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Perspective

Mathematics skills and STEM multidisciplinary literacy: Role of learning capacity

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Abstract: Previous studies highlighted the role of STEM (science, technology, engineering, and mathematics) education in the development of mathematical skills while how mathematical skills influence STEM multidisciplinary literacy is under researched. Therefore, the purpose of current study is to explore the significance of mathematical skills (spatial imagination ability, calculation ability, and reasoning ability) in STEM multidisciplinary literacy. Further, to better understand the relationship between mathematical skills and STEM multidisciplinary literacy, students learning capacities was investigated as a mechanism. The theoretical findings of the study show that spatial imagination ability, calculation ability, and reasoning ability positively linked with STEM multidisciplinary literacy. Additionally, the findings show that students learning capabilities mediate the relationship between mathematical skills and STEM multidisciplinary literacy. Future directions of the study are also discussed.

Keywords: STEM multidisciplinary literacy, spatial imagination ability, calculation ability, reasoning ability, learning capacities

1. Introduction

STEM is a multidisciplinary approach that gives students a learning environment to use science, technology, engineering, and mathematics in their everyday lives. Previous research argued that the amalgamation of STEM training in science, technology, engineering, and mathematics has the advantage of developing the STEM education program in the national economy, institutes, and teachers [1]. Knowledge and skills in STEM education can be transferred to the future issues and help individuals in their careers [2]. The practitioners and scientists believed that the students could study mathematics and science and also think of the future through their careers in science, technology, and engineering [3].

Wolfmeyer, Lupinacci, and Chesky [4] and Kumashiro [5] intended to examine the significant role of science and mathematics in STEM education to improve the economy and compete globally. Previous research also argued that mathematics “plays no less a colonizing role than any other discipline” [5]. It is not difficult to find examples in the previous studies explaining that getting STEM education provides opportunities to enhance the improvement of mathematical skills [6, 7]. However, these examples do not recognize the nature of the reciprocal relationship between mathematics and STEM. Many examples illustrated that STEM education provided opportunities of supporting the expansion of mathematical concepts and ideas but did not demonstrate that mathematics can also contribute to and influence the understanding of STEM disciplines or STEM literacy concepts and ideas.

The current theoretical study focuses on the influence of mathematical skills of learners including spatial imagination ability, calculation ability, and reasoning ability on STEM multidisciplinary literacy. Spatial imagination ability is defined as the ability to formulate mental images and to manipulate these images in the mind corresponding to the perception of an object [8]. Calculation ability refers to the ability to count, group objects, and compute mathematical facts and operations. Similarly, reasoning ability refers to a process of concluding a problem-solving from a given problem [9]. Previous studies highlighted that these skills are related to superior performance on counting tasks [10], nonverbal problem solving [11] as well as better overall mathematical attainment and performance [12, 13]. However, in the previous literature, the relationship of mathematical skills and STEM multidisciplinary literacy is under researched. Therefore, to enrich the current body of knowledge in this area, our theoretical study investigates the relationship between mathematical skills and STEM multidisciplinary literacy.

Moreover, this study considers how the underlying mechanism of learning capacities (i.e., innovation consciousness, and quality consciousness) can affect the translations of various mathematical skills to STEM multidisciplinary literacy. The extant literature has generally revealed that despite several inherent benefits of mathematical skills; however, mathematics still appears to be a discipline often underrepresented in integrated STEM based activities [14, 15]. The reason might be the inability to integrate mathematical skills with STEM multidisciplinary literacy due to the hidden factor that must explain the interconnecting mechanism between mathematical skills and STEM multidisciplinary literacy. Therefore, we expect that learning capacities might be that hidden factor which will mediate the relationship between mathematical skills and STEM multidisciplinary literacy.

In summary, this paper intends to elaborate two research perspectives: do mathematical skills positively influence STEM multidisciplinary literacy? and do learning capacities mediate the relationship between mathematical skills and STEM multidisciplinary literacy?

2. STEM multidisciplinary literacy

Science, technology, engineering, and mathematics were brought together into the STEM acronyms in the 1990s. These disciplines were actually used as the SMET, but were later converted to STEM because of phonatory reasons. In order to maintain the national economic competitiveness, the initiative was designed to improve the skills of young people and adults in STEM education. This approach was employed in order to create a more powerful unified political voice by engineers, scientists, mathematicians, and technologists. As a consequence, the first results were seen in 2005 when the Virginia Technology University introduced a STEM degree [15], as an approach that highlighted the role played by the education in ensuring the delivery of adequate STEM training [16]. From then on, international attention in the educational field was raised in the STEM acronym.

The focus of STEM is a multidisciplinary approach, including problem-solving and inquiry to get ready learners in the area of STEM education, and produce a large number of graduates to be prepare of STEM occupations [17]. Moreover, the focus of STEM education is to improve the skills and abilities of students in STEM which are in line with the 21st century skills for example, problem-solving, collaboration, critical thinking, self-directed learning, creativity, and technological, scientific and environmental literacy. Precisely, current literature suggested five domains for promoting STEM involvement which include competence and reasoning, career knowledge and acquisition, attitude and behavior, interest and engagement, and content knowledge [3].

STEM education and STEM literacy are closely related. Bybee [18] stated that one of the biggest challenges globally faced by STEM education is to develop STEM literacy as an aim and the identification of new curriculum programs, learning outcomes, and teaching practices. At present, there is no specific arrangements from any professional institutions who clearly present the definition of STEM literacy. Zollman [19] stated that "STEM Literacy is the literacies of science, technology, engineering and mathematics which commonly stated as four STEM strands, (a) Science literacy is defined as the ability of students to use and process to understand scientific knowledge such as physics, chemistry, biology and earth and space science; (b) Technology literacy is defined as the ability to operate and demonstrate technology effectively and productively to conduct research and solve the problem collaboratively; (c) Engineering literacy is defined as the ability to apply scientific and mathematics principal systematically and creatively to utilize practical ends; (d) Mathematics literacy is defined as the ability to identify, understand and engage in mathematics to think creatively about solving problems". Furthermore, Prima et al. [3] explained the STEM Literacy as the ability to identify, apply, and integrate concepts from science, technology, engineering, and mathematics to understand complex problems and provide solutions.

We used STEM literacy as a dependent variable in this research, and are theoretically investigating in the light of mathematical skills such as spatial imagination ability, calculation ability, and reasoning ability. To further clarify the relationship between mathematical skills and STEM literacy, we also intend to explore the mediating role of learning capacities.

3. Mathematical skills and STEM literacy

Schmidt and Houang [20] regarded mathematics as a foundation of the other disciplines of STEM because it functions as a language of all different fields like science, engineering, and technology. Therefore, the point of concern is the role of mathematics in STEM learning contexts. Mathematics has always been considered as a discipline that plays a supporting role in integrative STEM education. However, mathematics should be given more acknowledgment and be regarded as a facilitator in understanding the concepts in other disciplines. According to Silk, Higashi, Shoop, and Schunn [21], this can be done by 'repeatedly foregrounding' it and pushing other disciplines into the background. This shift in focus will bring mathematics back in the focus where the instrumental nature of the mathematics will reflect its explicitness within STEM learning contexts. This research is therefore, undertaken to determine theoretically the role of mathematical skills (i.e., spatial imagination ability, calculation ability, and reasoning ability) which will put mathematics more effectively to the forefront of learning experiences and STEM literacy.

3.1. Spatial imagination ability

Spatial imaging is defined as the ability to formulate mental images and handle these images in the mental according to an object's perception [8, 22]. Space capacity is recognized as an individual's ability, partly independent of general intelligence. However, in general there are various definitions of spatial capacity and of a different number of sub factors (2-10; according to D'Oliveira [23]) with still more labels. Therefore, the precise definition of 'spatial capacity' is difficult [24]. In general, spatial skills relate to the ability of "individuals to search for visual fields, to understand the forms, forms and positions of objects as seen, to form and manipulate mental representations of those forms, and positions mentally" [25]. In other words, it is necessary to establish and retain an internal representation of a perceived scene so that mental manipulations are possible.

Previous research has shown that almost 40% of mathematics contents such as trigonometry, algebra and calculus may include geometry at school level [26]. The goal is to improve the mathematical thoughts, logics, and spatial intuition of students about the real environment. Indeed, the geometry (space and surface) surrounds and forms our lives. Therefore, mathematical learning should be based on the understanding of the spatial dimensions of the life of our students. The main aim of the geometry learning project is to enable students to better understand spatial concepts and procedures found in their lives and thus to be able to solve the problems of space in their real lives [27] . Many studies have shown that the ties between different spaces and performance measurements are moderate to strong, especially in relation to STEM disciplines. A variety of space skills are, for example, positively linked to biological success [28]. Rochford [29] also pointed to problems in their practical anatomy classes in students with difficulties in space processes including sectioning, translating, rotating, and visualizing forms. These and several related results led Gardner [30] in concluding that "it is spatial capability that determines how far one is to progress in science". Therefore, we suggest that STEM multidisciplinary literacy is led by spatial imagination.

3.2. Calculation ability

Calculation is a process of summing, subtracting, multiplying, and dividing the numbers used in accordance with the prescribed procedures [31]. Calculation ability in children is the child's initial ability to gain knowledge about addition, subtraction, multiplication, and distribution of real numbers in accordance with predetermined rules. Although there has constantly been researched that fundamental computation skills covary with mathematical achievement (for example [32-34]), there are still uncertain reasons for this relationship. In elementary education the significance of basic calculation is emphasized, but there are different beliefs as to what constitutes competence and how to develop this skill [35, 36]. These observations may impact on the learning of children at home and in school.

The conventional view equates expertise with long-term storage of the simple calculation solutions for fast recovery. The advocates consider the learning of skills through rote memorization and practice. For mental and written arithmetic involving large numbers, application of arithmetic to daily life and advancement in mathematics, and the development of expertise are significant. While many US and

UK elementary teachers in mathematics still emphasize memorized solutions as the basis for computational fluence, they consider conceptual awareness to be an important part of their growth [37]. This view is defined by Baroody [35] as '*conventional wisdom*' and is focused on three different stages of growth. Primarily, by counting and using their fingers, children solve simple calculation problems. In the second level, arithmetic principles and knowledge of other combinations are applied, for example, by means of solving between 14 and 7 in the sense that subtraction is the opposite of addition and knowledge of the related truth, 7 + 7 = 14. The family of techniques known as decomposition constitutes solving problems by using concepts, relevant data, or decomposing numbers into bits. Finally, the child will find the answers [37].

Ability to calculate is needed in all human lives [38]. Researchers have consistently reported a positive relationship of mathematics/calculation skills with statistics courses and quantitative method courses performance [39]. Bayliss and Watts [40] explained why mathematics provide basis for the study of chemistry, in which mathematics enable chemistry students to draw useful conclusion about yield and energy, compositions, balances in reacting systems and other chemistry concepts that requires calculations and computation. Additionally, Adeboyel [41] stated significant dissimilarities in the performance of students having varied calculation abilities levels in science. Based on the above literature, we argue that calculation ability will positively influence STEM multidisciplinary literacy. Therefore, we propose that calculation ability leads to STEM multidisciplinary literacy.

3.3. Calculation ability

The capacity to render a reasoning refers to a method to overcome the problem [9]. Turmudi [42] argued that the capacity for mathematical reasoning is a brain dwelling like other housing, which must be built continuously in many contexts. Nurdalilah [43] states that reasoning is one way of thinking of relating two or more cases based on character and a certain law which has admitted the truth by taking demonstrative action until it has been concluded. Lithner [44] also claimed that the argument is an adopted thinking in order to obtain a statement that is not always based on the formal logic and that it is therefore unlimited in a proof. On the basis of the above claim, an operation, a process of thought or thinking, can be inferred or a new statement can be made right.

Basically, during the course of the mathematical learning process the students used the reasoning application. In [45], it states that "mathematical material and mathematical reasoning are two things that cannot be divided, namely that by reasoning the material can be understood, and by learning the math". This means that every mathematical problem has to be reasoned and some questions should be posed in special design to practice, so that pupils are accustomed to answering the questions. Mathematics is the reason why mathematical science is created or built. Using the rationalization of motives and character to generalize, to organize facts, or to justify ideas, the mathematical statement is necessary to improve the reasoning skills of students on the basis of a mathematical study [46], and students are expected to see that the mathematics is a logical study.

Lithner [44] explained that the rationale is an accepted way of thinking and seeking a solution of problems that does not always depend on formal logic. Students who are good at mathematical reasoning will experience and participate in developing meaningful knowledge and abilities which in turn apply and pass to solve new and more complex mathematical or other problems. Prima et al. [3] have suggested that reasoning is an important part of the literacy of STEM. We suggest that STEM multidisciplinary comprehension should also contribute to the skill of reasoning.

4. Mediating role of learning capacities

Capacity, in general, represents the potential to perform at peak levels [47]. Learning capacities are defined in the current study as the abilities to integrate mathematical skills or knowledge into STEM multidisciplinary literacy. Learning capacities are investigated in the current study as innovation consciousness and quality consciousness. Consciousness refers to human brain psychological awareness and intentional behavior [48] while innovation refers to the degree to which the new idea of an individual or a group of people is accepted relatively earlier than others [49]. The degree of knowledge to incorporate mathematical abilities into STEM multidisciplinary literacy relates to the degree of awareness of creativity. Innovative students are keen to learn, embrace and use new skills easily and effectively [50]. The combination of mathematical competences with STEM multidisciplinary literacy will thus grow creative spirits in students and facilitate positive and dynamic learning, so as to allow student's critical thinking capabilities to develop more efficiently and prolifically. The use of mathematical skills to enhance the standard of STEM multidisciplinary literacy refers to a high-quality sense of knowledge. Quality is a factor responsible for the success of the student [51]. The mathematical knowledge necessary for students will allow quality education and multidisciplinary STEM literacy to be given. Therefore, students are required to implement mathematical skills in multidisciplinary literacy if they are aware that mathematical skills boost education quality.

As stated earlier, mathematical skills are related to superior performance on counting tasks [10], nonverbal problem solving ability [11], as well as better overall student performance [13, 52]. Therefore, mathematical skills can also lead to enhance students learning capacities. Learning capacities enable students to learn new concepts and skills, and utilize them in the learning process effectively [50]. Hence, it is expected that student's mathematical skills improves learning capabilities, which in turn will positively influence STEM multidisciplinary literacy. We likewise assume that the learning capacities will mediate the relationship between mathematical skills and STEM multidisciplinary literacy as shown in Figure 1.

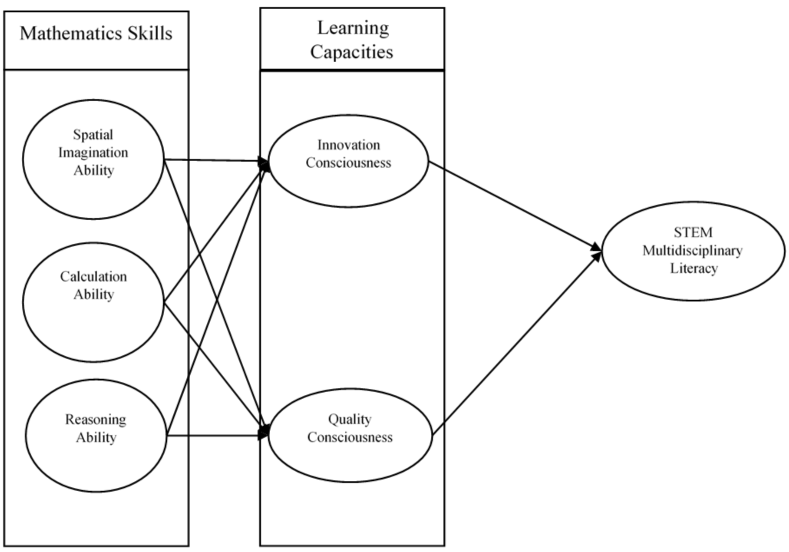

Figure 1. The conceptual model among mathematical skills, learning capacities and STEM multidisciplinary literacy

5. Conclusion and future work

Many researchers demonstrated the importance of STEM multidisciplinary literacy as a learning environment in which students are allowed to use science, technology, engineering, and mathematics in everyday life. Therefore, scholars argued that integrating STEM education has the advantage of developing this education program for the domestic economy, institutes, and professors [1] and that it offers knowledge and skills which are transferable to future problems and can help individuals in their professional lives [2]. Therefore, this paper suggests that certain mathematical skills such as spatial imagination ability, calculation ability, and reasoning ability might have a positive influence on individuals' STEM multidisciplinary literacy. We also propose that learning capacities (innovation and quality consciousness) would help to transform individuals' mathematical skills towards their STEM multidisciplinary literacy.

Although we suggested the possible areas which can advance the role of mathematics in STEM multidisciplinary literacy, including mathematical skills and students learning capacities, and a theoretical model which explains the relationship among mathematical skills, learning capacities, and STEM multidisciplinary literacy, a broader experimental and empirical research project should be conducted to test these mentioned propositions.

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