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# Knowledge Management:
## The Missing Bonding Discipline of STEM Education

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### ABSTRACT

STEM education has become vital to equip the next-generation knowledge workers for Industry 4.0 world. STEM education refers to a curriculum based on the teaching of science, technology, engineering and mathematics, aiming to prepare students with critical thinking, collaboration, communication, and creative thinking (4C) abilities. STEM education and its associated industry market have tremendously grown in the past decade. Developing knowledge management skills and understandings are equally critical in equipping lifelong knowledge workers. The knowledge, skills, attitudes, and abilities to identify, search, analyse, apply and disseminate information and media products are essential. However, knowledge management-related education programs, curricula or frameworks for K-12 education still need to be made available. This article examines the common characteristics of STEM and KM education, investigates the current practice of KM in STEM education in Hong Kong, and proposes a STEM curriculum with KM learning elements for K-12 education.

### KEYWORDS

Information Literacy, Knowledge Management Education, Knowledge Process, Personal Knowledge Management, STEM Education

### INTRODUCTION

Knowledge management (KM), a critical component of modern organizations, promotes the effective leveraging and sharing of intellectual capital. There has been an increasing importance of science, technology, engineering, and mathematics (STEM) education. In turn, there has also been a growing interest in exploring the potential of introducing KM education in K-12 STEM education. STEM education has become a focal point in preparing future generations to meet the challenges of technological advancement and global competitiveness.

Educators, organizations, academia, and governments have recognized the need for new skills and abilities since the early 1980s as specialization and professional knowledge in specific domains are no longer the only success factors for future workers. Instead, learning-based skills, people skills, and applied skills have become critical. Today, success is more than just learning and applying

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existing content knowledge. It also includes managing and generating new knowledge. For example, Partnership for 21st Century Learning (Battelle for Kids, 2019) identified three areas of mastery: (1) learning and innovation skills (creative thinking, collaboration, communication, critical thinking, and problem solving); (2) life and career skills; and (3) information, media, and technology skills. The National Research Council (2012) identified core abilities like cognitive competencies, critical thinking, problem solving, adaptive learning, information literacy, active listening, and innovation.

The competencies required by 21st-century knowledge workers include learning how to use knowledge effectively, search for the knowledge needed, generate new knowledge, organize and store knowledge, and share knowledge to benefit the larger whole. In the past decades, countries have developed education and training programs at professional, higher education, and K-12 levels to prepare current and future workforces. However, there have been few efforts to train students to handle knowledge in a proper and organized way for their long-term benefits.

KM is a valuable approach in the working environment. Yet education programs for KM only start at senior grades of higher education or the post-graduate level. Given that STEM education is being prioritized at all levels of education, especially K-12 groups preparing the future workforce, why is KM education not considered equally important?

With this background, this article aims to investigate the feasibility of introducing KM education in K-12 STEM education programs. Can KM education be introduced in K-12 STEM education programs? The article first conducts a comprehensive literature review to identify STEM and KM education characteristics. Then, it reports the use of a mixed research method, including three interviews with STEM teachers and one survey with STEM students, to identify the KM characteristics implicit in STEM education. The methodology, data collection, analysis, and findings are reported. The article then proposes the KM elements that can be integrated into STEM curriculum. Finally, the article discusses the limitations and significance of the study.

This is a concept article that seeks to provide a comprehensive understanding of the potential of integrating KM education into K-12 STEM education programs. Consequently, it is not an empirical paper that reports interventions to an existing program. Instead, the article aims to propose a STEM curriculum that includes KM learning elements in the program. The proposed curriculum is based on the literature review and mixed-method research findings, providing a framework for future research and implementation. By doing so, the article contributes to filling the gap in KM education for K-12 students.

## LITERATURE REVIEW

### STEM Education

STEM was adopted by the United States government and the private sector as a strategy for global competitiveness. Dr. Charles E. Vela, founder of the Center for the Advancement of Hispanics in Science and Engineering Education (CAHSEE), coined the term "STEM" and launched the STEM Institute in 1992. The National Science Foundation (NSF) funded the Science, Technology, Engineering, and Mathematics Teacher Education Collaborative (STEMTEC) in 1997 to "produce more, better prepared, and more diverse K-12 science and math teachers" and to conduct course re-design" (Sternheim, 2017, para.1).

The practical implementation of STEM around the world has grown. The United Kingdom was the first country to add coding to their K-12 curriculum in 2015. Every Year 7 student receives a free BBC micro:bit, a pocket-size computer, to learn to code. In June 2021, China's State Council issued the National Science Literacy Action Plan (2021-2035), noting that the main reason for introducing STEM in the country is the realization of a lack of "interdisciplinary scientific thinking, innovation, and the ability to solve practical problems" (The State Council of the People's Republic of China, 2021, para. 3.1). The research and publication of STEM education also increased, especially in the last five years. The top countries and regions with scholars who contribute to STEM education research in English publications include the U.S., UK, Australia, Canada, and Taiwan (Li et al., 2020).

Vela (2021) conceptualized STEM when he worked on the mapping of the brain at the Institute of Medicine, recognizing the complexity of the human genome, the need for information management, and the value of integrated knowledge (Martin & Pechura, 1991). The principles he affirmed in solving complex problems require deep and broad knowledge, an open mind, an interdisciplinary approach, and different bodies of knowledge, disciplines, and technologies.

The specific learning characteristics in STEM differ from other subjects. Integrated STEM education requires a holistic approach. It links the disciplines to make the education meaningful, focused, and relevant to learners and prepare globally competitive human capital (Johnson et al., 2021; Shahali et al., 2011).

### KM Education

KM education dates to the 1990s when it emerged as a discipline to manage and leverage intellectual capital in organizations. Initially, it focused on information management, technology, and library science. It expanded to include organizational learning, human resource management, and business strategy. With the rise of digital technologies, KM education now covers data analytics, artificial intelligence, and machine learning topics. Additionally, the emergence of social media and online collaboration tools has led to the development of new approaches to knowledge sharing and collaboration.

KM education is offered at all levels of education, from professional development courses to undergraduate and graduate degree programs. Integrating KM education into K-12 education is a relatively new concept. In fact, there have been limited efforts to introduce KM concepts into K-12 curricula. One reason is the perception that KM is a complex and abstract concept that may be difficult for younger students to grasp. Additionally, there is a lack of standardized KM education materials and curricula designed for K-12 students.

KM education is an interdisciplinary field that integrates knowledge and methods from various disciplines to understand KM comprehensively. KM education aims to enable students to understand and apply KM principles in real-world settings. The education emphasizes the use of technology, tools, and platforms to support KM practices in organizations. It also supports the development of social and community-oriented skills like communication, collaboration, and leadership. Active learning approaches (i.e., problem-based learning, case studies, and group projects) provide students with practical experience in applying KM concepts and tools in a real-world context.

### Similarities Between STEM Education and KM Education

Literature related to STEM education and KM education in Web of Science and Google Scholars are identified, respectively. Publications that concern the curriculum and teaching content of the respective domains are outside the scope of this article and are filtered. The papers related to the subjects' nature and pedagogy are examined. The characteristics are grouped into themes. Table 1 summarizes the characteristics of STEM education with identified themes.

Table 2 summarizes the characteristics of KM education with identified themes.

The literature review draws similarities between STEM education and KM education in the following aspects:

- Disciplinary integration (Multidisciplinary/Interdisciplinary/Transdisciplinary)
- Context relevance
- Social and community focus
- Use of technologies

## RESEARCH METHODS AND RESULTS

STEM education prepares 21st-century knowledge workers to respond to the rapid development and global competitiveness of a digitalized and technologically advanced world. It is equally important,

**Table 1. Characteristics of STEM education**

| Characteristics | Description | References |
|---|---|---|
| Disciplinary Integration (Multidisciplinary, Interdisciplinary, Transdisciplinary) | STEM education is a meta-discipline that integrates knowledge across domains. Integration can be multidisciplinary, interdisciplinary, or transdisciplinary. Multidisciplinary is defined as different disciplines working together and leveraging their disciplinary knowledge. Interdisciplinary is the integration of knowledge and methods from different disciplines using synthesis approaches. The interdisciplinary approach acknowledges the limitations inherent in the compartmentalized system of knowledge in various disciplines. Transdisciplinary goes beyond integrating disciplines, directly engaging with the production and use of knowledge outside a single discipline. It is recognized as the creative social process of knowledge production implementing group processes. Disciplinary integration in STEM can result in a synthetic whole that is greater than the sum of its parts. | Miller (1982), Morrison (2006), Sengupta et al. (2019), Shanahan et al. (2016), Takeuchi et al. (2020), Toomey et al. (2015) |
| Context Relevance | STEM integration has three forms: (1) content; (2) context; and (3) application/tool integration. Content and context are fundamental in education, with content referring to the subject matter and context referring to the situation where it is learned or understood. Discussions and debates highlight the need to shift from content-focused to context-focused education, as purely conceptual and theoretical principles may not be helpful in real-life situations. Deep content knowledge must be situated in an authentic and engaging context that enables students to recognize its relevance in the complex world. Providing an environment that allows an authentic context in learning is essential. Integrated STEM education should be connected to the real world and the community of students to be socially and culturally relevant. | Burrows et al. (2018), Johnson (2011), Moore et al. (2020, 2021), Pickering (2019) |
| Constructivism | Constructivism is an approach to learning that emphasizes active knowledge construction by the learners rather than passive knowledge transfer from the teacher. Knowledge is seen as complex and socially constructed. Learners make personal meaning of their experiences. Collaborative construction of knowledge among peers is vital. Learning is considered a generative and revisionary process. STEM education often involves real-life problem-solving activities that enable students to build their understanding through collaboration and communication. | Amala Jayanthi and Shanthi (2020), Asunda (2014), Brown et al. (1989), He (1997), Knowles et al. (2014), Magolda (2003), Moore et al. (2021), Mpofu (2019), Sanders (2009), Zollman (2012) |
| Connectivism | Connectivism, influenced by technological advances, sees learning as a network process connecting previous knowledge with present information to create new meanings and understandings. Some researchers apply the principles of connectivism in STEM classes, involving connections between the learner and technological and social networks, self-discovery of knowledge using technology, and social learning with peers and teachers. | Downes, 2019; Duke et al., 2013; Siemens, 2004; Smidt et al. (2017) |

if not more, that the next generations know how to manage their knowledge and put them to the best use by learning how to extract, organize, store, use, share, and create knowledge. Knowledge workers in the 21st century will work in multidisciplinary fields with advanced technology content and a highly complex transdisciplinary and integrated context. They will need ongoing construction of their knowledge based on existing and new knowledge and experience. Advanced knowledge in connecting with technologies for their work is required. STEM education with the characteristics listed provides a suitable environment to train students in KM to adapt to this work and life environment. This research aims to identify the KM elements in current STEM education and the possibility of integrating KM education into the STEM curriculum.

**Table 2. Characteristics of KM education**

| Characteristics | Description | References |
|---|---|---|
| Disciplinary Integration (Multidisciplinary, Interdisciplinary, Transdisciplinary) | KM education draws on multiple disciplines, including information science, organizational behavior, business strategy, and human resource management. The interdisciplinary approach integrates knowledge and methods from various domains (i.e., information science, computer science, business, psychology, and sociology) to comprehensively understand KM. The transdisciplinary approach goes beyond bridging knowledge disciplines and directly engages with the production and use of knowledge outside a single discipline. This approach recognizes that KM involves the management of explicit knowledge and tacit knowledge and social processes that occur in various contexts. | An et al. (2014), Bedford et al. (2017), Quarchioni et al. (2022), Takhom (2020) |
| Context Relevance | KM education combines theoretical concepts with practical application to enable students to understand and apply KM principles in real-world settings. KM theories include Nonaka and Takeuchi's SECI model, Polanyi's tacit knowledge theory, Wenger's communities of practice theory, and Brown and Duguid's situated learning theory, are best taught in a setting that is student-centred, engaging, and interactive, enabling learners to actively engage with the theories and apply them in a practical context. The approach should also foster a sense of community and collaboration, reflecting the social- and community-oriented nature of KM theories. Active learning, experiential learning, social learning, and reflective learning are examples of practical approaches. | Bedford et al. (2017), Brown et al. (1989), Owoc and Weichbroth (2020), Sun et al. (2017) |
| Community and Social Focused (Constructivism) | KM education recognizes that knowledge is not just stored in documents or databases. It also resides in the minds of individuals and within social networks. Therefore, KM education often focuses on developing social- and community-oriented skills (i.e., communication, collaboration, and leadership) on supporting effective knowledge management practices.<br>KM education fosters a community and social focus through active learning approaches, such as problem-based learning, case studies, and group projects. These approaches require students to work together to solve problems, share knowledge, and collaborate to achieve common goals. They help develop social- and community-oriented skills and provide students with practical experience in applying KM concepts and tools in the real world. | Bedford et al. (2017), Jörg (2010), Schmitt (2022), Tjakraatmadja (2022) |
| Use of Technology (Connectivism) | Technology is critical in creating, storing, sharing, and disseminating knowledge. KM education emphasizes using technology tools and platforms to support KM practices in organizations. The primary goal of a KM system is to enable organizations to capture, organize, and disseminate knowledge assets effectively. These knowledge assets can include explicit knowledge (documents, reports, and best practices) and tacit knowledge (expertise and experience). A personal learning environment network (PLEN) is based on a personal learning network (PLN) concept. A PLEN is a system or set of tools that individuals use to manage and support their learning. | Bedford et al. (2017), Deng (2012), Dneprovskaya (2020), Schmitt (2022), Tjakraatmadja (2022) |

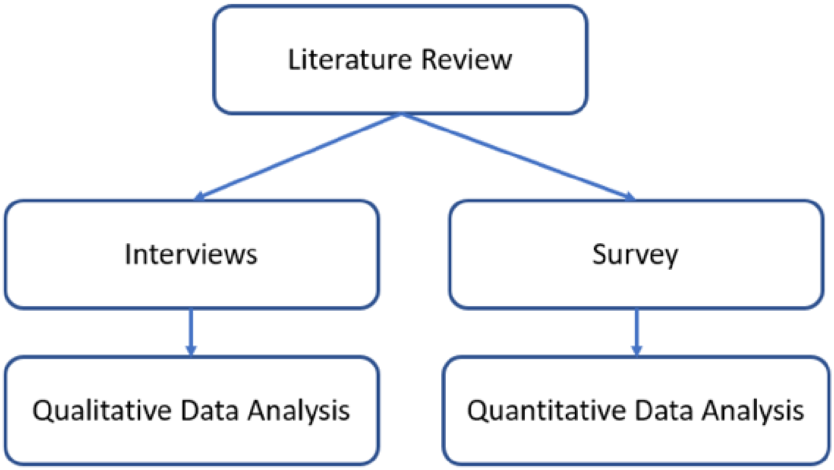
## Methodology

The current study adopts a mixed methods approach, combining literature review, quantitative and qualitative data collection, and analysis. Figure 1 illustrates the mixed-method flow.

The study conducted semi-structured interviews with STEM teachers in Hong Kong K-12 schools. The following four questions were prepared to frame the interviews:

1. Can you briefly describe how you developed the lesson plan for the STEM classes?
2. What are the different types of knowledge or abilities you want the students to learn in the STEM classes?
3. Do you have any KM-related experiences or concepts that you apply in your STEM classes?
4. What abilities do you want to teach your students so they can apply themselves in the future?

**Figure 1. Research Methodology**




The questions were used to initiate the conversation. Follow-up questions were used to deepen and clarify the understanding. The interviews were audio recorded. The conversations were transcribed and coded, followed by a qualitative data analysis.

A survey was also developed for students who attended a STEM summer program. A total of 17 questions were developed. The first question identified the class attended by the student. Ten questions inquired about the student's self-assessment on the increase of knowledge and learning interest after attending the STEM program. Six questions asked about the different knowledge sources of the STEM program. The results were analyzed quantitatively.

## Qualitative Data Collection and Data Analysis

Three full-time in-school STEM teachers were interviewed between December 2021 and February 2023. Table 3 lists the profiles of the teachers. The names of the teachers and schools are replaced with codes for anonymity.

The interviews were recorded and transcribed in Chinese (the language used in the interviews). Only those quotes in this article were translated into English. The transcriptions were read repeatedly for a complete understanding of the data. Then, sentences and phrases conveying similar ideas were grouped into codes. Similar codes were categorized and grouped into broader themes. Table 4 reports these themes. It is supported with interview details.

## Quantitative Data Collection and Data Analysis

The survey was collected on July 27, 2022. It was the last class of the summer STEM program at School BS. The summer STEM program had three classes: (1) media creation; (2) maker class; and (3) robotics and coding. Forty-nine students (25 female, 24 male) in the junior secondary grades were in attendance. A total of 41 responses were collected in Google Forms and analyzed.

Part 1 of the questionnaire identified each students' class. There were 8 (19.5%) respondents from media creation, 15 (36.6%) from maker class, and 18 (43.9%) from robotics and coding. Part 2 asked about the level of agreement with the statements. A Likert scale had a rating of 1 (strongly disagree) to 5 (strongly agree). Table 5 presents the mean and standard deviation of the responses.

Part 3 of the questionnaire asked about the sources of knowledge the students received in class. The Likert scale ranked from very rarely (1) to very frequently (5). Table 6 presents the mean and standard deviation of the responses.

**Table 3. Profiles of Interviewees**

| Teacher | School | Teaching Experience (years) | STEM Teaching (years) | Responsibilities of Teachers Related to STEM Education | School Information Relating to STEM Education |
|---|---|---|---|---|---|
| A | AS | 3 | 8 | Teaches ITC classes; leads after-school STEM interest groups; leads inter-school STEM competitions; leads ITC curriculum development | A secondary school ranks in the top 1% in Hong Kong. It prioritizes innovation and technology as one of the major learning areas and offers both classroom lessons and extra-curricular activities. The school also participates in external STEM and ICT local and international competitions. |
| B | BS | 3 | 5 | Teaches science classes; chief coordinator for overall school STEM courses; leads STEM curriculum development | Students are mainly from grassroots families and new immigrants. STEM education is new to the school. However, the school board and principal want to establish a STEM program and identify students interested in STEM to be trained in after-class interest groups and inter-school competitions. A formal STEM curriculum for S1-S3 will be introduced in the next year. |
| C | CP | 3 | 5 | eLearning and STEAM development team leader; supervisor of ITC subjects | A top-ranking primary school in Hong Kong. STEAM learning was introduced in all grades. Runs after-school interest class for selected students. An eLearning Development and STEAM team is established to promote information literacy to students, teachers, and parents. |

The students' end-of-program survey indicates that students feel that the STEM course has increased both their knowledge and interest in STEM topics. In addition, they indicate that the STEM course used constructive, inquiry-based, collaborative, and reflective pedagogies. The course has enabled the students to use their KM skill in knowledge discovery.

Regarding the source of knowledge, the teacher's teaching, hands-on experience, and discussion with classmates are equally important. Knowledge networks enable the students to learn from the teachers and with each other through knowledge sharing.

## DISCUSSION

### STEM Education With the KM Lens

The characteristics of STEM education and KM education are identified through the literature review. In many aspects, they share common elements. The interviews indicate that STEM teachers are aware of a need and desire to enhance students' KM skills through the teaching of STEM. The survey also indicates that students can learn KM through the STEM curriculum and pedagogies. The following subsections examine the possible correlations between KM concepts and STEM education.

#### *DIKW Model*

The data, information, knowledge, and wisdom (DIKW) model underlines various concepts (Henry, 1974; Zins, 2007). Ackoff (1989) defined a hierarchical model with data (symbols) as observations, information as processed data, knowledge as the application of information, and wisdom as values and the exercise of judgement. Zeleny (1987) added "enlightenment," creating the DIKWE chain. This includes "know-nothing," "know-what," "know-how," "know-why," and "know yourself." Criticisms and debates of the DIKW point out that a linear DIKW model is not fit for a complex system due to its lack of feedback and interdependence (Frické, 2009; Yao, 2020).

**Table 4. Qualitative Data Analysis of Theme and Sub-Themes**

| Theme | Subthemes | Quotes and/or Summaries |
|---|---|---|
| Purpose of STEM Education | Cultivating interest and experience | Teaching coding is not just to teach programming. Rather, use the different platforms to allow them to try out, experience the difficulties, and develop smarter ways of doing things. |
| | Appreciating technologies | Not every student will become a programmer or AI expert, but all need to appreciate the products. Everyone will be a user of new technologies and applications. Educating them to be able to search for the right tools is equally important to writing codes. |
| | Positive mindset | The training should enable the students to face challenging problems with a positive attitude. They should not fear failure … they should continue trying different solutions. |
| | Preparation for APL studies | The STEM learning experience can support the students to have better preparation for their APL (applied learning) studies in their senior secondary curriculum. |
| Methods of STEM Education | Collaborative learning | The lessons include motivational games, live situational problems, hands-on exercises, brainstorming, group discussions, design of possible solutions, testing, teaching concepts, challenges for improvements, and reflections. |
| | Constructivism | We teach STEM from shallower to deeper level. |
| | Project-based learning | The idea was generated based on one student's experiences when her friend encountered an asthma attack in primary school. |
| | Inquiry-based learning | I provided little guidance on what and how a solution should be found. I allowed the two students to use an inquiry-based approach to independently investigate, explore, search, research, and study to develop the solution. |
| | Depends on teacher's background | I am the teacher responsible for science subjects. First of all, STEM is promoted in my science classes … STEM activities relate to science … we mainly use computer class as a carrier for STEM. A teacher shared a project that uses programmable humanoid robots equipped with a unique walking mechanism. This enables each limb's movement individually. An AI camera with image recognition reads sheets of music. The robots read the music and play instruments with students in real time. |
| | Moving from interdisciplinary to transdisciplinary | In fact, after a few years of STEM, we will have independent STEM subjects in our junior high school next year. We really want to consider a more complete and integrated curriculum for Secondary 1 to 3. |
| Tools Used in STEM Education | Software | Scratch, micro:bits, Pythons, CoSpaces (for AR/VR), Metaverse |
| | Hardware | Intelligent cars, IoT, Marty the Robot, artificial intelligence and robotics (AIR), drones, 360 cameras |
| | KM | We teach them to use an image to do a reverse Google search. For example, we ask the students to use a picture of a popular singer to learn more about him. Then, we use Google Docs and Google Slide to integrate and store the information. When taking notes, we use Google Note and mind-mapping to record what they have learned. |
| | Concept introduction | Teachers must keep abreast with new technologies and introduce them to the students at appropriate times and levels. For example, ChatGPT is a hot – but controversial – topic. We've decided to introduce that to the students with the school's TV broadcast (in the form of news reporting) to help students have an awareness of the technology. |
| Abilities Developed with STEM Education | Problem-solving skills | Problem-solving skills are a frequently mentioned ability. The teachers want the students to develop this skill. |
| | Creativity | Creativity is also a frequently mentioned ability that the teachers want students to develop. |
| | Information literacy | Information literacy helps students learn other knowledge. Information literacy is to be able to use IT ethically. |
| | Awareness of new knowledge and applications | We can't teach them everything. New technologies are arising so fast … they should have an awareness of new knowledge and applications. |

*continued on following page*

**Table 4. Continued**

| Theme | Subthemes | Quotes and/or Summaries |
|---|---|---|
| | Human relationships | Work that involves human interactions will still be needed. During the project, one student will recognize that different people have different abilities. They must understand the differences among their classmates. You have your strength … and he has his strengths. Will trust in people diminish? |
| KM with STEM Education | Finding new knowledge | STEM is basically giving students a context to apply KM. They should know how to find new knowledge. |
| | Using retained knowledge | STEM is basically giving students a context to apply KM. They should know how to find new knowledge. |
| | Sharing knowledge effectively | Each student should have the freedom to decide how to organize and store their explicit knowledge. But they should be trained to be aware of the need to prepare the knowledge to share with others effectively and efficiently. |

**Table 5. Student Survey Results on Learning and Interest**

| | Level of Agreement to the Statements | Mean | Standard Deviation |
|---|---|---|---|
| 1. | The course increases my knowledge about the learning topics. | 3.80 | 1.10 |
| 2. | The course increases my interest in the learning topics. | 3.76 | 1.09 |
| 3. | I now know how to find the relevant information I need. | 3.66 | 1.15 |
| 4. | I now know where to find the relevant information I need. | 3.73 | 1.14 |
| 5. | I have continued to study related topics outside the class time. | 3.61 | 1.12 |
| 6. | The course allows me to use my creativity. | 3.73 | 1.14 |
| 7. | I have positive discussions with my classmates in the group. | 3.80 | 1.14 |
| 8. | This is a pleasant learning experience. | 3.83 | 1.12 |
| 9. | I want to continue to participate in the STEM course. | 3.71 | 1.17 |
| 10. | I want to have deeper learning in this subject. | 3.71 | 1.10 |

**Table 6. Student Survey Results on Sources of Knowledge**

| Source of knowledge | Mean | Standard Deviation |
|---|---|---|
| Teacher's teaching | 3.88 | 0.71 |
| Discussion with classmates | 3.83 | 0.74 |
| Online search | 3.41 | 0.89 |
| Hands-on experience | 3.88 | 0.84 |
| Learn from errors | 3.68 | 0.85 |
| Feedback on work | 3.68 | 0.85 |

The Internet of things (IoT) enables physical objects to generate real-time data and communicate with others. The data organization from the IoT constitutes information that allows humans or machines to gain insight into a situation, adding new knowledge to what it already owns. It can modify or reinforce the value system or decision model. The knowledge owner then makes specific actions based on the information and knowledge that reflects the wisdom. The action instruction is sent as an actuator to the original physical object or other objects. The sensors will continuously sense and inform the owner or system.

In a more complex situation, such as a smart city traffic system, multiple sensors simultaneously send information to multiple drivers or auto vehicles. Each must take the best action for the collective interest. A simple linear DIKW model is insufficient. A DIKW with a dynamic and collaborative knowledge flow model is needed.

The STEM curriculum should include the proper teaching of knowledge storage and sharing. Current IoT STEM lessons focus on using sensors for data collection and the technical solution response. Few details have been given to understand the process of turning data into information and knowledge or teaching students to organize the data to benefit future use or users. In other words, students are trained to be users of data and information rather than knowledge sources or knowledge brokers. Unfortunately, this lack of training will hinder the full development of knowledge workers. The asthma detector project in the study included the collection of historical data as part of the learning. If the storing and sharing of information and intelligent analytics are included, it will enrich the KM learning experience.

### *KM Process*

A basic knowledge cycle includes knowledge acquisition, sharing, development, preservation, and application. There are abundant sources of KM process models, ranging from high-level views to complex models with feedback loops. Raudeliūnienė et al. (2018) summarized their literature reviews and categorized the following five dimensions:

1. Knowledge distribution, dissemination, sharing, transfer, user achievement.
2. Knowledge use, utilization, integration, embedding, enable reuse.
3. Knowledge creation, development, generation.
4. Knowledge acquisition.
5. Knowledge preservation, capture, archiving.

Current STEM education includes teamwork and group presentation as learning elements. However, as the case indicated, group work is minimal. Individual work remains the focus to avoid difficulties with in-class time management and assessment. In other words, personal learning is still in its early stage. However, teamwork reinforces knowledge sharing and is critical for knowledge dynamics and social learning. The teacher pointed out that asking questions is essential for knowledge acquisition and sharing. The current presentation is a one-way method with little feedback. More discussion and interaction during the project (rather than at the end of the project) will aid the students in future work environments and provide more agile development.

### *Personal KM*

In the interview, a teacher shared his focus on teaching students to search for knowledge. For example, after defining the problem, the students must independently search for the answer, possible solutions, software applications and tools, and hardware equipment like cables. However, there needs to be a plan that teaches students how to manage their knowledge. The teacher also pointed out the need to collect and store the students' questions throughout the years as a repository. This will allow him to better prepare and answer questions.

The future learning and careers of the teachers and students will benefit from acquired skills and methods in personal KM (PKM). PKM is critical for knowledge workers in the knowledge economy (Wiig, 2011). Helping students develop their skills and ability to establish and maintain PKM affords lifelong rewards. It is a critical part of the development of digital and information literacy, which aligns with government advocacy efforts (Education Bureau HKSAR, 2018).

PKM is the process of collecting information to gather, classify, store, search, retrieve, and share knowledge in daily activities (Grundspenkis, 2007). It highlights the 5W1H (who, what, when, where, why, how) of the information one searches for or receives. The students who learn to build a personal learning environment and network (PLE&N) can construct their own knowledge repositories and networks as they navigate through their lifelong learning journey (Altinpulluk, 2019; Dabbagh & Casstaneda, 2020). A PLE&N framework can guide the students to manage their information sources like social media, news feeds, and social networks (Tsang & Tsui, 2017). In fact, generations within the digital age are accustomed to digital media and social media. The COVID-19 pandemic further drove the use of hybrid forms of education (both face-to-face and online learning).

## Proposal: Adding KM Elements in STEM Education

The case study identified KM elements in the STEM education process. It supported the proposition that KM and STEM education share common characteristics. Therefore, this article proposes the addition of KM into the STEM education curriculum to optimize the learning experience, enhance outcomes, and avoid unnecessary or redundant resources and effort.

Based on the constructivism and connectivism nature, the STEM education program can incorporate PLE&N at the beginning of the STEM course. This can be continued throughout the course to support understanding and usage. In this way, KM education can be smoothly blended into STEM education.

KM technologies are needed when setting up a PLE&N for students. There are many KM tools available. The options can vary. The initial setup should be fundamental and straightforward, allowing students to begin without confusion or discouragement. Table 7 lists the tools that can be used in KM process. The examples are based on the authors' experience. Tools with similar functionalities are also available. Different geographic locations may have other preferences and constraints.

### *Stage 1: Beginning of the Course*

The following activities and setup can be used at the beginning of the STEM curriculum:

- Introduction of KM concepts
- Introduction of PLE&N concept
- Setup of relevant PLE&N tools

### *Stage 2: During the Course*

Throughout the course, the teachers can guide students in using the tools by:

- Encouraging the sharing of knowledge in the PLE&N.
- Setting up small groups for experience sharing in specific technology or tools (cultivate student experience and habits in tacit knowledge sharing and the formation of community of interest [CoI] or community of practice [CoP]).
- Promoting the sharing and adoption of new tools as students expand and explore their PLE&N (train students to develop lifelong learning and KM skills).

**Table 7. PKM Tools**

| Knowledge Process | Tools | Examples |
|---|---|---|
| Knowledge Acquisition | Search Engine<br>News Aggregator / RSS Feed<br>Social Network<br>Media | Google, Bing<br>Feedly, Inoreader<br>MeWe, Facebook<br>YouTube, TED |
| Knowledge Storage | Storage | Google Drive, Dropbox |
| Knowledge Sharing | Social Network | MeWe, Facebook |
| Knowledge Application | Integration<br>Collaboration | Wiki, Neo4j<br>MS Teams, Google Docs/Sheets, Trello |
| Knowledge Creation | Ideation | Coggle, Google Jamboard |

### *Stage 3: End of Course*

- The teachers can review the KM and PKM concepts with the students, encouraging them to continue to use their PLE&N for other subjects, future STEM classes, and personal interests.
- The teachers can revisit their own PLE&N to update tools and knowledge acquired through the course and from the students.

The proposal offers a basic framework for introducing KM into STEM education. Further details can be finetuned based on student level. For example, teachers may allocate more time to teaching elementary and junior high school students to use KM tools in their projects. For higher-grade students, teachers may explain KM concepts in more detail, illustrating how these concepts are utilized in different KM tools.

## SUMMARY AND CONCLUSION

STEM education is used in K-12 curriculum to prepare future knowledge workers. The ability to manage knowledge is an essential skill. This article asks: Can KM education be introduced in K-12 STEM education programs? The question is examined in both theory and practice.

The literature review identifies similar characteristics between STEM education and KM education. Teacher interviews and student surveys uncover potential opportunities to integrate KM education into the existing STEM curriculum in K-12 education.

### Contributions

The present study addresses a research gap in KM and STEM education. First, there is limited literature on the integration of KM into STEM education in the K-12 curriculum. This study is among the first to consider such an integration. Second, to the authors' knowledge, most of the literature focuses on the implementation and practices of STEM education. The examination of STEM education characteristics from a knowledge perspective is uncommon. This article aims to enrich the knowledge theory of STEM education.

### Limitations

This article investigates the current KM elements implicitly found in the STEM education of Hong Kong K-12 schools. It found that specific knowledge characteristics can be identified in STEM education; however, many others need to be included. They share similar educational characteristics. Thus, resources and learning experiences can be optimized with KM education embedded in STEM education. This is an initial investigation with limited cases in Hong Kong. More studies in STEM education in different geographic locations and levels are necessary to construct a clearer picture and establish methods to conduct KM education in K-12.

## CONCLUSION

The Fourth Industrial Revolution, or Industry 4.0, was presented by the German government in its High-Tech Strategy 2006. In 2011, it was formally announced at the Hannover Messe. Initially focused on the digital transformation of manufacturing and production processes and industries, it is now included as a part of smart cities (Lom, Pribyl, & Svitek, 2016; do Livramento Gonçalves et al., 2021).

Over the past decade, countries have announced strategies, plans, and activities to meet the challenge of Industry 4.0. It demands innovation in government policy, organization, and technologies, as well as the preparation of human capital. Education and training that produce a workforce that fits the Industry 4.0 knowledge society are crucial. Knowledge in big data, IoT, the industrial IoT (IIoT), cloud computing, artificial intelligence, and smart city learning is needed for the next generation of knowledge workers. Hence, STEM education is regarded as critical for preparing the future workforce. The underemployment of knowledge workers is a significant problem identified in realizing the full potential of Industry 4.0 (Corò, 2021).

The characteristics of a knowledge worker in Industry 4.0 include computational thinking, complexity thinking, critical thinking, creativity, collaboration, and communication skills. These factors are somewhat embedded in STEM education; however, a systemic method that enables students to be trained in a knowledge-based framework still needs developed. As demonstrated, STEM education and KM education share common characteristics like disciplinary integration, context relevance, social and community focus, and the use of technologies. Therefore, using STEM education to support KM education is natural and appropriate for teachers and learners.

## CONFLICT OF INTEREST

The authors of this publication declare there are no competing interests.

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