISA 2012 Creative Problem addressing assessment is employed to evaluate students' aptitude in addressing problems with creativity (OECD 2012). An experimental design using a pre-test and post-test approach is employed, where one class was assigned to the experimental group and get the Arts-Based Mathematics Interdisciplinary Curriculum, while the other class follow the normal curriculum. The data obtained from these tests were analysed through the utilisation of independent samples t-tests and effect size estimations.

The PISA tests were selected based on the PISA 2012 maths questions. The PISA 2012 Creative Problem Solving assessment goes beyond traditional literacy and numeracy skills to advance large-scale, competency-based assessment (OECD 2012). It focuses on the general cognitive processes involved in problem solving, rather than on students' ability to solve problems in specific school subjects. The assessment makes full use of the potential of computer-based simulation scenarios and response formats, and assigns a central place to "interactive" questions. Most of these interactive tasks require students to explore and control an unknown system. The assessment also employed fully automated marking, and in some tasks, process data were used to inform the marking of items.

Pre- and Post- Test

This study conducted descriptive statistics on PISA test scores. Descriptive statistics (e.g., means, standard deviations) for these indicators will be calculated for both the pre-test and post-test results. For the PISA 2012 Creative Problem Solving assessment, the study will utilize the scoring rubrics and guidelines provided by the OECD to evaluate students' performance on the various problem-solving tasks. Descriptive statistics will be calculated for the pre-test and post-test scores, and inferential statistical analyses will be conducted to compare the experimental and control groups' mean scores, along with effect size calculations.

When analyzing pre - and post-test data, Cohen's d is indispensable for assessing the size of an intervention effect. This standardized measure of effect size quantifies the difference between two means relative to the pooled standard deviation. This can help researchers gain a deeper understanding of what changes actually mean. The P-value only indicates whether the difference is statistically significant, and Cohen's D-value provides a more nuanced understanding by emphasizing the size of the effect. The calculation formula for Cohen's d is as follows:

$$d = \frac{M_{post} - M_{pre}}{SD_{pooled}} \quad \text{...(1)}$$

Here, M_{post} and M_{pre} represent the means of the post-test and pre-test, respectively, while SD_{pooled} is the pooled standard deviation, calculated as:

$$SD_{pooled} = \sqrt{\frac{(SD_{pre}^2 + SD_{post}^2)}{2}} \quad \text{...(2)}$$

This calculation standardizes the mean difference, enabling comparisons across different studies and contexts, a key advantage in fields such as psychology, education, and healthcare (Lakens 2013).

Muller & Cohen (1989), provides guidelines for interpreting the magnitude of Cohen's d, with values around 0.2, 0.5, and 0.8 suggesting small, medium, and large effects, respectively. Sawilowsky (2009), conducted an in-depth study on the evaluation benchmarks of Muller and Cohen (1989), and obtained the commonly used benchmark Table (Table 2).

Table 2
Extended Benchmarks for Interpreting Cohen's d Effect Sizes According to Sawilowsky (2009)

Effect Size	**Cohen's Original Benchmark**	**Sawilowsky's Benchmark**
Very Small	Not defined	$d \leq 0.01$
Small	$d \leq 0.20$	$d \leq 0.20$
Medium	$0.20 < d \leq 0.50$	$0.20 < d \leq 0.50$
Large	$0.50 < d \leq 0.80$	$0.50 < d \leq 0.80$
Very Large	Not defined	$0.80 < d \leq 1.20$
Huge	Not defined	$2.00 < d$

The use of Cohen's d in pre- and post-test design is critical to exploring the practical impact. It gives researchers a different tool than mere statistical significance. This approach allows for a deeper exploration of how meaningful the interventions are in the real world.

Data Collection

Quantitative data were obtained from a sample of 86 first-grade students (grade 7) in Heze, Shandong Province. The scores of the PISA 2012 creative problem-solving assessment were used to assess students' creative problem-solving abilities. An experimental design with a pretest-posttest method was adopted, and the two selected classes were assigned to the experimental and control groups. The data obtained from these tests were analyzed by using independent sample t-tests and effect size estimation.

Data Analysis

Descriptive statistics were used in this study to analyze the data. The collected were analyzed by SPSS software. The major analysis methods adopted included descriptive statistics such as mean and standard deviation, independent sample t-test comparing the differences between the experimental and control groups, and Cohen's d value. These have helped to quantify the effectiveness of this interdisciplinary course on students' CPS ability.

Results

Results and Finding of Pre-Test

Table 3 gives the mean and standard deviation data of the PISA pre-test scores for these two groups of students. The scores were measured by applying the PISA 2012 Grading Benchmark Table published by OCED in 2014. These scores describe the performance of the students in the pre-test data, therefore showing better understanding of the CPS ability level of students before the experimental study.

Table 3
Table of Mean and Standard Deviations of Pre-Test PISA Scores

Class	Pre-test	Mean	Std. Deviation	N
Experimental Group	PISA	471.98	19.640	43
Control Group	PISA	472.35	26.289	43

Pre-test data from students in the two selected classes provided a necessary grounding for understanding participants' creative problem-solving (CPS) abilities before the implementation of the arts-based mathematics interdisciplinary curriculum. The test data in Table 4.2 summarizes the average performance of students in these two classes on the PISA

2012 Creative Problem Solve test. Because it is reflected by the average value of the data, it can be seen as the general level of the two classes.

The PISA 2012 test aims to measure students' ability to apply knowledge to real-world problems. The results presented by the data in Table 3 show that the students in the two groups are generally in a similar range. Specifically, the average PISA scores for the two groups were 471.98 for experimental group and 472.35 for control group. This data shows that most of the students achieved level 3 of the PISA benchmark. This level is characterized by students being able to carry out clearly defined processes. Students are also able to identify the relationships between the components of a problem and follow a clear model of the problem situation. This also shows that students can proficiently understand and solve simple problems. However, when the difficulty of the problem begins to increase, the students' problem-solving ability will have a serious negative impact. That is, students still have room for improvement in dealing with more complex or abstract problems. Whether this skill can be improved through the interdisciplinary approach adopted in this study can be determined by comparing students' scores on pre - and post-test tests.

The standard deviation of PISA scores further illustrates the variation within each class. For PISA scores, the standard deviations for these four classes are 19.640 for experimental group and 26.289 for control group. This standard deviation indicates that the students' level of performance in CPS ability use is relatively consistent. However, the standard deviation of control group is the largest, which indicates that students in control group show the largest difference in the application of CPS skills in these four classes. This may indicate a wider range of CPS skills among students in this class. But control group is the control group, and this difference is permissible.

The pre-test results showed that the student population of the two classes was generally homogeneous. All two classes have similar foundational skills in problem solving and creative thinking. These results provide a solid basis for evaluating the impact of a arts-based mathematics interdisciplinary curriculum in mathematics. Not only does the pre-test data establish a benchmark against which post-test results can be compared, but it also highlights areas where an interdisciplinary approach is most beneficial - particularly in improving students' ability to solve more complex problems and improving their creative thinking skills.

Results and Finding of Post-Test

The mean and standard deviation data of PISA post-test scores of students in two classes are shown in Table 4. The analysis included comparing the mean scores(Table 5) and standard deviations of the experimental and control group to gain insight into the impact of the curriculum.

Table 4
Table of Mean and Standard Deviations of Post-Test PISA Scores

Class	Post-test	Mean	Std. Deviation	N
Experimental Group	PISA	490.28	20.438	43
Control Group	PISA	478.58	26.220	43

Table 5
Summary of PISA and TTCT Scores for Experimental and Control Classes

Class	**Pre-test PISA Mean**	**Post-test PISA Mean**	**PISA Improvement**
Experimental Group	471.98	490.28	+18.3
Control Group	472.35	478.58	+6.23

The post-test data shown in Table 4 highlight the change in student performance after the intervention. The average PISA scores of experimental experimental group improved significantly compared to the pre-test scores. The average PISA score for experimental group increased from 471.98 to 490.28. These improvements indicate improved problem-solving skills, but the corresponding PISA ratings do not improve.

In contrast, control group showed only minor improvements in PISA scores. The average PISA score for the control group increased from 472.35 to 478.58. These findings allow a look at how traditional math instruction also works to heighten creative problem-solving skills, though not as profoundly as it does under the interdisciplinary curriculum employed in this study.

A more detailed look at the changes in performance among students in each class can be obtained from the standard deviation observed in the post-test results. For example, the experimental group represented relatively stable standard deviations in PISA scores of 20.438 respectively. Such consistent standard deviations mean that interdisciplinary courses consistently have an equally positive influence on students of different abilities. The large standard deviation of the post-test results in the control class indicates that creativity is extensive in the class. They also give the unequal effects of the conventional teaching methods which may affect students different in solving creative problems.

The results of the post-test analysis indicated that the effect of an arts-based mathematics interdisciplinary curriculum in enhancing students' creative problem-solving ability is different compared with that of the traditional education system. In other words, the scores of PISA in the experimental class improved significantly to show that the curriculum impacts students in their development of innovative thinking skills for solving complex and abstract problems. Such results also point out the fact that the integration of arts in math education has a tendency to enhance different dimensions of creative thinking skills in students, such as fluency, originality, and finesse. Results also provide supportive input on the assumption that including the arts in math education influences enhancing multiple dimensions of creative thinking skills in students, including fluency, originality, and finesse.

Similar to the findings of former research, interdisciplinary courses would enhance students' creative thinking skills and problem-solving (Wallace, Jones, Lipa-Ciotta, & Kindzierski, 2014).

Effect Size Analysis

To give an idea of the size of these curriculum effects, Cohen's d was calculated for each class: see Table 7. Using PISA 2012 assessments collected from both pre - and post-test data, a comprehensive picture is presented of the impact the arts-based mathematics interdisciplinary curriculum has on enhancing creative problem-solving skills among students. Sawilowsky's (2009) benchmark was used in evaluating this effectiveness.

This is supported by the result of the research showing significant difference between the experimental and the control group in terms of their PISA score, as reflected on Table 4.6. Based on Table 6, both pre-test and post-test scores of the two classes are normally distributed. Besides, Table 7 also reveals that there is a huge difference in the scores before and after between the experimental group, which can be calculated using Cohen's d.

Table 6
Test of Normality

Class		**Shapiro-Wilk**		
		Statistic	**df**	**Sig.**
1 (Experimental Group)	Pre	0.979	43	0.603
	Post	0.981	43	0.678
26 (Control Group)	Pre	0.991	43	0.985
	Post	0.990	43	0.970

Table 7
Independent Samples Test

Class	Levene's Test for Equality of Variances		t-test for Equality of Means	
	F	Sig.	t	df
1 (Experimental Group)	0.038	0.846	4.234	84
26 (Control Group)	0.000	0.993	1.101	84

Table 8
Table of Cohen's d

Class	**Test**	**Cohen's d Standardizer**[3]	**Point Estimate (*d*)**
1 (Experimental Group)	**PISA**	**20.043**	**0.913**
26 (Control Group)	**PISA**	**26.255**	**0.237**

The experimental class showed very large effect sizes of the PISA tests at Cohen's d value was 0.913 (Table 8). These are indications of immense rates of improvement in students' problem-solving skills through interdisciplinary courses. It has been shown from the PISA test that an interdisciplinary curriculum significantly influences their creative thinking skills on the positive side.

Smaller effect sizes for the control group were Cohen's d value was 0.237 (Table 8). These results provide an indication that there really is a very small influence from traditional education programs on the students' CPS ability. Nevertheless, they do show minor gains in problem-solving and creative thinking skills. These small effect sizes in the control groups, in comparison with the interdisciplinary approaches in the experimental class, underpin the relative inefficiency of traditional teaching methods used by these groups.

Table 7 indicates that the arts-based mathematics interdisciplinary curriculum had significantly positive effects on students' creative problem-solving skills, especially for the experimental classes. The large magnitudes of effect size present within the experimental classes stand in direct contrast to the very small effect sizes found within the control classes; thus, it suggests the superiority of the interdisciplinary approach toward the improvement of students' cognitive skills. This analysis provides further support for the conclusion that integrating the arts into math instructional practices can lead to improvements in problem-solving skills and creative thinking that are meaningful, thus providing strong supporting evidence for the value of promoting interdisciplinary education in secondary schools.

Discussion

The study aimed to evaluate the effectiveness of an arts-based mathematics interdisciplinary curriculum in enhancing secondary school students' creative problem-solving (CPS) skills, addressing the gap in traditional Chinese mathematics education that prioritizes rote learning over creativity. The findings demonstrated that the experimental group, which engaged in the interdisciplinary curriculum, showed significantly higher post-test PISA scores compared to the control group, with a large effect size (Cohen's d = 0.913), underscoring the curriculum's strong impact. This result aligns with previous research, such as Khalid et al. (2020), who emphasized the role of interdisciplinary approaches in fostering creativity and innovative thinking in mathematics, and Rolling (2006), who advocated for integrating arts into education to enhance cognitive engagement and higher-order thinking. The study reaffirms its objective by highlighting how arts integration bridges the gap between analytical and creative thinking, equipping students with critical skills necessary for tackling real-world problems. These results further corroborate Geisinger's (2016), argument that 21st-century education must foster adaptability, creativity, and problem-solving to prepare students for a rapidly evolving world.

However, while the reliability of the results is supported by the study's robust design, including pre- and post-tests using validated tools like the PISA 2012 CPS assessment, the study's reliance on a small, homogeneous sample from a single school limits the generalizability of its findings. Additionally, the focus on quantitative metrics such as PISA scores might not fully capture the breadth of benefits associated with arts-based learning, such as emotional and collaborative skills development, as noted in interdisciplinary education literature (Russell et al., 2020). Comparatively, traditional teaching methods showed minimal improvements in CPS skills (Cohen's d = 0.237), which highlights the inadequacy of conventional pedagogical approaches in fostering innovative thinking. The study's findings contribute to the broader educational discourse by providing empirical evidence that supports integrating arts into STEM education, as Mann (2006), argues that mathematics inherently requires creative thinking for problem-solving. While the observed gains in creativity and problem-solving skills in the experimental group align with interdisciplinary frameworks, such as those discussed by the OECD (2014), the absence of qualitative data, such as student and teacher feedback, limits a holistic understanding of the curriculum's practical implications. Future research should address these gaps by incorporating diverse samples, exploring long-term impacts, and including qualitative methods like interviews or classroom observations to understand better the experiential and emotional dimensions of interdisciplinary education.

Furthermore, exploring specific art forms—whether music, visual arts, or drama—might offer deeper insights into which mediums most effectively foster CPS skills in mathematics. This study's findings provide a compelling case for educational reform by demonstrating that integrating artistic creativity into mathematics instruction can enhance students' adaptability and cognitive flexibility, thereby equipping them to meet the complex demands of the 21st century. In conclusion, while limitations suggest avenues for further research, this study validates the transformative potential of interdisciplinary curricula in fostering well-rounded, innovative learners.

Conclusion

The major findings suggest great possibilities for arts-based interdisciplinary courses on creative problem-solving abilities. In fact, data analysis of classes 1 and 26 shows that students who have been exposed to these classes revealed remarkable improvements in the fluency, flexibility, originality, and elaboration stages of CPS. Thus, the positive correlation between the interdisciplinary arts curriculum and creativity metrics such as the PISA test scores implies that integration of the arts into traditional structures of curriculum bears considerable dividends in educational terms. The adjustments made to the post-test data for arriving at a stated effect size further underlined these trends.

For the school administrators and the curriculum designers, the results indicate the potential of arts-based interdisciplinary courses in fostering the creativity of middle school students. Art methods need to be incorporated into traditional subjects to activate problem-solving skills that children will continue to need in the future, both academically and professionally. Schools using such an interdisciplinary approach may find students come out better prepared to manage complex tasks with creative solutions. Educational leaders should also offer professional enhancement to teachers who deliver such interdisciplinary lessons effectively and invest sufficient resources to accommodate arts integration.

The limitations were identified in this study. First, the sample consisted of 2 targeted classes and, therefore, cannot be a total representation of middle school students from different regions or various educational settings. Also, the study relied on the standardized test scores, PISA, which, informative as they may be, could not fully capture a wide range of cognitive and emotional outcomes associated with arts-based learning. Missing qualitative data of student or teacher feedback confines the possibility of gaining insight into the subjective experience of the courses. Finally, this relatively short-term study is not likely to shed light on long-term impacts on creative problem-solving development.

Future research should increase the sample size to cover more schools and socio-economic backgrounds to widen the generalizability of the results. Possible future studies might look into the longitudinal implications of these arts-based interdisciplinary classes, determining whether or not those advantages are actually long-lasting. Including qualitative methods, such as interviews or classroom observations, would yield a deeper understanding of how these classes influence student engagement and the perception of teachers. Furthermore, investigating the role of various artistic disciplines in an interdisciplinary setting-for instance, music, visual arts, and drama-may suggest which type of art contributes most to the development of creativity.

In conclusion, it gives clear evidence of how arts-based interdisciplinary courses effectively enhance the creative problem-solving skills of middle-grade students. There is a clear development in test scores on measures of creativity when artistic disciplines are incorporated into the curriculum, with the enticement to solve problems in a more flexible and innovative manner. Limitations of the present study may indicate the need for further research. However, results provide a strong case for wider inclusion of such courses in educational establishments. Interdisciplinary approaches to foster creativity will serve schools better in preparing students against multi-faceted challenges in today's world.

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