Students' Perceptions about Mathematics-Literature: A Pilot Study

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【摘要】

本研究採用問卷調查和深度訪談法，旨探究專科學生對數學文學的看法，進一步了解其對數學學習的影響。問卷結果顯示，單獨與數學或中文寫作能力相比，學生在撰寫數學文學時普遍缺乏信心，對於能藉由寫作或撰寫數學文學而學習數學之方式感到懷疑。然問卷結果亦顯示，因數學文學創作而提升動機的學生，則更加能藉由寫作學習數學；數學文學的撰寫能力、中文寫作能力、認同藉由寫作學習數學之看法，這三者之間相關性皆高於學生數學能力的影響。研究結果顯示學生對數學文學之定義為數學和語言的結合一學生有技巧地運用文字表達抽象的數學概念，利用押韻、數字與文字的諧音詞、標點符號、隱喻或創作具有故事性質並反映自身生活之數學詩，加以勾勒動態的數學意像，拉近與數學的距離。撰寫數學文學亦成為加分工具，提升學習動機。本研究強調師生在數學及語言間跨學科教育的重要性。

【關鍵字】

數學文學，數學，寫作，跨學科合作，跨學科教育

【Abstract】

Through questionnaire and interviews, this study aims to investigate junior college students' perceptions about mathematics-literature in hopes of understanding the role it plays in the learning of mathematics. Questionnaire results indicate that far fewer participants felt confident in composing mathematics-literature and motivated to learn mathematics by writing or by mathematics-literature than those who felt competent in either mathematics or Chinese writing competence alone. Notwithstanding, the results signify the importance of incorporating writing and mathematics-literature into a mathematics class, especially for those feeling confident in the use of writing and the creation of mathematics-literature in mathematics-learning. Research results disclose that the perceived definition of mathematics-literature is the combination of both elements; usually words are used to deliver abstract mathematical concepts, bringing students closer to mathematics. Depicting the dynamic nature of mathematics, the participants strategically used rhythmic words, numeric homophonic words, punctuation or metaphors to create vivid images or they constructed poetry with a plot that mirrors life. The creation of mathematics-literature also becomes a grade

boosting incentive to learn mathematics. This study highlights the significance of interdisciplinary education between mathematics and language for both teacher and students.

【Keywords】
mathematics-literature, mathematics, writing, interdisciplinary collaboration, interdisciplinary education

1. Introduction

This study aims to investigate students' perceived definition of mathematics-literature. Because of the mathematics-literature contest, studies related to it have received growing attention in mathematics and interdisciplinary education (Chen & Liu, 2018; Hsu, 2017). In Taiwan, this yearly mathematics-literature contest started in 2015 and used to be a competition organized for technological and vocational college students, but now it is open for each university student according to Chen, Tung-Hsien who is the 2018 Ministry of Science and Technology project chair for the promotion of the mathematics-literature contest (personal communication, August 7, 2018). The contest aims to encourage students to combine mathematics and literature creating a mathematics-based literary work, so as to motivate students to read more books, explore mathematical knowledge within them, and create a literary work to increase students' interests in learning mathematics and to prompt them to associate creativity with mathematics (Chen & Liu, 2018). This event that focuses on the interdisciplinary collaboration invites a few studies, mostly the reports about incorporation of mathematics-literature into a class (see Hsu, 2017), promotion of a contest and analysis of students' award-winning work (Chen & Liu, 2018), and collaborations between mathematics and writing teachers (Chang & Lee, 2019a, 2019b).

Nevertheless, studies in Taiwan on mathematics-literature tend to focus on teachers' perceptions about it while studies on the students' perceptions remain relatively rare. This gap therefore needs to be filled through research on the students' view of mathematics-literature, so as to more fully understand the impact of mathematics-literature on the learning process for the participant students, and thus, potentially maximizing the benefits of it in interdisciplinary education.

Through questionnaire and interviews, this study aims to investigate junior college students' perceptions regarding mathematics-literature, shedding light on the possible impacts of mathematics-literature on the participant students, teachers and the interdisciplinary education/collaborations.

Research question: What are the junior college students' perceptions about mathematics-literature?

1. Literature review

Before presenting the growing attention the mathematics-literature contest in Taiwan receives and the research on it, studies on the close relation between mathematics and writing and then mathematics-literature should be reviewed.

2.1 Studies on the close relation between mathematics and writing

Unlike the generally perceived literature, mathematics-literature is a different genre because writers of mathematics-literature need to accurately and poetically use words to integrate mathematical concepts into their literary creation; in this regard, it is safe to state that mathematics-literature should have a positive impact on students' learning of mathematics. Chen and Liu (2018) indicated that mathematics-literature is the extension of mathematics culture, and many similarities between literary theory and mathematical thinking exist. For instance, the derivation of mathematical proof and the construction of novels are similar in nature (Chang & Lee, 2019a, 2019b). Also, Chiu (2017) further stated that "when literature writers appreciate scenes through their eyes or express their feelings, they might adopt the strategies of exaggerating or beautifying what they have seen or felt; mathematicians might construct or build a perfect framework to understand what they have seen" (p. 23). Both literature writers and mathematicians actually pursue the beauty or perfection of their work as they do it, but both employ different ways to achieve their goals. Chen and Liu (2018) also pointed out that the process of creating mathematics-literature helps students clarify and respond to the mathematical knowledge that they acquire, suggesting the positive influence that mathematics-literature itself brings to mathematics education. Through the creation of mathematics-literature, students integrate the correct mathematical knowledge into literary work, be it a poetry or prose, and further communicate with others through their literary writing.

In fact, not only the close relation between mathematics and writing has been supported but also the importance of implementing writing as an integral part in a mathematics class has been highlighted by a body of studies (Beavers et al., 2015; Bicer, Capraro, & Capraro, 2013; Freeman, Higgins, & Horney, 2016; Gould, 2013; Kenney, Shoffner, & Norris, 2014; Lee, 2010; Pugalee, 2001; Seto & Meel, 2006; Urquhart, 2009; Watson, 1980; Yang & Chiang, 2008).

Several scholars, such as Freeman et al. (2016), Lee (2010), Urquhart (2009) and Watson (1980), emphasized the significant role that writing plays in a mathematics class and offer some writing activities used in it to enhance learning, such as journaling and the process explanations of solving mathematical problems. The idea is that when students are able to explain their logic, reasoning or analysis of mathematical concepts through writing, they need to be precise, clear, and explain the purpose of communication with their intended audience; when this type of writing takes place, students present their mastery or command of the mathematical concepts (Freeman et al., 2016; Gould, 2013; Lee, 2010). Furthermore, studies examined the use of writing in a mathematics class. Pugalee's study results indicated that students' writing about their mathematical problem solving processes demonstrates the "engagement of various metacognitive behaviors during orientation, organization, execution, and verification phases of mathematical problem solving" (p. 236, 2001). The study by Seto and Meel (2006) indicated that the three adopted types of writing assignments, mathematical biographies, minute papers, and journaling, in a mathematics class lead both teachers and students to "reflect on classroom experiences and negotiate adjustments to the learning environment in order to benefit all" (p. 230). Also using journaling as a method of incorporating writing into a mathematics class, Beavers et al. (2015) discovered that although students are doubtful about the place of writing in a mathematics class and tired of explaining solutions to mathematical problems in written form on a daily basis, their responses to interview questions and questionnaire demonstrate that keeping math journals helps them "understand mathematical concepts and organize their thoughts more clearly" (p. 26). Similar results were also revealed from Yang and Chiang's study (2008) conducted in Taiwan. Their study findings presented both parents' as well as junior high school students' doubts about the effects of journaling and also teachers' concerns about its application within the limited class time, but writing in a mathematics class effectively enhance the participant students' skills of reorganizing and integrating conceptual knowledge into learning and problem solving ability. Teachers' concerns about the use of writing in a mathematics class were also addressed in Kenney et al.'s study (2014), but again their study results illustrated the preservice teachers' positive perceptions after the incorporation of

writing, such as a reflection journal. These participant preservice teachers perceived writing as a useful tool which connects mathematics and other subjects as "a means to assess student understanding of mathematics, and a beneficial support for student conceptual learning" (p. 283).

2.2 Studies on mathematics-literature

Moreover, other than keeping math journals and writing process explanations, some scholars even encouraged teachers to incorporate writing in a mathematics class in a more creative way; some started the collaborations between discipline practitioners, namely, mathematics and language teachers (Growney, 2011; von Renesse & DiGrazia, 2018; Hsu, 2017; Chang & Lee, 2019a, 2019b).

Conducting a workshop relating mathematics to words, Growney (2011) encouraged and offered strategies for teachers to guide students to combine mathematical ideas with poetry, conveying mathematical concepts by playing with language at its best. Several ways of creating such literary works are that writers change texts using mathematical concepts or create texts with certain patterns of number formations. The activity of using mathematics to make poetry "influences the beauty and effectiveness of words" (p. 621). Challenging the seemingly structural boundary of two disciplines, both mathematics and composition teachers, von Renesse and DiGrazia (2018) first illustrated the role rhetoric played in connecting the art of writing and doing mathematics and second combined their two courses where an inquiry-based learning community is created—instead of teachers lecturing in class, students are guided by instructors to "develop definitions, theorems, and proofs themselves" (p. 27). Both teachers and students are challenged to face their individual and disciplinary beliefs, and at the same time both are enabled to practice the deep thinking they value by themselves and by a liberal arts education. Through students' writing assignments for both courses and survey evaluation results, both researchers shedded light on the challenges that interdisciplinary learning creates, yet furthermore they presented the learning opportunities for both teachers and students to generate from such an inquiry-based learning environment.

Because of the mathematics-literature contest held in Taiwan since 2015, collaborations between mathematics and language teachers also have emerged, inviting a few studies on the influence of the contest. Hsu (2017) was engaged in the

teaching of two general education courses on mathematics and Chinese composition. Mathematical literary creative activities were promoted in each class, and the researcher guided the students to finish their work after class. Students' poetry of mathematics-literature revealed that students in the Chinese course are able to compose well-structured poems, while citing inappropriate mathematical concepts. On the other hand, students in the mathematics course often lack the language ability to compose proper poems. Nonetheless, they tend to incorporate the narrative better with mathematics.

In a recent study, Chang and Lee (2019b) presented an interdisciplinary dialogue between a composition teacher and a mathematics teacher based on students' award-winning works of mathematics-literature published in an academic journal. Similar to von Renesse and DiGrazia's (2018) study results on the challenges of interdisciplinary collaborations, Chang and Lee's study showed the different expectations for words and works from teachers of the two disciplines. However, Chang and Lee's shared expectation and achieved consensus were only possible when "truth" and "beauty" co-exist, that is, when the concepts of mathematics can be warmly received and embodied in words, and when the power of words can truly express the profundity of mathematics. Then both Chang and Lee (2019a) further extended their research to the elements that constitute the work of mathematics-literature from both teachers' and students' perspectives. Based on Ivanic's framework of discourse analysis, both Chang and Lee (2019a) defined mathematics-literature as the literary work that helps both teachers and students see mathematics, see literature, and see themselves; that is, mathematics-literature needs to include not only mathematics and literature, the two main elements, but also something coming from the fusion or combination of both which is naturally born, usually something related to the writers themselves—discoursal self—"it is constructed through the discourse characteristics of a text, which relate to values, beliefs and power relations in the social context in which they were written" (Ivanic, 1998, p. 25). Then both researchers concluded their study stating that only when the teachers across disciplines and students reached a consensus could a fulfilling mathematical literary writing be born. They offered constructive comments on the development of general education that highlights the effectiveness of interdisciplinary collaborations.

Additionally, Chen and Liu (2018) also analyzed students' award-winning works of mathematics-literature. Based on Petocz et al.'s five scale rubric of views of mathematics (2006, p. 440), Chen and Liu developed a measurement analyzing students' mathematics-literature, and they categorize them into three dimensions. The first is the narrow dimension that the students perceive mathematics as a tool of description, using numbers, symbols and calculation to create their literary work. The second is the broad dimension that students build up the mathematical model to convey ideas, analyze, and compose text. The third is the widest dimension that students use mathematics to explore and describe life.

In short, studies have presented the possible benefits and challenges of incorporating writing into a mathematics class and the impacts such incorporation brings to both teachers and students located in Taiwan or outside of it. Because of the nature of interdisciplinary teaching and learning, the existence of both potential benefits and challenges of combining writing and mathematics rationalizes the investigation of mathematics-literature and its place in mathematics education and learning in general. In recent studies in which the mathematics-literature researchers have analyzed students' literary work, the analysis from students' perspective is lacking. Although Chang and Lee's study (2019a) included students' voices about mathematics-literature, there were only three participants in their study. Therefore, as a pilot-study and exploratory in nature, this paper aims to report students' perceptions about mathematics-literature in hopes of identifying their perceived definition of it and pointing out the possible impacts of mathematics-literature on the participant students, teachers, and interdisciplinary collaborations.

2. Methodology

Because of the mathematics-literature competition, a mathematics teacher Wang[1] who serves in the language department of a vocational and technological college collaborated with a composition teacher Lin[2] to co-instruct students in the math class. Wang used the competition award and a term grade bonus as the incentive to encourage and motivate students to participate in this competition. Furthermore,

[1]The pseudonym is used for the preservation of confidentiality.
[2]The pseudonym is used for the preservation of confidentiality.

in the process, students were encouraged to engage in creative writing using the mathematics knowledge they have acquired in class. While these liberal arts students were adept at language subjects, most of them felt trepidation about mathematics and science subjects. Therefore, the teachers hoped that by participating in this creative competition, these students may discover new interest in learning mathematics and use their mathematics knowledge as a medium for creative writing.

3.1 Participants

The participants were first year junior college students majoring in German and English languages. After they submitted their work to the contest, 100 participant students were surveyed, but only 90 questionnaires by 15 male students and 75 female students were valid and analyzed. The participants could compose as many works closely related to mathematics as possible outside of the class and submitted to the contest on their own.

The interviewees included seven volunteer students out of 100 participant students, four from the Department of German; three from the Department of English. Interviewees A, B, C were English majors and Japanese minors; interviewees D, E, F, and G were German majors and English minors.

3.2 Instruments

3.2.1 Questionnaire

A questionnaire composed of six items, evaluated using a 5 point Likert-scale, and one open-ended question was adapted for this study. The six questions were about the participant students' perceptions regarding their mathematics and composing competence as well as their enhancement of motivation through writing in general and through mathematics-literature writing in particular. The open-ended question was aimed to discover the participant students' perceived definition of mathematics-literature.

3.2.2 Interviews

Both teachers discussed the interview questions together, and there were two sections: the first section was about the participant students' educational background, and the second section was about their idea of composing mathematics-literature. Both sections help illustrate students' perceived definition of mathematics-literature and its effect to their learning.

3.2.3 Interview dialogues

For a better understanding of students' creation of mathematics-literature and their definition of mathematics-literature, based on the students' work of mathematics-literature, this study also documented the interdisciplinary dialogues of teaching and learning among the mathematics teacher, the composition teacher, and two participant students.

3.3 Data analysis

Regarding the analysis of questionnaire results, descriptive statistics were included, and a Pearson correlation coefficient was computed to assess the relationships among the six items from the questionnaire.

Interview data were transcribed, and the transcripts were read and then analyzed by the researcher and another teacher. Reading the transcripts independently, both coded the data into a category when key words/phrases/ideas appeared more than one time, and then both compared the categories to reach agreement. For instance, one of the key ideas, mathematics-literature is the combination of two elements, if they occurred in the interview data more than one time, they would be classified into one category. Furthermore, if the participants defined mathematics-literature as the combinations of both elements as well as the revelation it had on their life, then such a definition would be classified into two categories. Additionally, the same approach was applied in analyzing the open-ended question regarding the perceived definition of mathematics-literature from the questionnaire. Discrepancies of the categories between the researcher and the other teacher were discussed until an agreement was reached, and the inter-coder reliability was 85%.

3. Results

The questionnaire results demonstrate most of the participants' perceived definition of mathematics-literature and its influence to them, and the following interview results more specifically indicate their reasons for the definition of mathematics-literature and its influence on their learning. In particular, the dialogue analysis with the two students illustrates their strategies of using words to depict mathematical concepts, creating a certain literary work in which both words and mathematics are combined/fused appropriately for the meaning of their creation.

4.1 Questionnaire results

Table 1 indicates the participant students' perceptions regarding mathematics-literature.

Regarding question 1, "How much do you like mathematics," 43.4% of the participants did not like mathematics as a subject, and 31.1% felt neutral about it, and only 25.5% of the participants like it. When the participants were asked to evaluate their perceived competence of mathematics, the pattern of the results for this question corresponds to that of their perceived degree of liking mathematics. About question 2, "How do you perceive your ability of mathematics," 40% were not confident in their ability of mathematics, and even though 35.6% felt neutral about their mathematics competence, 24.4% felt confident in it.

Yet, the participants felt more confident in their Chinese writing competence compared to their perceived mathematics competence. About question 3, "How do you perceive your writing competence in Chinese," 23.3% felt less confident in their Chinese writing competence, but 35.6% felt confident, and 41.1% felt neutral. Although the participants felt more confident in their Chinese writing competence, their perceived confidence greatly decreases when asked about their writing competence of mathematics-literature. About question 4, "How do you perceive your writing competence in mathematics-literature," 47.7% did not feel confident in their competence of composing mathematics-literature, but only 11.1% felt confident in it; 41.1% of the participants felt neutral about their competence of mathematics-literature.

Furthermore, about question 5, "To what degree do you feel being helped to learn mathematics through writing by creating mathematics-literature," 50% did not feel that they could learn mathematics with ease through writing, 34.4% felt neutral about it, and 15.6% felt they could learn math through writing. Regarding question 6, "Whether they were motivated to learn mathematics by mathematics-literature," 56.6% failed to believe so, and only 13.3% felt motivated; 30% felt neutral about it.

In brief, there were fewer participants who felt competent in composing mathematics-literature and motivated to learn mathematics by writing or by mathematics-literature than those who felt competent in either mathematics or Chinese writing competence alone.

Table 1. Participants' perceptions regarding mathematics-literature.

Item	Mean	SD	a little				a lot
			1	2	3	4	5
1. How much do you like mathematics?	2.58	1.18	24 (26.7%)	15 (16.7%)	28 (31.1%)	21 (23.3%)	2 (2.2%)
2. How do you perceive your ability of mathematics?	2.60	1.17	24 26.7%	12 13.3%	32 35.6%	20 22.2%	2 2.2%
3. How do you perceive your writing competence in Chinese?	3.14	.95	4 (4.4%)	17 (18.9%)	37 (41.1%)	26 (28.9%)	6 (6.7%)
4. How do you perceive your writing competence in mathematics-literature?	2.51	.93	13 (14.4%)	30 (33.3%)	37 (41.1%)	8 (8.9%)	2 (2.2%)
5. To what degree do you feel being helped to learn mathematics through writing?	2.57	1.04	13 (14.4%)	32 (35.6%)	31 (34.4%)	9 (10.0%)	5 (5.6%)
6. To what degree do you feel motivated	2.33	1.02	22 (24.4%)	29 (32.2%)	27 (30.0%)	11 (12.2%)	1 (1.1%)

to learn mathematics by creating mathematics-literature?	

N = 90

Table 2 indicates the correlations among the six items from the questionnaire. Not surprisingly, there was a significant positive correlation between participants' degree of liking mathematics and perceived mathematics ability (r = .813, $p < .01$).

A medium positive correlation was found between participants' perceived degree of learning mathematics through writing and perceived motivation of learning mathematics through mathematics-literature (r = .681, $p < .01$). There was a medium positive correlation between participants' perceived competence of mathematics-literature and perceived Chinese writing competence (r = .487, $p < .01$). Additionally, there was a medium positive correlation between participants' perceived competence of mathematics-literature and perceived degree of learning mathematics through writing (r = .407, $p < .05$).

There was a low positive correlation between participants' perceived motivation of learning mathematics through mathematics-literature and perceived degree of liking mathematics (r = .240, $p < .05$). Also, there was a low positive correlation between participants' perceived motivation of learning mathematics through mathematics-literature and perceived competence of mathematics-literature (r = .223, $p < .05$). Last, there was a low positive correlation between participants' perceived competence of mathematics-literature and perceived mathematics ability (r = .222, $p < .05$).

Table 2. Correlations among the six items from the questionnaire

		1.	2.	3.	4.	5.	6.
1.	Perceived degree of liking mathematics	1	-	-	-	-	-
2.	Perceived mathematics ability	.813**	1	-	-	-	-
3.	Perceived Chinese writing competence	-015	.163	1	-	-	
4.	Perceived competence of mathematics-literature	.056	.222*	.487**	1	-	-
5.	Perceived degree of learning mathematics through writing	.023	.022	.154	.407**	1	-
6.	Perceived motivation of learning mathematics by mathematics-literature	.240*	.142	.042	.223*	.681**	1

N = 90

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

* Correlation is significant at the 0.05 level (2-tailed).

As Table 3 indicates, there were four main categories revealed from the results of the one open-ended question, "How do you define mathematics-literature?" The categories were first, "mathematics plus literature," second, "perceptions toward mathematics-literature in relation to one's life," third, "passion/feeling revealed from mathematics-literature," and fourth, "combination/fusion of mathematics and literature."

Table 3. Participants' defined mathematics-literature from the questionnaire results

Categories		Number of participants
1.	Mathematics + literature	11 participants
2.	In relation to one's life	8 participants
3.	Passion/feelings revealed from the literary work	7 participants
4.	Combination/fusion of mathematics-literature	14 participants

N = 90

The first category was very easy to be spotted for its simple explanation as precise as, "mathematics + literature," in the following participants' answers to this question: 44, 49, 24, 25, 71, 78, 75, 70, 18, 51, and 76.

The second category appeared when the term "my/self" or the idea of it in relation to one's life was mentioned in the participants' definition of mathematics-literature, and they were 46, 7, 60, 41, 1, 47, 65, and 3. For example, Participant 7 said, "combining mathematics and words together creates a delicate way of using words to express my ideas about mathematics." Participant 1 put, "with my feelings toward the work, using simpler and comprehensible words to illustrate the abstract and difficult idea of mathematics formula or terms." Participant 65 wrote, "using words to represent the mathematical concepts with my feelings and passion expressed in language." Participant 3 failed to use the "my/self" in her answer, but her statement was also classified into this category. She said, "using mathematics to represent literature, then representing living, which interprets life."

The third category was the participants' statement regarding the presentation of feeling/passion, and they were 13, 79, 81, 15, 1, 47, and 65. For example, instead of stating passion created by the combination of mathematics and literature, Participant 79 said, "words represent mathematics and passion." Participant 15 said, "using words to depict mathematical concepts, be it poetry or prose, being able to express feelings."

The last category was the idea or words that showed the "combination/fusion"

of mathematics and literature, and the difference between the fifth and first was that the fifth one was of the emphasis on the outcome or extension from the combination/fusion of the two elements rather than one plus one. They were Participants 16, 14, 33, 42, 86, 7, 45, 21, 88, 90, 9, 64, 69, and 12. For instance, Participant 16 said, "the combination of mathematics and literature with a different method of expressing the mathematical ideas." Participant 33 put, "fusing both mathematical concepts and literature, reaching a balance." Participant 42 said, "the combination of mathematics and literature, and using more modified words to express mathematics." Participant 45 wrote, "it is the ability of cross disciplines that fuse both mathematics and Chinese competences." Participant 21 said "combining two most beautiful things together, which creates a new beauty." Participant 9 put, "it is the literature that fuses with mathematics." Participant 88 stated, "one of the main reasons that mathematicians love math is that it is very definite, yes is yes, no is no, but when the combination of mathematics and literature occurs, mathematics is less straightforward, and literature is more straightforward, less pretentious, a very new creation derived from both."

Furthermore, the common key words were also revealed from the results stating mathematics-literature as the method of gaining extra points for the course, and the participants were 80, 43, 61, 77, and 62. For example, participants 80, 77, and 61 put, "for extra points for this course." Participant 43 wrote, "the combination of words and mathematics and the assignment for extra points." These key words might not be suitable for the definition of mathematics-literature, but such a view might indicate that composing mathematics-literature worked as an incentive for them to make effort for the course.

4.2 Interview results

As Table 4 presents, regarding the interview results, three main categories were discovered, "mathematics ability," "Chinese writing competence," and "definition of mathematics-literature."

Among the seven volunteer interviewees, five of them stated that their mathematics ability was adequate, but two of them directly said it was bad. For instance, while both Students F and B said, "It was adequate," Student E said frankly that "it was really bad." Student C felt frustrated and admitted that "his mathematics

has been bad since then," and his grades were not presentable, either. However, when they were asked about the Chinese writing competence, six of them directly stated that they felt confident in it, and only one, Student G, failed to explicitly state whether she felt confident in it; instead, she said, "I feel perhaps I haven't read any books since last year, so I feel I am not making progress in it." Here the interviewees' responses regarding their perceived Chinese writing competence and mathematics ability corresponded to the questionnaire results that there were more participants feeling more confident in Chinese writing competence than in mathematics ability.

Table 4. Categories from the interview results

Categories		**Number of participants**
1.	Mathematics ability—adequate	5 participants
2.	Chinese writing competence—confident	6 participants
3.	Mathematics-literature is the combination/fusion of mathematics-literature—using language to depict mathematics	4 participants

N = 7

Although the participants' perceived definition of mathematics-literature varies, most of them defined it as using language to depict mathematics.

For instance, Student B defined it as "the combination of mathematics and Chinese, using words to describe mathematics," and she felt that "it allows her to have a wild imagination." Similarly, Student G stated that "for me, mathematics-literature is a channel that adopts literature as a method to deliver mathematics and other concepts. I mean it is difficult to understand math, so language should be used to deliver it, and mathematics-literature is working as a simpler way and thus as the product to help people accept mathematics." Student C gave his definition: "mathematics-literature was like using language to represent abstract concepts." He further explained that mathematics contains certain terms, but if some concrete

examples are used, it might be felt closer to daily life." Student A's definition concludes what these three participants' idea of mathematics-literature on the combination of mathematics and literature is, and the power it creates, and she said, "mathematics-literature is using words to reveal the mysterious aspect of mathematics. Both sides of rationality and sensibility of mathematics can only be unveiled by literature, so mathematics can be the epitome of life, description of feeling, and that of a story." In short, these four participants' perceived definition of mathematics-literature is that it combines both elements, usually language is used to help explain mathematics and increase the understanding of it because of the abstract concepts it embodies, and the fusion of both elements shapes mathematics into a more concrete and tangible subject and brings people closer to it and relates it to their daily life.

Other than the above mentioned definition, two of the participants, Students D and E acknowledged mathematics-literature as a tool for earning extra points for the semester grade, but both also mentioned the additional benefits of participating in this activity. Student D stated that "it helped her work be recognized by others, and especially by teachers," indicating her self-esteem was elevated because of the activity of mathematics-literature; Student E also offered the advantage of creating mathematics-literature by saying that it helped her remember certain technical terms of mathematics.

4.3 Dialogue results

Because the category, combination of mathematics and literature, has been revealed from questionnaire and interview results, the following dialogues with the two students unveil how it unfolds during the process of composing mathematics-literature.

The following poetry is Student A's original draft—The Meaning of Angles. The mathematical concepts that Student A uses here are angles and the formation of a full circle, a fairly simple idea. The added meanings for each angle present the effect that language brings to the poetry. On the basis of mathematical concepts, literature is gradually incorporated. The poetry depicts the gradual steps of a full circle being formed.

Student A's original draft:

The Meaning of Angles

90 degrees is the upright attitude, 180 degrees is the tolerant attitude;
360 degrees is the fulfilled radian; 520 degrees is the warmth of feeling.
With the uprightness of 90 degrees and keeping the tolerance of 180 degrees, life achieves the fulfillment of 360 degrees and the warmth of feelings of 520 degrees.

The following conversation with Student A clearly reveals her creative intention and process, suggesting her method of combining mathematics and words.

Lin: How did you construct the work and how did you come to the last line? I want to know how you deconstructed the structure.
Student A: We began to learn from the most basic 90 degrees and extended to 180 degrees and then 360 degrees, which then becomes a full circle; that's why I wrote "fulfilled radian." I used 520 degrees because we often use 520 now (which is I love you), so this extends to the warmth of feelings. But I felt that this was a little short, so I wrote out the whole sentence. If there were only the four angles, then there would not be enough content, so I added the meanings associated with the four angles, and then added the last line and the last conclusion.
Wang: Which is 520! Did you add 520?
Student A: Yes.

Student A fully understands the mathematical concepts and begins to construct the poem from 90 degrees, gradually adding degrees to the fulfillment of a full circle. The poem presents a very vivid and dynamic picture, and reading along the line, readers can picture the formation of a full circle. Being aware of the inadequacy of using only numbers with the mathematical concepts, she started to create meanings for each angle; the student precisely depicts the implications that each angle conveys: uprightness, tolerance, fulfillment, and feelings, and combines them with reality and life. Then she used 520 degrees which is the homophonic phrase, "I love you," to

endow feelings of love to the angle, symbolizing the writer's expectation.

The following dialogue shows how she was concerned about 270 degrees, which might destroy the beauty of the poem and her intention of using words to increase the rhythm of it. Again, her response shows her strategies of incorporating words into the poem that is mathematics-based as well as her careful planning for the beauty that the words would bring to her anticipated poem.

Wang: Your original draft includes 90 degrees, 180 degrees, and 360 degrees, but why don't you include 270 degrees?
Student A: I don't like it because I feel it looks ugly.
Lin: Do you mean the number 270 looks ugly?
Student 1: Yes, it looks ugly.
Lin: So you decided to start from 90 degrees, 180 degrees, and then a full circle is formed. Right?
Student A: Yes. Also, I would like to write with rhythm so in the end of each line, I use "attitude."

Student D employed mathematical concepts, set theory, including the intersection set, union set, and universal set. A love story was included in the poem that describes the process of two people gradually getting closer, creating an intersection set, and then a union set, but the writer's ultimate goal of the two is becoming one, which depicts the universal set.

Student D's poetry

Take Student D's work for example:

I Will Be Your Universe

Girl,
Ever since I saw you,
As if struck by Cupid's arrow,

I could never forget your captivating beauty.
So I strived for opportunities,
To create an intersection with you,
I strived to devise topics,
In search of commonalities with you.
But that is not enough,
I am a greedy man,
I want to know everything about you--
All! I want to know all!
Yet,
I also crave your craving,
I want to tell you everything, the future I want to promise you.
I want us to be each other's only support.
I want 'we' to become 'one.'
I will be your universe,
Orbiting around you,
While others
Can only watch you from billions of light years away.
Take me,
And I will take your everything,
Holding you tightly against my chest
So that no one can harm you.

With Student D's illustration, in their minds two people gradually come closer and closer until they intersect, which is the intersection set. But having the intersection is not enough because the first person in the poem desires more; before wanting to be the other's universe, Student D describes the union set that two people have become, and then the narrator's ultimate goal is revealed: the total overlapping state and becoming a universe, which is the universal set. It is interesting to note the tone Student D adopted when writing this work. It is possible due to the love pursuit stereotype, both teachers had assumed this work to be written by a male student, for its tone is filled with the dominance typical of a man's pursuit of a woman, which

actually corresponds to the idea of the universal set, the exclusive possession. That is not to say that a woman should not pursue a man; yet, as typically perceived, women's pursuit of men should not display such a strong and direct tone. However, interestingly and surprisingly, this poetry was written by a female student. The following dialogue presents Student D's explanation for constructing this poem.

Lin: Why did you choose to write "Girl, ever since I saw you" instead of "boy"?
Student A: I don't know, I felt it was better to write from a man's perspective.
Lin: Why?
Student D: I don't know. I just wanted to express a man madly in love because a woman may not be so involved; I don't know how to put it. Could be that I think a man would....
Lin: So you felt you should write from a man's perspective. Is that correct?
Student D: In such case, I feel this man would be quite devoted.
Lin: But you could also say "boy ever since I saw you," is that not true?
Student D: But if I write from a woman's perspective, I feel that things like love pursuit may not be so powerful as written from a man's perspective because a woman tends not to do such things.
Wang: You mentioned at the beginning that the desire for domination is strong; so you can write more freely about domination from a man's perspective.
Student D: Maybe, more or less.
Wang: Because the speaker wants all in the end, so it has to be very domineering, so it is a man's tone.

Student D's greater familiarity with mathematical concepts allowed her to strategically employ the set theory to construct her work and to express her perceived expectations of a man and woman in the process of getting near to each other. The most brilliant part lies in the student's assumption of the male voice through the use of words to express the fervent wish to be with the other, instead of describing the process of a female in pursuit of the other. Nonetheless, it is also because she adopts the male tone that the entire work is able to vividly portray images of intersection, union, and universal set, especially the last set, that includes all the objects, and

therefore equals the "universe" that the writer wants to express.

In addition to the tone, the use of words also demonstrated Student D's incorporation of literature into the poetry. After both intersect, she started to use words like "greedy" and "all" explicitly to emphasize the writer's intense desire to be together with the other person. The exclamation mark after the "all" further intensifies the extraordinary force. Then the use of consecutive "crave (craving)" directly and straightforwardly depicts the man's desire to be together with the woman. All the words prepare the readers for the writer's ultimate goal for both to become the one, the universal set. Illustrating the image of becoming one, Student D wrote lines, such as "I want to be your universe," "while others can only watch you from billions of light years away," and "And I will take your everything, Holding you tightly against my chest So that no one can harm you," that again stresses the formation of the universe combining both people. The tension was built up to lead readers to understand how "I want to be your universe" works.

In short, the fusion of both elements, mathematics and writing, shapes mathematics into a more concrete and tangible subject and brings people closer to it and relates it to their daily life, which is the mathematics-literature.

5. Discussion

This study investigates junior college students' perceptions regarding mathematics-literature through a questionnaire and interviews.

The questionnaire results indicate that when mathematics-literature was engaged, far fewer participants felt confident in composing it and felt motivated to learn mathematics by writing or by mathematics-literature than those who felt competent in either mathematics or Chinese writing alone. Even though this was the case, questionnaire results have also indicated a medium positive correlation between participants' perceived motivation of learning mathematics through the creation of mathematics-literature and perceived degree of learning mathematics through writing, indicating that the more they felt motivated to learn mathematics through the creation of mathematics-literature, the more they felt helped by it to learn mathematics through writing, and vice versa. The medium positive correlations were also discovered (1) between participants' perceived competence of composing

mathematics-literature as well as their Chinese writing competence and (2) between participants' perceived competence of composing mathematics-literature as well as their perceived degree of being helped through writing. That is, the more they felt confident in composing mathematics-literature, the more they felt confident in their Chinese writing, and vice versa. And correspondingly the more they felt confident in composing mathematics-literature, the more they felt helped by it to learn mathematics through writing, and vice versa.

There were low positive correlations (1) between participants' perceived motivation to learn mathematics through mathematics-literature as well as their perceived degree of liking mathematics and (2) between participants' perceived motivation to learn mathematics through mathematics-literature as well as their perceived competence of composing mathematics-literature. In other words, the more they felt motivated to learn mathematics through mathematics-literature, the more they liked mathematics, and vice versa. And correspondingly, the more they felt motivated to learn mathematics through mathematics-literature, the more confident they felt in composing mathematics-literature, and vice versa. The last low positive correlation was observed between participants' perceived competence of mathematics-literature and perceived mathematics ability, suggesting that the more confident they felt in composing mathematics-literature, the more confident they felt in their mathematics ability, and vice versa.

Not surprisingly, there was a significant positive correlation between participants' degree of liking mathematics and perceived mathematics ability ($r = .813$, $p < .01$), indicating the more they liked mathematics, the more confident they felt in their mathematics ability, and vice versa.

The analysis of open-ended question results demonstrates that the participants defined mathematics-literature as a combination/fusion of both elements, and a literary work that reveals their passion/feelings or that is related to their life. Such research results on the definition of mathematics-literature correspond to the study findings by Chang and Chen (2019a) and Chen and Liu (2018). In this study, the participants' defined mathematics-literature as the combination/fusion of both elements which matches Chang and Chen's take on it as a literary work including mathematics, literature, and "self." Especially those more motivated participants'

definition of it greatly resonates with Chang and Chen's definition as the "self" that was effortlessly and naturally derived or constructed from the combination of mathematics and words. Similarly, the participants' mathematics-literature definition also echoes Chen and Liu's three categorized dimensions (2018), in particular the narrow dimension and widest dimension, that the narrow dimension is closer to the participants' definition as the combination of mathematics-literature; the widest dimension is closer to the literary work relating to their life.

Then triangulating all the research data—questionnaire, one open-ended question, and interviews—reveals that regardless of the degree of positive correlations, participants' perceived competence of composing mathematics-literature was positively correlated to their perceived Chinese writing competence, perceived mathematics ability, and perceived motivation of learning mathematics through mathematics-literature. Compared to their perceived mathematics ability, their perceived competence of composing mathematics-literature was more closely correlated to their perceived Chinese writing competence and perceived motivation of learning mathematics through mathematics-literature.

Also, regardless of the degrees of positive correlations, participants' perceived motivation of learning mathematics through mathematics-literature was positively correlated to their perceived degree of liking mathematics, perceived degree of learning mathematics through writing, and perceived competence of composing mathematics-literature. Their perceived motivation of learning mathematics through mathematics-literature was especially more correlated to their perceived degree of learning mathematics through writing than perceived degree of liking mathematics.

Furthermore, triangulation of research data discloses (1) the shared perceived definition of mathematics-literature is the combination of mathematics and language, usually words are used to deliver abstract mathematical concepts, and (2) effect of the combination turns mathematics into a concrete object and brings people closer to it. The mathematics-literature also becomes a grade boosting incentive for the participants to pay more attention to mathematics as a subject.

Because most participants defined mathematics-literature as the combination/fusion of the two elements, how the combination/fusion takes place is more specifically and clearly revealed from the dialogues with the two volunteer

students. The analysis of the dialogues with them further indicates their strategies of employing words for the literary mathematics-based work. In both cases of this study, students gave meanings to the numerical numbers, such as 90, 180, 520, or mathematical concepts, such as the set theory. The meanings of the literary work were created by words or the combination of both words and mathematical concepts. Depicting the dynamic nature of mathematics, the participants strategically used rhythmic words, numeric homophonic words, punctuation or metaphors to create vivid images, or they constructed their poem with a plot that usually mirrors their life or an analogy of their life. The participants' method of creating a story that describes the mathematical concepts corresponds to Doxiadis' term, "mathematization of narratology" (2007) that uses mathematics and literature to describe or narrate, in which mathematics plays a crucial part in the writers' narrative stories. According to Doxiadis, there are two ways of mathematization; first, "applying number to stories;" second, manipulating symbols as being algebraic. These two approaches were also observed in the students' literary work. In relation to these two approaches, Hung (2015) defines mathematical narrative as a narrative approach to communicating or constructing meanings in mathematics. Again, such an approach was also used by the students who told a story in their literary work.

6. Conclusion

This study investigates junior college students' perceptions about mathematics-literature. Although far fewer participants felt confident in composing mathematics-literature and felt motivated to learn mathematics by writing or by mathematics-literature than those who felt competent in either mathematics or Chinese writing alone, the present study's findings should not be ignored—the discovered medium positive correlations between participants' perceived motivation of learning mathematics through mathematics-literature and perceived degree of learning mathematics through writing; between participants' perceived competence of composing mathematics-literature and perceived motivation of learning mathematics through mathematics-literature. These positive correlations signify the importance of incorporating writing and mathematics-literature into a mathematics class, especially for those who felt confident in the use of writing and the creation of mathematics-

literature in mathematics-learning.

The controversial issue of the use of writing in a mathematics class was in fact commonly addressed from the previous studies, not to mention the more challenging writing task, such as the creation of mathematics-literature, the focus of this study. Studies by Beavers et al. (2015), Kenney et al. (2014) and Yang and Chiang (2008) pointed out certain distinct features, such as students' doubts of keeping a journal and its effects of enhancing mathematics learning as well as teachers' concerns about its incorporation into a very limited class time. Yet, even though the doubts still remain, a close relation between writing and mathematics is unquestionable, and a body of studies demonstrated the effectiveness of using writing as a tool to learn, in particular mathematics (Banger-Drowns, Hurley, & Wilkinson, 2004; Freeman et al., 2016; Gould, 2013; Lee, 2010; Pugalee, 2001; Seto & Meel, 2006; Watson, 1980). For both teachers and students, writing in mathematics classes offers students a chance to demonstrate their metacognitive process of problem solving and at the same time guides teachers to identify the places that students are confused about during their process of mathematical thinking (Pugalee, 2001).

In this regard, the creation of the mathematics-based literary work also serves a similar function as the incorporation of writing in mathematics classes that both teachers and students are able to see whether teaching and learning are effective for comprehension of certain mathematical concepts. When students are able to express and explain their reasoning and justify their thought processes and solutions correctly in writing, it shows their command of the concepts (Baxter, Woodward, & Olson, 2005; Gould, 2013), and teachers know immediately the effectiveness of their teaching. What is more, unlike the usual way of using writing in a mathematics class, such as keeping a journal, explanations of problem solving or reflection papers (see Kenney et al., 2014; Pugalee, 2001; Yang & Chiang, 2008), the creation of mathematics-literature requires not only mastery of mathematics, language, but also adeptness of grasping both together for mathematics-literature, suggesting its challenging aspect (Chang & Chen, 2019). This study again highlights the significance of interdisciplinary education between mathematics and literature for both teachers and students.

Mathematics and literature are two disparate academic subjects in terms of

teaching and learning; through the combination of mathematics-literature, a new fusion is created, leading to the interdisciplinary teaching and learning that involves two or more academic disciplines and encourages learners to develop dynamic thinking through the use of various aspects of knowledge. Thus, the boundaries become permeable, promoting dialogue and cooperation between discipline practitioners, and helping learners develop innovative problem-solving abilities in order to overcome complex predicaments in reality. In this study, because of the interdisciplinary collaborations, students' mathematical literary writings revealed how well they combined mathematic and literature—the correctness of mathematical concepts was checked by the mathematics teacher; the writing teacher helped confirm whether students' descriptions conformed to the expectations of a literary work. The students' works allowed the practitioners of two different disciplines to engage in dialogue; the longer teachers collaborated, the more students' works naturally combined mathematics and literature. School curriculum designed in an interdisciplinary way makes learning better-rounded rather than focusing on one specific ability.

As a pilot-study that is exploratory in nature, this study results might benefit greatly from future research on students' actual mathematics and Chinese writing performance in which the cross-analysis of perceptions and performance might more specifically indicate the effectiveness of mathematics-literature. Also, more participant teachers that participate in the contest of mathematics-literature should be recruited to understand their attitude towards it in hopes of identifying more effective ways of interdisciplinary teaching and learning.

References

Banger-Drowns, R. L., Hurley, M. M., & Wilkinson, B. (2004). The effects of school based interventions on academic achievement: A meta-analysis. *Review of Educational Research, 74*, 29–58.

Baxter, J. A., Woodward, J., & Olson, D. (2005). Writing in mathematics: An alternative form of communication for academically low-achieving students. *Learning Disabilities Research and Practice, 20*, 119–135.

Beavers, Alyssa; Fox, Brandon L.; Young, Jamaal; Bellows, Elizabeth M.; and Kahn, Leah (2015). Integrating Writing in the Middle-Level Mathematics Classroom: An Action Research Study. *MLET: The Journal of Middle Level Education in Texas, 2*, 1–34.

Bicer, A., Capraro, R., & Capraro, M. (2013). Integrating writing into mathematics classrooms to increase students' problem solving skills. *International Online Journal of Educational Sciences, 5*, 361–369.

Doxiadis, A. (2007). The mathematical logic of narrative. In M. Manaresi (Ed.), *Mathematics and culture in Europe* (pp. 167–177). Heidelberg, German: Springer Verlag.

Freeman, B., Higgins, K. N., & Horney, M. (2016). How students communicate mathematical ideas: An examination of multimodal writing using digital technologies. *Contemporary Educational Technology, 7,* 281–313.

Gould, P (2013). Teaching mathematical reasoning: The challenge of the new syllabus. Retrieved on 1 April 2019 from https://eis.uow.edu.au/content/groups/public/@web/@inf/@math/documents/doc/uow152422.pdf

Growney, J. (2011). Using Mathematics to Make Poetry. *Bridges 2011:Mathematics, Music, Art, Architecture, Culture*, 621–624.

Ivanic, R. (1998). *Writing and identity: The discoursal construction of identity in academic writing*. Amsterdam, The Netherlands: John Benjamins Publishing Company.

Kenney, J. M., Hancewicz, E., Heuer, L., Metsisto, D., & Tutttle, C. L. (2005). *Literacy strategies for improving mathematics instruction*. Alexandria, VA: ASCD.

Lee, K. (2010). A guide to writing mathematics. Retrieved on 1 April 2019 from http://web.cs.ucdavis.edu/~amenta/w10/writingman.pdf.

Petocz, P., Reid, A., Wood, L. N., Smith, G. H., Mather, G., Harding, A., Engelbrecht, J., Houston, K., Hillel, J., & Perrett, G. (2007). Undergraduate students' conceptions of mathematics: An international study. *International Journal of Science and Mathematics Education, 5*, 439–459.

Pugalee, D. K. (2001). Writing, mathematics, and metacognition: Looking for connections through students' work in mathematical problem solving. *School Science and Mathematics, 101*, 236–45.

Seto, M., & Meel, E. D. (2000). Writing in mathematics: Making it work. *Primus: Problems, Resources, and Issues in Mathematics Undergraduate Studies, 16*, 204–232.

von Renesse, C., & DiGrazia, J. (2018). Mathematics, Writing, and Rhetoric: Deep Thinking in First-Year Learning Communities. *Journal of Humanistic Mathematics, 8*, 24–63.

Watson, M. (1980). Writing has a place in a mathematics class. *The Mathematics Teacher, 73*, 516–519.

丘成桐（2017）。數理與人文。**數學傳播季刊，41**(1)，14–16。

洪萬生（2015）。**比喻與數學的敘事理解**。線上檢索日期：2019年 04月 01日，取自：台灣數學博物：http://mathmuseum.tw/2015/07/788/

徐惠莉（2017）。數學遇見美學的實踐與創作－談跨領域教學。**通識在線，12**(73)，76–83。

陳東賢、劉柏宏（2018）。理性數學與感性文學的協奏曲。載於劉淑爾（主編），**閱來越智慧**（260–289頁）。臺中市：滄海出版社。

張慈珊、李雪甄（2019a）。連結瞬間：見數學、見文學、見自己。**通識學刊：理念與實務，7**(1)，73–108。

張慈珊、李雪甄（2019b）。文學與數學的一場對話。**數學傳播季刊，43**(2)，84–93。

楊德清、姜淑珍（2008）。數學寫作融入國三數學課室實踐歷程與影響之研究。**科學教育學刊，16**，439–458。

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