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Metaphoric beliefs of students engaged in dynamic mathematics lessons

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Abstract
Students' beliefs and attitudes have a direct impact on their behavior and engagement in the learning of mathematics. This study examined students' beliefs of dynamic mathematics lessons through the lens of the contemporary theory of metaphor. Participants of the study were grade 10 students in a Macao private secondary school. 51 students attended dynamic inquiry-based lessons and used dynamic geometry software. After the lessons, students' attitudes of the dynamic lessons were uncovered using open-ended questions and a Likert-item questionnaire. Students held a polarized view regarding the dynamic mathematics lessons claiming they were rewarding but challenging. In order to develop students' positive attitudes towards the dynamic mathematics lessons, teachers should plan more diversified pedagogy to meet the different learning approaches of students.

Keywords: contemporary metaphor theory, dynamic mathematics lessons, beliefs, attitudes, metaphors, dynamic geometry software

INTRODUCTION

Students' attitudes toward mathematics may shape their learning approaches and performances. Skilling et al. (2020) studied the patterns of students' engagement in mathematics with respect to their beliefs about their achievement level, behaviors, and feelings towards the subject. In that study, engaged students tended to have a high level of self-efficacy, which led to their valuing and enjoying mathematics. They were attentive in class and raised questions when their understanding faltered. Disengaging students tend to have a high level of anxiety, uncertainty, and avoidance of mathematical activity. High achieving disengaging students focused on their performance rather than mastery of knowledge. Low achieving disengaging students always felt hopelessness and were less likely to seek help from others. International studies of mathematical literacy revealed that students with low level of mathematics self-efficacy performed worse in mathematics (OECD, 2015). Therefore, students' engagement in mathematics is important to practitioners.

Many students perceive mathematics as a difficult and abstract subject (OECD, 2015), and teachers have been looking for ways to motivate students in mathematics classes. Integration of dynamic geometry software (DGS) in mathematics instruction is one approach to motivate students, especially teenagers, as teenagers have claimed a preference to work in a computer environment (Zilka, 2020). DGS facilitates students' cognition of different mathematical concepts, representations, and their interconnections (Chan & Zhou, 2020; Pierce et al., 2011). In such computer-based environments, students can simulate, model, and verify mathematical relations (Olivero & Robutti, 2007). Studies have found that use of DGS improves students' mathematics achievements (Chan & Leung, 2014), motivation, and engagement (Isiksal & Askar, 2005). In this study, the term dynamic mathematics lessons refers to lessons in which students use DGS as a tool to explore and learn mathematics, i.e., they manipulate mathematical properties through the DGS (Bokosmaty et al., 2017).

Previous research on attitudes about dynamic mathematics lessons were based on classroom observations (e.g., Erbas & Yenmez, 2011) and data was collected through questionnaires (e.g., Adelabu & Makgato, 2019). Although classroom observations provide a rich picture of students' behavior in the classroom, it is hard to infer students' attitudes. Questionnaires are convenient and quick to collect students' attitudes, but the collected data might not be rich enough to fully appreciate the complexity of students' beliefs. Considering the limited resources such

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Contribution to the literature

- The research reports students' engagement in the dynamic mathematics lessons through the contemporary theory of metaphor.
- The study reveals that boys engage more in the dynamic mathematics lessons than girls.
- Students believe dynamic mathematics lessons are rewarding but challenging.

as time and manpower in a real secondary mathematics classroom, this study aimed to examine secondary students' attitudes of the integration of dynamic mathematics lessons into their regular mathematics classroom regime. Phillip (2007, p. 259) defines attitudes as "manners of acting, feeling, or thinking that show one's disposition or opinion" and beliefs as "psychologically held understandings, premises, or propositions about the world that are thought to be true". There is a distinction between ''attitudes'' and ''beliefs'' because attitudes are easier to change than beliefs and less cognitive than beliefs. Although the two terms vary in degree of cognition and intensity, beliefs encompass the construct of attitudes, and it is common for these terms to be used interchangeably (Pettit, 2011). Therefore, the terms beliefs and attitudes are used interchangeably in this paper to refer to the same construct. This study collects students' beliefs of dynamic mathematics lessons through the use of a data collection technique that adopted contemporary metaphor theory (Schinck et al., 2008). The following section briefly introduces the theory that guided the current study.

THEORETICAL FRAMEWORK

Dynamic Mathematics Lessons and Students' Beliefs

Integration of technology, especially DGS, into mathematics education has attracted lots of attention in the past 10 years (Cheung & Slavin, 2013). Both educators and researchers are interested in studying how DGS is shaping the teaching and learning of mathematics. In this line of research, some researchers have been looking for ways to enable users to explore and experiment with mathematical concepts in a technological environment (Selaković et al., 2020). Others have been studying users' behavior in technology settings. For example, Guven and Karatas (2009) studied how student teachers learnt spherical geometry in a DGS environment. Another line of research has worked on studying the impact of technology-based instruction in students' mathematical achievements (Isiksal & Askar, 2005; Koklu & Topcu, 2012). Dynamic mathematics lessons that utilized DGS increased students' spatial visualization skills more than that of physical manipulative-based instruction and teacher-centered instruction (Baki et al., 2011). This means that DGS-based instruction has been found to be beneficial in improving mathematics achievement of students.

Despite the positive impact of DGS-based instruction, studies exploring students' attitudes about dynamic mathematics lessons are limited. Among those few that have been conducted, Funkhouser (2002) studied the impact of DGS on grade 10 and 11 students' learning and attitudes. He found that the treatment group scored higher than the control group in terms of geometry performance but their attitudes towards mathematics did not change significantly after DGS use. Isiksal and Askar (2005) compared grade 7 students' mathematics self-efficacy and their mathematics achievement after DGS-based instruction. They found that there was significant differences between the DGS group and the traditional instruction group with respect to mathematics achievement but not in math self-efficacy. Erbas and Yenmez (2011) analyzed classroom observation data and found that grade 6 students in a DGS-based environment showed greater interest and motivation towards mathematics. Adelabu and Makgato (2019) investigated grade 9 students' attitudes towards the integration of DGS into a mathematics classroom. They found that students had positive attitudes towards DGS use. Birgin and Topuz (2021) investigated grade 7 students' attitudes towards geometry in DGS contexts. Students' attitudes towards geometry increased significantly higher than those in the control group. Existing empirical evidence on students' beliefs towards dynamic mathematics lessons seem to show that students' attitudes towards a more context-specific area of mathematics increases with the use of DGS while their beliefs about mathematics and math self-efficacy in general remained steady.

Gender Differences in Dynamic Mathematics Lessons

Previous studies report that female students have less interests, more anxiety and less self-efficacy in mathematics (Devine et al., 2012; Else-Quest et al., 2010). In a meta-analysis of 51 research studies, male students were shown to have a more favorable attitude towards technology use, particularly in their terms of beliefs and self-efficacy (Cai et al., 2017). Therefore, it is interesting to consider if there are any gender differences towards students' attitudes about dynamic mathematics lessons. Reviewing existing empirical studies of dynamic mathematics lessons, Isiksal and Askar (2005) found that there was no such difference in math self-efficacy based on gender. Erbas and Yenmez (2011) analyzed classroom observation data of students and found that boys were more engaged in a computer-based learning environment. In another study of dynamic mathematics lessons, Adelabu and Makgato (2019) found a slight difference between the attitudes of girls and boys before the intervention, but a similar attitude after the treatment. They concluded that gender was not a factor determining their attitudes towards DGS.

The Contemporary Theory of Metaphor

Metaphors are often used in daily life communication, and they are not just used for the purpose of language embellishments. Since Lakoff and Johnson (1980) wrote the book "Metaphors We Live By," metaphor has been proposed as a fundamental conceptual mechanism to understand humans' experiences and reasoning (Martínez et al., 2001). The Contemporary Theory of Metaphor is a conceptual framework that emphasizes the value of using metaphors to "understand a relatively abstract or inherently unstructured subject matter in terms of a more concrete, or at least a more highly structured subject matter" (Lakoff, 1993, p. 39). Metaphors are a type of conceptual mapping between target and source domains. Metaphors are embodied states of our minds within the psychology of embodied cognition. This perspective views the thought and act of learners as socially constructed and situated within the context of learning (Núñez et al., 1999). Therefore, metaphors are both individual and social. This implies that the construction of metaphors by an individual is also affected by social interaction. Metaphor theory provides a rich and vivid image of one's thoughts based on the experience of learners.

The application of metaphors has gained much popularity among teachers and researchers and has been used to understand and explain abstract concepts, attitudes, and educational practices. For example, some researchers have used metaphor as a tool for teaching (Font et al., 2010; Willox et al., 2010). It has been advocated as a means to help teachers and students develop a shared language of learning in the classroom (Lai, 2013; Thomas & McRobbie, 2001). Teachers use metaphor to explain concepts to students with the intention to ease students' understanding. When instructional metaphors are used, the teacher has to ensure that students understand the source domain (Niebert et al., 2012) because students might not ascribe to the meaning that the teacher intends to communicate. Metaphor has also been used as an assessment tool to obtain students' feedback on a curriculum and to understand students' thinking about mathematics (Noyes, 2006; Schinck et al., 2008).

Previous studies have applied metaphor theory to unpack students' attitudes towards mathematics. Lim (1999) studied adults' images of mathematics in the UK. He showed that metaphor analysis provided a rich and varied understanding into people's views, feelings, and their experiences related to mathematics education. Noyes (2006) explored pre-service mathematics teachers' beliefs about mathematics through metaphor to provide professional development courses. Schinck et al. (2008) conducted a study to examine the mathematical beliefs of grade 9 and 10 students. These students described mathematics as an underground sewer system or a video game to represent their well-developed and complex views about mathematics. In order to cope with this complex system, students believed that effort was needed. Markovits and Forgasz (2017) explored the beliefs about mathematics of Israeli primary grade 4 and 6 students using animal metaphors. Students had mixed beliefs about mathematics and considered it as important, difficult, and complicated. All of these studies showed that metaphor analysis is a possible and relevant approach to understand students' beliefs about mathematics due to its ability of providing rich and vivid information.

Contemporary metaphor theory provides another lens to study students' experiences and beliefs of dynamic mathematics lessons. Metaphors have the potential to allow researchers to understand complex and abstract issues through concrete analogies. Understanding students' beliefs of dynamic mathematics lessons can shine light on creating a better environment to foster students' active construction of knowledge in technology settings. This approach also can uncover information that may not be detected using existing approaches. As revealed in the literature review, previous studies exploring students' views and beliefs about dynamic mathematics lessons were mainly based on classroom observations and mathematical assessment scales, which might not fully illustrate students' beliefs about a new educational environment. As a result, students' attitudes towards dynamic mathematics lessons should be explored through a more suitable approach. The purpose of this study was to gauge students' view of dynamic mathematics lessons using an alternative approach involving metaphors. This study fills a gap in the literature by uncovering the metaphoric beliefs of students about dynamic mathematics lessons. The following research questions guided this study:

1. What are the metaphoric beliefs of students about inquiry-based dynamic mathematics lessons?
2. What do these metaphors reveal about students' beliefs about inquiry-based dynamic mathematics lessons?
3. Is there any difference between the perceptions of male and female students about dynamic mathematics lessons?

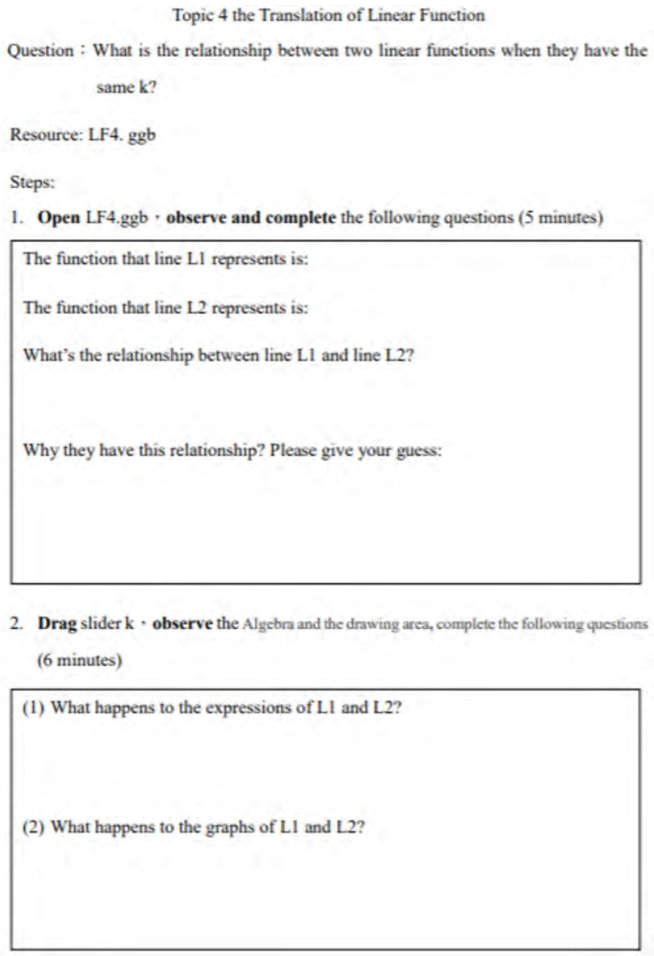
CONTEXT OF THE STUDY

Macao, a special administration of region of China, follows the so called Far East education system (Wong, 2003). The repeated call for the use of information and communication technology in education has been changing the mathematics teaching in Macao. Teachers are more willing to use technology such as DGS in their classrooms as they have acknowledged its affordances in supporting instruction (Chan & Leung, 2014). They have used the visualization affordances of DGS to help students understand mathematical concepts (Zengin & Tatar, 2017). This implies that students are usually presented with mathematical concepts that are demonstrated by teachers' operation of technology. Therefore, the mathematics education in Macao still follows a traditional "sage on the stage" transmission of knowledge approach for the teaching of mathematics. That is, a mathematics teacher mainly teaches about a mathematics topic by lecturing on general principles before illustrating how these principles can be applied in mathematical contexts through either traditional or technological means. After that, students practice these taught principles. Teachers perceive that this approach is efficient to achieve the taught content within the limited instructional time (Bryan et al., 2007). While this approach has been valued in the Macao SAR due to students' good performance in the Program for International Student Assessment (PISA) (OECD, 2012), some researchers have questioned its ability in motivating students as more than 40% of students in Macao hold negative attitudes towards mathematics (Cheung et al., 2013).

Overview of Dynamic Mathematics Lessons

Dynamic mathematics lessons were designed with the intention to foster students' positive attitudes towards mathematics through the integration of DGS. Inquiry-based learning has the potential to develop a positive attitude towards the subject and to deepen learning (Prince, 2004). The principle of inquiry-based learning was embedded in lesson design, where students were given real-world problems to observe with, experiment, analyze and solve with guidance provided by the teacher. Students had to make active use of DGS to explore, test, and verify mathematical concepts. They had opportunities to discuss the problem with classmates using DGS and an inquiry worksheet. The inquiry worksheet included instructions, cues, and prompts that formed a scaffold for students during the whole learning process. Such an inquiry-based instructional approach is substantially different from what mathematics teachers are practicing in the Macao classroom (Cai & Wang, 2010). Teachers have been hesitant to employ a constructivist approach of instruction as teachers believe that this approach takes more instructional time, and they are not sure about its effect on students' learning.

One private secondary school in Macao was willing to implement dynamic mathematics lessons. Based on the school mathematics curriculum, the school allocated five lessons for the implementation of an inquiry-based instructional approach. The topic was about the concept


Topic 4 the Translation of Linear Function

Question：What is the relationship between two linear functions when they have the same k?

Resource: LF4. ggb

Steps:

1. **Open** LF4.ggb，**observe and complete** the following questions (5 minutes)

The function that line L1 represents is:

The function that line L2 represents is:

What's the relationship between line L1 and line L2?

Why they have this relationship? Please give your guess:

2. **Drag** slider k，**observe** the Algebra and the drawing area, complete the following questions (6 minutes)

(1) What happens to the expressions of L1 and L2?

(2) What happens to the graphs of L1 and L2?

Figure 1. A worksheet of the dynamic mathematics lesson

of linear function and its multiple representations. Students were given a worksheet as shown in **Figure 1**. Following the instruction written in the worksheet, students explored the properties of linear function in the DGS environment as shown in **Figure 2**.

Participants

Participants (n=51) were grade 10 students (female=26 and male=24) aged 15 to 18 years old enrolled in a private secondary school in Macao. One student did not report a gender. After students experienced the dynamic lessons, they were invited to provide their beliefs about the dynamic mathematics lessons.

Data Collection

In order to evaluate the effect of the inquiry-based dynamic mathematics lessons and shed light on the potentials for its future improvement, students were given an anonymous questionnaire that tapped into their beliefs about the dynamic mathematics lessons; one part collected demographic information such as gender and age while the other part collected information about their beliefs. Students were asked to use food (Kaplan, 2000) and animal (Woodside, 2008) metaphors to

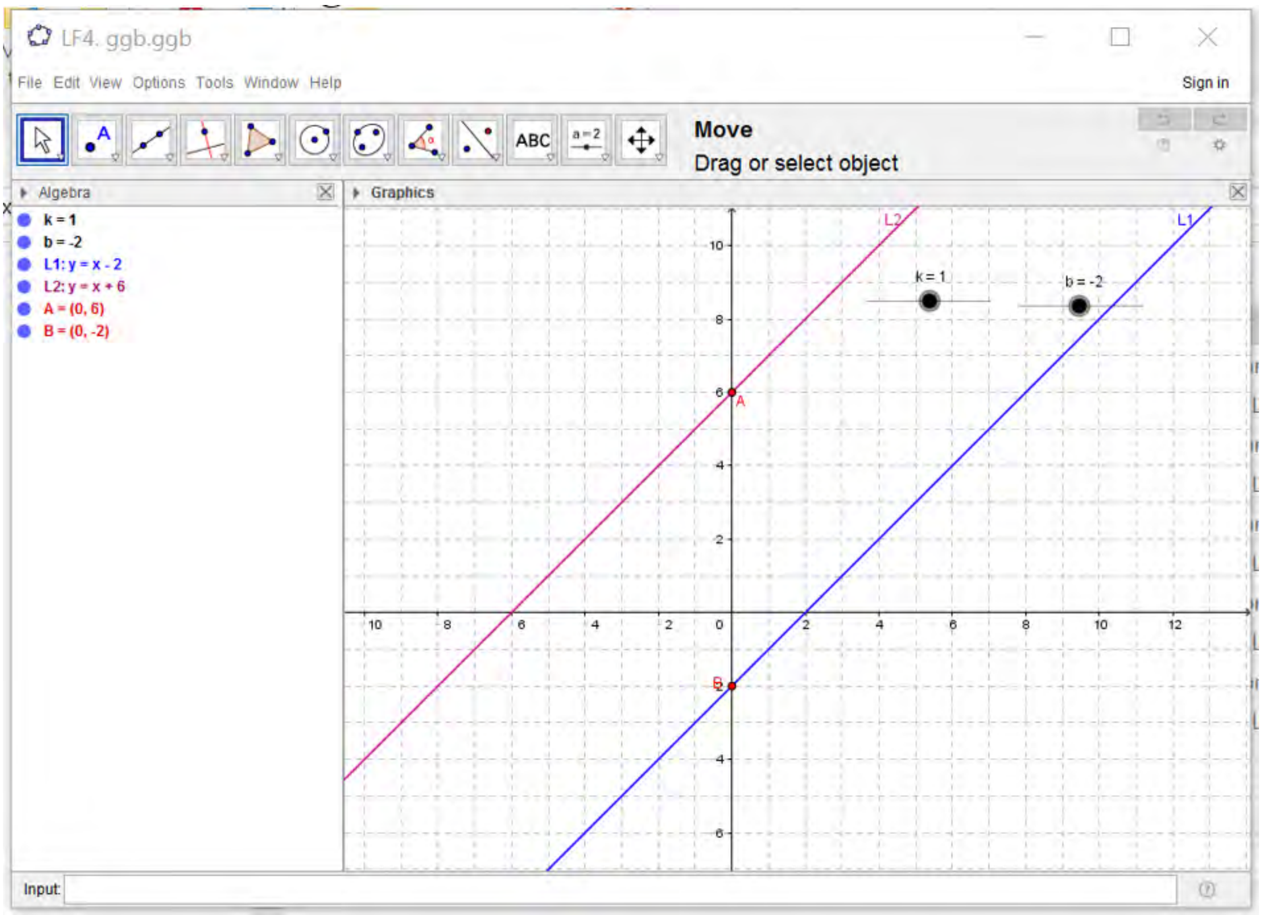


Figure 2. The DGS working environment

describe their experience of the dynamic mathematics lessons. The rationale of using these two metaphors is that they are quite concrete to adolescents. Students may easily associate these two metaphors with their attitudes of the dynamic mathematics lessons.

To avoid the problem of metaphor responses being too ambiguous and abstract to be interpreted accurately (Lim, 1999), a series of Likert scale items with the following anchors were included: 1 strongly disagree, 2 disagree, 3 neutral, 4 agree, and 5 strongly agree. These items were designed to assess students' views on various factors in the process of the inquiry-based dynamic mathematics lessons. Factors included role of teachers, DGS, learning materials, peers, compatibility, self-perceived control of technology, students' overall judgments of the dynamic lessons, and their intention to learn via dynamic lessons. Since students had to explore mathematical concepts in the DGS environment with their peers using a worksheet, their view on DGS, learning materials, and peers were measured. Research shows that if students perceive control of a technology, they are more likely to use it (Davis et al., 1989). As such, their perceived control of DGS was collected. The compatibility of new practice with existing practice is also conducive to effective learning (Rogers, 2003). Students' views on the compatibility of the dynamic lessons with existing practice was measured as it is an indicator of their engagement in such environment. Finally, to provide an avenue for potential improvements of the intervention, students were asked to provide their views on potential areas for improvements. The Cronbach alpha calculated was 0.965 which showed that the internal consistency of the questionnaire responses was reliable. The time required for completion of the questionnaire was about 20 minutes.

Data Analysis

For the open-ended items, collected data were analyzed using the systematic metaphor analysis procedures proposed by Schmitt (2005). Metaphor analysis has the potential to reduce the complexity of qualitative research data into more clearly structured patterns. First, valid metaphors constructed by the participants were identified. If a student did not provide an explanation for a metaphor, that metaphor was considered as invalid. Second, valid metaphoric responses were categorized into positive, negative, or mixed feelings by two independent researchers. For example, a male student, A4, used "salmon, a fresh experience" to describe his feelings of the dynamic mathematics lessons and he amended that "the feature of this lesson is collaborating with peers". His metaphor was classified as positive. After that, the first level beliefs

Table 1. Metaphoric beliefs of students on the inquiry-based dynamic mathematics lessons

Themes	Food (n=51)	Male (n=24)	Female (n=26)	Animals (n=51)	Male (n=24)	Female (n=26)
Positive feelings	25	17	7	24	16	8
Negative feelings	19	6	13	23	7	15
Mixed feelings	7	1	6	4	1	3
Total	51	24	26	51	24	26

Table 2. Positive beliefs of students' metaphors in food and animal with frequency

Theme	Sub-theme	Metaphors	Frequency	Total
Food	Environment	Apple, banana, egg, herbal tea, lemon, & vegetables	8	
	Pedagogy	Apple, banana, bread, curry beef rice, ginseng, green chili, kinder egg, potato chips, salmon, snack, stinky tofu, & vegetables	13	
	Outcome	Bitter gourd & collagen	4	25
Animal	Environment	Bee, cat, cockroach, cow, fish, leopard, monkey, puppy, snack, & amoeba	10	
	Pedagogy	Cat, panda, puppy, & tiger	9	
	Outcome	Insect, puppy, & rabbit	5	24

were further classified into subcategories of environments, pedagogy and outcomes based on the second round of coding. The metaphor of the student, A4, was further coded as pedagogy. The student described his positive experience of the dynamic mathematics lessons and chance to communicate with classmates. First, two researchers separately grouped students' metaphors. After that, they cross-checked their codes to reach consensus. For Likert scale items, descriptive statistics such as mean and standard deviation, was calculated to support the results of the metaphor analysis.

RESULTS

Metaphoric Beliefs of Students About the Inquiry-Based Dynamic Mathematics Lessons

Students used a variety of foods and animals to represent their beliefs about the dynamic mathematics lessons. Themes and frequency of students' metaphoric beliefs about the inquiry-based dynamic mathematics lessons are listed in **Table 1**. Students' beliefs of the dynamic mathematics lessons were polarized. About half of the participants enjoyed learning mathematics through use of DGS while the other half did not. A few of them had mixed feelings about this instructional approach. For example, two students described the dynamic mathematics lessons using the food metaphor "bitter gourd". They acknowledged the benefits of dynamic lessons as eating healthy food. On the other hand, they perceived the process of learning unenjoyable and similar to the bitter taste of the bitter gourd. In total, students were able to name 37 different types of food and 17 different types of animals to represent their beliefs about the dynamic mathematics lessons. The complete list of food and animal metaphors named by the students are provided in **Appendix A**. Among the food metaphors, apple was the most popular with five students having used it to express their positive attitudes. Among the animal metaphors, puppy was the most popular among students. Thirteen students associated puppy with their experience of the dynamic mathematics lessons. Some of them perceived the dynamic lessons as interactive and comprehensible while some did not enjoy the new learning environment. Since one student did not report a gender, the number of positive food metaphors and the number of negative animal metaphors were not equal to the sum of the corresponding metaphors provided by male and female students.

Positive beliefs about the inquiry-based dynamic mathematics lessons

Themes and frequency of students' positive metaphoric beliefs of the inquiry-based dynamic mathematics lessons are listed in **Table 2**.

Eight students showed their affection towards the inquiry-based dynamic learning environment with the food metaphors of "apple", "banana", "egg", "herbal tea", "lemon" and "vegetables". The integration of DGS in the learning environment was supported by students. They considered this environment as interesting, attractive, and useful because of the availability of the computer for them to explore and learn. The following quotes illustrate students' views.

> "The textbook is like bitter water. The availability of the computer is better than a textbook and pen" (B33, male).

> "Learning in the computer room is more interesting and catches my attention" (A6, female).

Similarly, students used different animals to represent their views of the dynamic mathematics lessons. In terms of environment, eleven students used "bee", "cat", "cockroach", "cow", "fish", "leopard", "monkey", "puppy", "snake" and "amoeba" to express their views of the new learning environment. For example, a female student, B30, used monkey to express the efficiency of "learning in the computer environment"

Table 3. Negative beliefs of students' metaphors in food and animal with frequency

Theme	Sub-theme	Metaphors	Frequency	Total
Food	Environment	Coca cola with salt, enoki mushroom, fried food, potato chips, sweets, & water	6	
	Pedagogy	Chewing gum, durian, green chili, junk food, onions, & leftovers	6	
	Outcome	Bark, chewing gum, disgusting food, junk food, grass, papaya, & rice	7	19
Animal	Environment	Cat, puppy, snake, & tiger	8	
	Pedagogy	Bacteria, cockroach, donkey, fox, & mosquito	8	
	Outcome	Cockroach, fly, mosquito, mouse, snake, & puppy	7	23

and the potential of "developing self-learning ability". A male student, A14, used "a large number of fish" to mean the various functions in DGS and it was "helpful to learn about the topic" and "enjoyable".

In terms of pedagogy, thirteen students expressed their appreciation for the chance of discussion in class and teacher's clear instruction. They used the food metaphors of "apple", "banana", "bread", "curry beef rice", "ginseng", "green chili", "kinder egg", "potato chips", "salmon", "snack", "stinky tofu" and "vegetables". Examples of students' responses illustrate their preference of such approach to learning.

> "The teacher's instruction was clear, so it was easy to understand" (A9, male).

> "I can discuss the question with my classmate. This enhances my understanding of the topic" (A19, female).

For animal metaphors, nine students used "cat", "panda", "puppy", and "tiger" to express similar views. For example, a male student, B24, used puppy to express his preference of the "interactive" approach of the instruction and warned about the potential issue of "distraction" at the same time. Another female student, B1, explained the following challenge:

> "It is not easy to achieve a successful discussion if one has little knowledge of dogs (the topic or discussion skills)" (B1, female).

To represent their views about the positive learning outcome of the dynamic mathematics lessons, four students used the food metaphor "collagen" and "bitter gourd", and five students used the animal metaphor "insect", "puppy", and "rabbit". The students shared:

> "It is great to learn with this approach" (A25, male).

> "Learning in the computer room is more enjoyable and relaxing. I hope that we can always learn in the computer room" (B17, male).

A male student, A1, used rabbit to express his view of the dynamic mathematics lessons with reason of "very good! Interesting! Vivid". A female student, B3, justified her positive view of the dynamic mathematics lessons by sharing that this approach was "more relaxing than typical instruction" like a puppy.

Negative beliefs of the inquiry-based dynamic mathematics lessons

Themes and frequency of students' negative metaphoric beliefs of the inquiry-based dynamic mathematics lessons are listed in **Table 3**.

Six students did not enjoy the inquiry-based dynamic learning environment. They used the food metaphors of "coca cola with salt", "enoki mushroom", "fried food", "potato chips", "sweets", and "water" to express their feelings. They noted the demand of the new learning environment. For example, a female student used the metaphor of coca cola with salt to express her concern of the new learning environment. She did not enjoy learning in the computer room because of the increased physical and cognitive demand.

> "I have to walk five floors to get to the computer room, and I feel tired physically and mentally" (B5, female).

Similarly, seven students expressed their concern of new learning environment with the animal metaphors "cat", "puppy", "snake", and "tiger". They questioned the effectiveness of such a learning environment. For example, a male student, B20, used the snake metaphor to show his dislike of learning with the computer and questioned the suitability of such learning environments for all students.

In terms of pedagogy, six students expressed their concern of the chance of discussion in class and teacher's clear instruction. Common metaphors in this subgroup included "chewing gum", "green chili", "junk food, "onions", "papaya", and "leftovers". A female student, B27, showed her preference of learning from the teacher rather than discussion with classmates through the metaphor "Papaya, looks good on the outside, hard to eat the inside". For animal metaphors, four students used "bacteria", "cockroach", "donkey", and "fox" to express their views. A male student, B7, used donkey to express his concern of the active learning in the dynamic mathematics lessons as "a greater degree of freedom." He also questioned the effect of such an approach by sharing that "Dynamic math is not for everyone". A female student, B12, used mosquito to acknowledge the pedagogy of inquiry-based learning being "flexible" but also expressed her feeling of annoyance.

For the negative learning outcomes, seven students expressed their beliefs with the food metaphor of "junk

Table 4. Descriptive statistics of students' view on the inquiry-based dynamic mathematics lessons

	Students	SD	Male	SD	Female	SD
Overall judgment	2.94	.80	3.49	.83	2.67	.79
Compatibility*	2.87	.89	3.39	.86	2.57	.88
Future intention	2.88	.78	3.37	.82	2.62	.72
Role of teacher*	3.26	.74	3.64	.70	3.09	.76
Role of peers	3.29	.68	3.57	.68	3.14	.69
Role of learning materials	3.01	.78	3.40	.80	2.85	.85
Role of DGS*	3.10	.88	3.60	.89	2.87	.82
Self-perceived control*	3.16	.86	3.63	.82	2.90	.83

Note. *$p<0.05$

food", "chewing gum", "disgusting food", "grass", "papaya", "rice", "bark," while five students used the metaphor of "cockroach", "fly", "mouse", "snake", "puppy", "mosquito". These students did not like the approach and found it boring and uninteresting. For example, a female student, A18, used the "onion" metaphor to express that she did not like it. Another female student, A11, used serious term of "leftovers" to express her negative view of "even worse and boring than usual math lesson."

Additional Indicators of Students' Beliefs about the Inquiry-Based Dynamic Mathematics Lessons

Students' responses to the Likert scale items are presented in **Table 4**. Students' overall responses to the items were less than three. This implies that their beliefs about the dynamic mathematics lessons were slightly negative. The indicator of compatibility (M=2.87) may explain students' overall impression (M=2.94) and intention (M=2.88). Students found that the dynamic mathematics lessons were different from the typical instruction because they were not used to being provided inquiry opportunities in class. Aside from these three indicators, all the other indicators in **Table 4** were above three. Participants were neutral about the role of the teacher, peers, the DGS and learning materials in the process of learning. Students confirmed the support of teacher and their classmates in the learning process. All these sources helped them to learn about the mathematics topics. In addition, students believed that they were capable of using DGS to explore the mathematics topic.

Male and female students' perceptions of the dynamic mathematics lessons

Comparison of male and female students' metaphoric beliefs in **Table 1** found that boys had more positive feeling codes and less negative feeling codes than girls. In addition, students' responses to the Likert scale items in **Table 4** showed that the score of the boys is higher than that of the girls. Boys seemed to be more comfortable with the inquiry-based instruction in which they had to explore and verify mathematical ideas through discussion with peers while using DGS. While they perceived that they could manage to use DGS, they also appreciated the facilitating role of teacher. On the other hand, many indicators of the girls were below three. Girls were not as enthusiastic about this new instructional approach. They found that the dynamic lessons were quite different from the common practice of learning mathematics. They were not familiar with DGS and the teaching resources. They seemed to show less confident in using DGS too and were less willing to have the dynamic lessons. An independent-samples t-test was further conducted to compare the beliefs of students in term of gender on various elements of the dynamic mathematics lessons. There was a significant difference in the scores by gender for various elements of dynamic mathematics lessons as shown in **Table 4**. Results suggest that boys involved in this study preferred dynamic mathematics lessons more than the girls involved in this study.

DISCUSSION

The purpose of the present study was to explore students' beliefs about the inquiry-based dynamic mathematics lessons through the use of contemporary metaphor theory. As shown in the *Results* section, students used rich and vivid metaphors to express their beliefs about the dynamic mathematics lessons supporting the finding of Schnick et al. (2008). Students' metaphors were positive and negative, and helped them to explain their beliefs of learning mathematics with DGS. The positive metaphors expressed through food or animal metaphors ranged from 47% to 49% of the participants. This group of students perceived that the dynamic mathematics lessons were necessary and pleasant. Positive views of dynamic mathematics lessons have been supported by Erbas and Yenmez (2011). The negative metaphor group expressed in food or animal metaphors ranged from 37% to 45% of students. They considered the dynamic mathematics lessons as difficult and unpleasant. This result is similar to the findings reported by Latterell and Wilson (2016).

Students' positive metaphors revealed that the dynamic mathematics lessons were interesting, interactive, convenient, and valuable because they had the chance to learn mathematics and interact with peers and the DGS environment. They found that the hands-on practice of learning was fresh and helpful to understand the mathematics concepts (Adelabu & Makgato, 2019; Bokosmaty et al., 2017). Students who had a positive attitude towards the dynamic mathematics lessons felt the experience was rewarding and even precious. They preferred the collaborative interactive learning environment (Zengin & Tatar, 2017). On the other hand, students noticed the effort needed to engage in the dynamic mathematics environment. They were not accustomed to an inquiry approach of instruction where they were required to explore and examine mathematical concepts with the DGS environment. Students' self-evaluation of the role of DGS in facilitating learning and their self-perceived control of DGS was average which implied that they were not well prepared to learn in the DGS environment. The survey items that measured students' views of different elements in the dynamic mathematics lessons verified students' negative opinions expressed through the negative metaphors.

Similar to previous findings (Noyes, 2006; Schinck et al., 2008), this study found that students held reservations about the inquiry approach of learning in the dynamic environment. As participants in this study were requested to explore DGS by themselves for the first time, they were uncertain about the new instructional practice using technology and inquiry learning. They felt unpleasant during the learning process, as this approach was different from their existing instruction. Possible explanations for this finding are given as follows:

1. The short duration of the intervention might be a reason why students expressed more direct personal feeling.
2. Dynamic lessons designed with the principle of inquiry were new to students and incompatible with their existing practice of learning mathematics.
3. Students were not accustomed to learning with limited teachers' oral guidance because they were used to receiving instruction only from teachers.
4. Their negative attitudes towards mathematics was well developed so their view could not be changed easily after only a short intervention (Cheung et al., 2013).

Hence, the finding seems to reveal that they were not well prepared to engage in the inquiry-based dynamic mathematics lessons. Evidence of students' metaphoric responses showed that boys engaged more in the dynamic mathematics lessons than girls. Boys were more inclined towards the technology environment and the new approach of instruction. Results from the survey data also confirmed that the acceptance of boys towards the inductive approach of the dynamic mathematics lessons was comparatively higher than that of the girls. Girls' self-perceived control of DGS was significantly less than that of the boys. More girls indicated difficulty in understanding mathematics concepts presented in the dynamic lessons. Therefore, the study supported the existing research on gender difference in attitudes towards the use of technology in mathematics (Cai et al., 2017). It seems to suggest that that boys were more comfortable with this inductive approach of learning with DGS more than that of girls (Erbas & Yenmez, 2011; Vale & Leder, 2004). This study confirms the findings of Tsai and Tsai (2010) that boys like to use exploration-oriented tasks in technological environments.

Students in the study held complex beliefs about the inquiry-based approach of instruction. They found the new process of learning challenging and rewarding, but they also indicated negative feeling towards the new approach of instruction. Following the logic of embodied cognition (Núñez et al., 1999), it is hypothesized that the context of the intervention might have affected students' perception of the dynamic mathematics lessons. Students' beliefs about the dynamic mathematics lessons identified in this study may have been affected by their well-developed beliefs and attitudes towards mathematics. Many students in Macao hold negative attitudes towards mathematics (Cheung et al., 2013). In addition, other factors such as duration of the instruction and the mathematics culture in Macao society may have further affected students' beliefs. More study should be conducted to verify these conjectures.

Implications for Theory and Practice

The study filled the research gap of providing empirical evidence of students' perceptions of dynamic mathematics lessons through the lens of the contemporary theory of metaphor. Even though DGS-based instruction has the potential to improve students' achievement, its effect might be decreased if there is no consideration of students' beliefs of dynamic mathematics lessons. In order to maximize the impact of dynamic mathematics lessons, students' beliefs should be taken into consideration. This study provides findings that mathematics teachers should consider in real classroom contexts. With reference to the metaphoric beliefs of students, teachers should provide interactive learning environments for students to discuss and solve problems. They should clarify students' concerns about the new learning environment before asking students to engage in such learning. As some students still preferred the teacher's direct instruction, teachers should plan more diversified pedagogical activities to meet the different learning approaches of students.

Limitations

This study is limited in several ways. First, participants in this study were mainly in grade 10 of a private secondary school in Macao. Hence, replication studies are needed in order to generalize the results of this study to secondary students in other contexts and even primary students in Macao. Within the field of embodied cognition, the findings of this study might be affected by cultural issues. Study of students' perceptions of dynamic mathematics lessons in other cultures should be conducted in the future. The duration of students' experience of the dynamic mathematics lessons was short in this study. A longitudinal study is needed to track students' perception of the dynamic environment. It would be interesting to know if there is any change in their perception after some time. Pre-service and in-service teachers' perceptions of dynamic lessons should also be investigated as teacher beliefs can also affect teachers' instructional practices.

CONCLUSION

Integration of technology into mathematics education changes pedagogy. It also requires students to adapt to a new learning environment. This study involved an inquiry-based dynamic mathematics lessons where students learned in pairs to explore mathematics concepts. It examined students' perception of the constructivist approach of dynamic mathematics lessons through the contemporary theory of metaphor. Students' metaphoric expressions and survey data showed that students had different beliefs about the inquiry-based dynamic lessons. This study provides valuable information for practitioners to design a better learning environment using DGS technology.

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REFERENCES

Adelabu, F. M., & Makgato, M. (2019). Attitudes of male and female students to dynamic geometry computer software for learning mathematics. *World Transactions on Engineering and Technology Education, 17*(3), 314-319.

Baki, A., Kosa, T., & Guven, B. (2011). A comparative study of the effects of using dynamic geometry software and physical manipulatives on the spatial visualisation skills of pre-service mathematics teachers. *British Journal of Educational Technology, 42*(2), 291-310. https://doi.org/10.1111/j.1467-8535.2009.01012.x

Birgin, O., & Topuz, F. (2021). Effect of the GeoGebra software-supported collaborative learning environment on seventh grade students' geometry achievement, retention and attitudes. *The Journal of Educational Research, 114*(5), 474-494. https://doi.org/10.1080/00220671.2021.1983505

Bokosmaty, S., Mavilidi, M.-F., & Paas, F. (2017). Making versus observing manipulations of geometric properties of triangles to learn geometry using dynamic geometry software. *Computers & Education, 113*, 313-326. https://doi.org/10.1016/j.compedu.2017.06.008

Bryan, C. A., Wang, T., Perry, B., Wong, N. Y., & Cai, J. (2007). Comparison and contrast: similarities and differences of teachers' views of effective mathematics teaching and learning from four regions. *ZDM, 39*(4), 329-340. https://doi.org/10.1007/s11858-007-0035-2

Cai, J., & Wang, T. (2010). Conceptions of effective mathematics teaching within a cultural context: Perspectives of teachers from China and the United States. *Journal of Mathematics Teacher Education, 13*(3), 265-287. https://doi.org/10.1007/s10857-009-9132-1

Cai, Z., Fan, X., & Du, J. (2017). Gender and attitudes toward technology use: A meta-analysis. *Computers & Education, 105*, 1-13. https://doi.org/10.1016/j.compedu.2016.11.003

Chan, K. K., & Leung, S. W. (2014). Dynamic geometry software improves mathematical achievement: Systematic review and meta-analysis. *Journal of Educational Computing, 51*(3), 311-325. https://doi.org/10.2190/EC.51.3.c

Chan, K. K., & Zhou, Y. C. (2020). Effects of cooperative learning with dynamic mathematics software (DMS) on learning inversely proportional functions. *International Journal of Emerging Technologies in Learning, 15*(20), 210-225. https://doi.org/10.3991/ijet.v15i20.14339

Cheung, A., & Slavin, R. (2013). The effectiveness of educational technology applications for enhancing mathematics achievement in K-12 classrooms: A meta-analysis. *Educational Research Review, 9*, 88-113. https://doi.org/10.1016/j.edurev.2013.01.001

Cheung, K. C., Sit, P. S., Mak, S. K., & Ieong, M. K. (2013). *Macao PISA 2012 report: Assessment of mathematical, scientific and reading literacy performance of 15-year-old students from an international comparison perspective*. https://www.oecd.org/pisa/keyfindings/pisa-2012-results-overview.pdf

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management Science, 35*(8), 982-1003. https://doi.org/10.1287/mnsc.35.8.982

Devine, A., Fawcett, K., Szűcs, D., & Dowker, A. (2012). Gender differences in mathematics anxiety and the relation to mathematics performance while controlling for test anxiety. *Behavioral and Brain*

Functions, 8(1), 1-9. https://doi.org/10.1186/1744-9081-8-33

Else-Quest, N. M., Hyde, J. S., & Linn, M. C. (2010). Cross-national patterns of gender differences in mathematics: A meta-analysis. *Psychological Bulletin, 136*(1), 103. https://doi.org/10.1037/a0018053

Erbas, A. K., & Yenmez, A. A. (2011). The effect of inquiry-based explorations in a dynamic geometry environment on sixth grade students' achievements in polygons. *Computers & Education, 57*, 2462-2475. https://doi.org/10.1016/j.compedu.2011.07.002

Font, V., Bolite, J., & Acevedo, J. (2010). Metaphors in mathematics classrooms: Analyzing the dynamic process of teaching and learning of graph functions. *Educational Studies in Mathematics, 75*(2), 131-152. https://doi.org/10.1007/s10649-010-9247-4

Funkhouser, C. (2002). The effects of computer-augmented geometry instruction on student performance and attitudes. *Journal of Research on Technology in Education, 35*(2), 163-175. https://doi.org/10.1080/15391523.2002.10782377

Guven, B., & Karatas, I. (2009). Students discovering spherical geometry using dynamic geometry software. *International Journal of Mathematical Education in Science and Technology, 40*(3), 331-340. https://doi.org/10.1080/00207390802641650

Isiksal, M., & Askar, P. (2005). The effect of spreadsheet and dynamic geometry software on the achievement and self-efficacy of 7th-grade students. *Educational Research, 47*(3), 333-350. https://doi.org/10.1080/00131880500287815

Kaplan, E. B. (2000). Using food as a metaphor for care middle-school kids talk about family, school, and class relationships. *Journal of Contemporary Ethnography, 29*(4), 474-509. https://doi.org/10.1177/089124100029004003

Koklu, O., & Topcu, A. (2012). Effect of Cabri-assisted instruction on secondary school students' misconceptions about graph of quadratic functions. *International Journal of Mathematics Education in Science and Technology, 43*(8), 999-1011. https://doi.org/10.1080/0020739X.2012.678892

Lai, M. Y. (2013). Constructing meanings of mathematical registers using metaphorical reasoning and models. *Mathematics Teacher Education and Development, 15*(1), 29-47.

Lakoff, G. (1993). The contemporary theory of metaphor. In A. Ortony (Ed.), *Metaphor and thought* (pp. 202-251). Cambridge University Press. https://doi.org/10.1017/CBO9781139173865.013

Lakoff, G., & Johnson, M. (1980). *Metaphors we live by*. University of Chicago Press.

Latterell, C. M., & Wilson, J. L. (2016). Math is like a lion hunting a sleeping gazelle: Preservice elementary teachers' metaphors of mathematics. *European Journal of Science and Mathematics Education, 4*(3), 283-292. https://doi.org/10.30935/scimath/9470

Lim, C. S. (1999). *Using metaphor analysis to explore adults' images of mathematics*. https://education.exeter.ac.uk/research/centres/stem/publications/pmej/pome12/article9.htm

Markovits, Z., & Forgasz, H. (2017). "Mathematics is like a lion": Elementary students' beliefs about mathematics. *Educational Studies in Mathematics, 96*(1), 49-64. https://doi.org/10.1007/s10649-017-9759-2

Martínez, M. A., Sauleda, N., & Huber, G. L. (2001). Metaphors as blueprints of thinking about teaching and learning. *Teaching and Teacher Education, 17*(8), 965-977. https://doi.org/10.1016/S0742-051X(01)00043-9

Niebert, K., Marsch, S., & Treagust, D. F. (2012). Understanding needs embodiment: A theory-guided reanalysis of the role of metaphors and analogies in understanding science. *Science Education, 96*(5), 849-877. https://doi.org/10.1002/sce.21026

Noyes, A. (2006). Using metaphor in mathematics teacher preparation. *Teaching and Teacher Education, 22*(7), 898-909. https://doi.org/10.1016/j.tate.2006.04.009

Núñez, R. E., Edwards, L. D., & Matos, J. F. (1999). Embodied cognition as grounding for situatedness and context in mathematics education. *Educational Studies in Mathematics, 39*(1-3), 45-65. https://doi.org/10.1023/A:1003759711966

OECD. (2012). *Closing the gender gap*. OECD Publishing. https://doi.org/10.1787/9789264179370-en

OECD. (2015). *The ABC of gender equality in education: Aptitude, behaviour, confidence*. OECD Publishing. https://doi.org/10.1787/9789264229945-en

Olivero, F., & Robutti, O. (2007). Measuring in dynamic geometry environments as a tool for conjecturing and proving. *International Journal of Computers for Mathematical Learning, 12*(7), 135-156. https://doi.org/10.1007/s10758-007-9115-1

Pettit, S. K. (2011). Teachers' beliefs about English language learners in the mainstream classroom: A review of the literature. *International Multilingual Research Journal, 5*(2), 123-147. https://doi.org/10.1080/19313152.2011.594357

Philipp, R. A. (2007). Mathematics teachers' beliefs and affect. In F. K. Lester (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 257-315). National Council of Teachers of Mathematics.

Pierce, R., Stacey, K., Wander, R., & Ball, L. (2011). The design of lessons using mathematics analysis software to support multiple representations in secondary school mathematics. *Technology, Pedagogy and Education, 20*(1), 95-112. https://doi.org/10.1080/1475939X.2010.534869

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education, 93*(3), 223-231. https://doi.org/10.1002/j.2168-9830.2004.tb00809.x

Rogers, E. M. (2003). *Diffusion of innovations*. Free Press.

Schinck, A. G., Neale, H. W., Pugalee, D. K., & Cifarelli, V. V. (2008). Using metaphors to unpack student beliefs about mathematics. *School Science and Mathematics, 108*(7), 326-333. https://doi.org/10.1111/j.1949-8594.2008.tb17845.x

Schmitt, R. (2005). Systematic metaphor analysis as a method of qualitative research. *The Qualitative Report, 10*(2), 358-394.

Selaković, M., Marinković, V., & Janičić, P. (2020). New dynamics in dynamic geometry: Dragging constructed points. *Journal of Symbolic Computation, 97*, 3-15. https://doi.org/10.1016/j.jsc.2018.12.002

Skilling, K., Bobis, J., & Martin, A. J. (2020). The "ins and outs" of student engagement in mathematics: Shifts in engagement factors among high and low achievers. *Mathematics Education Research Journal, 33*, 469-493. https://doi.org/10.1007/s13394-020-00313-2

Thomas, G. P., & McRobbie, C. J. (2001). Using a metaphor for learning to improve students' metacognition in the chemistry classroom. *Journal of Research in Science Teaching, 38*(2), 222-259. https://doi.org/10.1002/1098-2736(200102)38:2<222::AID-TEA1004>3.0.CO;2-S

Tsai, M.-J., & Tsai, C.-C. (2010). Junior high school students' Internet usage and self-efficacy: A re-examination of the gender gap. *Computers & Education, 54*(4), 1182-1192. https://doi.org/10.1016/j.compedu.2009.11.004

Vale, C. M., & Leder, G. C. (2004). Student views of computer-based mathematics in the middle years: Does gender make a difference? *Educational Studies in Mathematics, 56*(2-3), 287-312. https://doi.org/10.1023/B:EDUC.0000040411.94890.56

Willox, A. C., Harper, S. L., Bridger, D., Morton, S., & Orbach, A. S., Silvia. (2010). Co-creating metaphor in the classroom for deeper learning: Graduate student reflections. *International Journal of Teaching and Learning in Higher Education, 22*(1), 71-79.

Wong, N. Y. (2003). The influence of technology on the mathematics curriculum. In A. J. Bishop, M. A. Clements, C. Keitel, & F. K. S. Leung (Eds.), *Second international handbook on mathematics education* (pp. 271-321). Kluwer Academic. https://doi.org/10.1007/978-94-010-0273-8_10

Woodside, A. G. (2008). Using the forced metaphor-elicitation technique (FMET) to meet animal companions within self. *Journal of Business Research, 61*(5), 480-487. https://doi.org/10.1016/j.jbusres.2007.06.029

Zengin, Y., & Tatar, E. (2017). Integrating dynamic mathematics software into cooperative learning environments in mathematics. *Journal of Educational Technology & Society, 20*(2), 74-88.

Zilka, G. C. (2020). Teenagers connected to digital environments–what happens when they get to school? Commonalities, similarities and differences from their perspective. *Education and Information Technologies, 25*(3), 1743-1758. https://doi.org/10.1007/s10639-019-10052-y

APPENDIX A

Table A. The complete list of food and animal metaphors named by students

Food	Food	Food	Food	Animal	Animal
Apple	Collagen	Grass	Pickled vegetables	Cow	Amoeba
Banana	Curry beef rice	Green chili	Potato chips	Cat	Mosquito
Bark	Durian	Junk food	Rice	Cockroach	Mouse
Bitter gourd	Egg	Kinder chocolate	Salmon	Donkey	Panda
Bread	Enoki mushroom	Kiwi	Sauce	Fish	Puppy
Candy	Feces	Lemon	Snack	Fox	Rabbit
Chewing gum	Fried food	Medicine	Stinky toufu	Koala	Snake
Coffee	Fruit	Onion	Vegetables	Leopard	Tiger
Coke with salt	Ginseng	Papaya	Water	Monkey	
Coke with mentos					

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