Implementation of 4C skills through problem solving: a study among mathematics teachers in Malaysia

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ABSTRACT

In the current realm of education 4.0, teachers play a pivotal role as facilitators of holistic skill development. The shift in focus towards accentuating creativity, communication, critical thinking and collaboration (4C) skills signifies an acknowledgment of the changing demands brought about by the industrial revolution 4.0. This transformation in educational approaches contributes significantly to the collective adaptability and innovative potential of succeeding generations. Against this backdrop, this study was conducted to investigate how mathematics teachers in Malaysia implement the 4C skills, specifically through problem-solving. The study applied a survey method involving 250 mathematics teachers in Malaysia. Data were collected using a questionnaire, meanwhile, descriptive statistics were used to analyze and present the research data. Overall, the study's outcomes revealed that mathematics teachers exhibit adeptness in effectively integrating the 4C skills within the context of problem-solving. However, the study also brought to light challenges encountered by mathematics teachers, particularly in the realm of creative teaching, especially when incorporating technology. These identified challenges resonate with broader concerns in the educational landscape, underscoring the imperative for robust support systems, continual professional development initiatives, and a transformative shift in the educational paradigm towards embracing innovative teaching methodologies.

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1. INTRODUCTION

The industrial revolution 4.0 (IR 4.0) involves the latest developments in automation and data sharing within manufacturing and other sectors. It features the use of advanced technologies like the internet of things (IoT), artificial intelligence (AI), and cloud computing, resulting in enhanced efficiency, personalization, and connectivity in production processes [1]. This revolution has drastically altered work and lifestyle and is expected to continue shaping the future of industry and society. As noted by Faizal *et al*. [2], IR 4.0 has brought about more significant changes than any previous industrial revolution. Consequently, many fields, including education, have adapted to meet the needs of IR 4.0.

Education is crucial in equipping the workforce for the new era, ensuring that both students and workers acquire the skills and knowledge needed to use the advanced technologies driving industry 4.0 [3]. This includes fostering digital literacy, coding, data analysis, and understanding IoT, AI, and other emerging technologies. Additionally, education should focus on soft skills like creativity, problem-solving, and critical thinking, which will be increasingly important in the IR 4.0 era [4]. These skills enable individuals to adapt to new challenges and uncertainties, fostering innovation and agility in a constantly evolving technological landscape. Thus, a transformation in the national education system is required to cultivate human resources capable of meeting its demands [5].

The national education system must prioritize equipping students with essential skills for the IR 4.0 era. Skills like creativity, communication, critical thinking, and collaboration (4C) will be highly sought after in the future workforce. These abilities will enable employees to adapt to new technologies and work effectively in teams to solve complex problems [6]. Teachers play a crucial role in preparing students for IR 4.0, providing them with the skills and knowledge needed for future success. As facilitators of learning, teachers should create meaningful learning experiences that challenge students to think critically and creatively [7]. To meet future job demands, teachers must be well-versed in advanced technologies and new teaching methods, such as project-based learning, and create environments that foster creativity, communication, critical thinking, and collaboration [8]. The education system must move away from traditional teaching methods and adopt hands-on approaches like problem-based learning (PBL) that encourage student engagement.

As a result, Alakrash and Razak [9] emphasized that teachers must implement effective teaching practices, engage in meaningful education, incorporate 21st-century learning, and conduct holistic assessments. These measures are essential for preparing students to thrive in a rapidly evolving technological landscape, where traditional methods may no longer suffice. Teachers need to be innovative and responsive to the changing needs of their students, utilizing diverse strategies to create dynamic and interactive learning environments. To address the needs of students in the IR 4.0 era, teachers should foster active, student-centered learning environments that promote meaningful and collaborative learning. Methods such as project-based learning, PBL, and inquiry-based learning, which involve real-world problems and projects, help develop critical thinking, problem-solving, and teamwork skills.

Moreover, incorporating technology into teaching can enhance learning by providing students with various resources and information, facilitating interactive and engaging learning experiences, and allowing for personalized instruction tailored to individual needs [10]. With digital tools and platforms, teachers can offer a more diverse array of learning materials, such as videos, simulations, and interactive modules, which can cater to different learning styles and preferences. Tools like Google Docs or Trello can facilitate teamwork and communication, while coding platforms and simulation software can teach students about IoT and AI. Teachers can also encourage creativity and critical thinking by prompting students to generate and evaluate multiple solutions and engage in debates and discussions on different perspectives [11]. Using open-ended questions and problem-solving activities helps students develop independent and creative thinking.

In mathematics education, teachers can cultivate 4C skills through problem-solving tasks [12]. These tasks inspire students to generate innovative ideas and apply them to real-world situations. Problem-solving activities encourage the exploration of various solutions and foster creative and critical thinking. Providing students with open-ended problems or real-world projects that require mathematical knowledge can enhance creative problem-solving [13]. When students tackle problems, they must think beyond routine solutions and develop new approaches [14]. Group problem-solving tasks teach students to collaborate and communicate effectively, whether through group projects or discussions about problem-solving strategies. Presenting and sharing problem-solving solutions enhances communication skills [15], and teacher feedback on both process and solution helps students reflect on and improve their mathematical understanding.

In conclusion, the advent of IR 4.0 has significantly impacted work and life, influencing the Malaysian educational system. Teachers must adapt their teaching methods to create engaging learning environments that help students develop essential 4C skills for the IR 4.0 era. These skills are crucial for students to thrive in the new technological landscape and adapt to future workforce changes. Therefore, it is crucial to explore how 4C skills are integrated into mathematics education, particularly through problem-solving approaches, given that existing research has largely focused on teachers' readiness and challenges in applying 21st-century learning principles in different contexts [16]–[20]. To that, this study aims to address these gaps by exploring the implementation of 4C skills in problem-solving teaching among Malaysian mathematics teachers. The research is significant for its potential to enhance teacher preparedness, improve student competencies, contribute to pedagogical knowledge, and influence educational policies, thereby aiding the continued evolution of the Malaysian educational system amidst contemporary challenges.

2. LITERATURE REVIEW

The onset of the IR 4.0 has introduced various challenges to the education sector. In this new era, the education system plays a vital role in nurturing a generation skilled in 4C [21]. To tackle these challenges, teachers must adapt their teaching strategies to equip students with the essential skills for success in the IR 4.0 era [22]. Mathematics teachers need to integrate 4C skills into problem-solving activities, as these activities promote the generation of new ideas and innovations among students [23]. They can design problem-solving tasks that involve real-world issues, such as group projects, case studies, or design challenges, to enhance students' critical thinking and problem-solving capabilities. Furthermore, incorporating technology into teaching can enrich learning and provide access to various resources and information [24]. Digital tools like interactive whiteboards, tablets, and online resources can visually and interactively present mathematical concepts, offering immediate feedback and support for students' problem-solving skills [25]. Online resources, including videos, simulations, and virtual manipulatives, can deepen students' understanding of mathematical concepts and offer diverse approaches to problem-solving tasks.

The 21st-century learning model framework guides effective classroom teaching, emphasizing the development of 21st-century skills, including the 4C skills. This framework is based on the premise that students must apply their knowledge and skills in real-world contexts to thrive in the 21st-century [26]. One of its primary goals is to prepare students for the digital age and the IR 4.0 era by incorporating real-world problem-solving tasks to support skill development. A study by González-Pérez and Ramírez-Montoya [27], found that most teachers use this framework to implement teaching methods that promote 21st-century skills. Another study by Huang and Iksan [28] confirmed that mathematics teachers use the 21st-century learning model framework to teach problem-solving skills. By employing this framework, teachers can design lessons and activities that foster 4C skills and provide students with opportunities to apply them in real-world scenarios. Additionally, the framework encourages integrating real-world problems and projects, helping students develop critical thinking and problem-solving skills and preparing them for IR 4.0 challenges.

Despite the emphasis on 21st-century skills, researchers have noted a gap in studies focusing on the elements of 4C skills in mathematics education, particularly through problem-solving teaching methods. Previous research has primarily examined teachers' readiness and constraints in implementing 21st-century learning in other contexts [16]‒[20]. Recognizing this gap, the researchers propose investigating the incorporation of 4C skills through problem-solving teaching methods among mathematics teachers in Malaysia. This research aims to address gaps in the existing literature and clarify the practical application of 4C skills in Malaysian mathematics education. The study is expected to identify areas where teachers need additional support or training, facilitating the effective implementation of these methods and ultimately improving students' learning outcomes.

3. METHODOLOGY

3.1. Sample and data collection

This study utilized the survey method, which is effective for collecting data from a large population. This approach is commonly used to gather quantitative data on various subjects, including attitudes, beliefs, and behaviors [29]. Surveys are particularly useful for generalizing about a population based on the responses from a sample group. An essential aspect of this method is the sample size, as it influences the precision and accuracy of the results. The sample size must be sufficiently large to ensure it is representative of the population being studied [30]. The sample size for a study can be determined through various techniques, such as statistical power analysis or referencing previous research studies [31]. Consequently, 250 mathematics teachers were selected as participants for this study.

3.2. Instrument

To measure the variables, the study employs an instrument. Properly designed questionnaires are essential for effective data collection. A well-crafted questionnaire can increase response rates, ensure the reliability and validity of the data, and enhance the overall quality of the study [32]. The questions should align with the research objectives, and their sequence should be logical and smooth. In this study, the researchers adapted an instrument from Ratminingsih *et al.* [33], which comprises two sections. Part A includes two statements to collect basic information on participants' gender and teaching experience. Part B consists of four sub-constructs with a total of 21 items designed to assess the construct of 4C skills through problem-solving teaching methods, as detailed in Table 1 meanwhile the specifics of each sub-constructs's items are provided in Table 2.

Table 1. Details of questions item

Part	Construct/sub-construct	Numbers of items
Part A	Demography	2
Part B	4C skills through problem solving	
	Communication	5
	Collaboration	5
	Critical thinking	6
	Creativity	5
	Total	23

Table 2. Details of sub-constructs's items

Sub-construct	Item	
Communication	Allow students to rephrase questions in their own words	C1
	Promote discussions of problem-solving strategies among students	C2
	Facilitate group activities where students can share their ideas	C3
	Let students explain the problem-solving strategies they have chosen	C4
	Encourage students to provide feedback on their peers' problem-solving strategies	C5
Collaboration	Organize group activities with students of different skill levels	Colla1
	Ensure students take responsibility for tasks assigned in groups	Colla2
	Foster an environment where group members value each other's contributions and ideas	Colla3
	Involve every student in groups by assigning tasks according to their abilities	Colla4
	Guide students to respect and accept different problem-solving approaches	Colla5
Critical Thinking	Encourage students to explore multiple problem-solving options	Ct1
	Provide opportunities for students to consider various problem-solving strategies	Ct2
	Use the memorization of keywords and related formulas as a method	Ct3
	Apply the Polya Model specifically for addressing problem-solving questions	Ct4
	Encourage the use of diverse learning resources	Ct5
	Conduct hands-on activities to provide practical learning experiences	Ct6
Creativity	Integrate ICT with effective teaching methods	Cr1
	Employ 21st-century learning techniques (e.g., flipped classroom)	Cr2
	Use a variety of problem-solving strategies to deepen students' understanding	Cr3
	Diversify the types of questions to inspire problem-solving ideas	Cr4
	Develop learning materials that cater to students' varying abilities	Cr5

3.3. Instrument's face and content validity

Before commencing the pilot study, the validity of the instrument was assessed both in terms of its face and content to ensure its quality. Face validity gauges how well the instrument appears to measure its intended construct, while content validity scrutinizes whether it adequately covers all facets of the construct under examination [32]. This involves assessing if the questions or items in the instrument adequately represent the sub-constructs of the measured construct [33]. Typically, experts in the field determine face and content validity by reviewing the questions or items and evaluating their comprehensiveness and representation of the construct. The outcomes offer an initial indication of the instrument's effectiveness in measuring its intended variables [34].

In this study, four experts specializing in Malay studies, curriculum development, mathematics education, and assessment and evaluation were selected to evaluate the face and content validity of the instrument. The number of experts involved may vary; generally, three experts are recommended for content validity [35], and at least two for face validity [36]. Polit *et al*. [37] state a minimum of three experts are necessary to establish the content validity index. These experts were tasked with making language corrections, refining sentence structures and terminologies, assessing the appropriateness of the proposed items, determining the sufficiency of the number of items, and evaluating the items using a 4-point scale. Consequently, all 16 items in the questionnaire were deemed to possess high validity based on expert evaluations.

3.4. Instrument's reliability

Reliability pertains to the constancy and steadfastness of a measurement tool, signifying how consistently it yields results over time [38]. It stands as a pivotal facet of measurement quality. Various approaches exist to gauge reliability, such as test-retest reliability, inter-rater reliability, parallel-form reliability, and internal consistency reliability. In this study, internal consistency reliability was assessed employing Cronbach's Alpha [39]. The researchers computed the Cronbach's Alpha value and compared it with benchmarks proposed by Bond [40]. The findings revealed that the 16 remaining items of the instrument showcased a commendable and robust level of consistency, with a Cronbach's Alpha value of 0.93.

3.5. Data analysis

The use of descriptive statistics in this study aims to provide a concise summary of the data collected from the survey. Descriptive statistics, which include measures such as mean, median, and mode, help organize and present data in a clear and understandable way. This analytical approach, as emphasized by Bond [40], is advantageous for researchers as it allows them to derive immediate and ongoing insights from the collected data. In the context of this study, the researchers employed a Likert scale to explore the incorporation of 4C skills through problem-solving teaching methods among mathematics teachers in Malaysia. The Likert scale used in this study was divided into five levels, as shown in Table 3, following the recommendation of Gilbert [41]. This five-tiered classification provides a nuanced understanding of participants' responses, enabling a more detailed analysis of how 4C skills are integrated through problem-solving teaching methods among mathematics teachers.

Table 3. Mean range and its interpretation

Range	Descriptive rating
4.50–5.00	Extensively implemented
3.50–4.49	Well implemented
2.50–3.49	Moderately implemented
1.50–2.49	Limited in implementation
1.00–1.49	Limited and poorly implemented

4. RESULTS

The descriptive analysis presented in Table 4 illustrates the distribution of mean scores concerning mathematics teachers' perceptions of integrating 4C skills into their problem-solving teaching methods, categorized by specific items. In contrast, Table 5 provides a descriptive analysis of mean score distributions based on various factors. Overall, we found that the implementation of 4C skills in problem-solving among mathematics teachers is well implemented (M=4.30, SD=0.36) based on the 5-point scale used. The implementation of 4C skills in problem-solving teaching is more focused on communication (M=4.35, SD=0.48), followed by collaboration (M=4.31, SD=0.36), critical thinking (M=4.30, SD=0.25), and creativity (M=4.17, SD=0.36).

Table 4. Mean scores based on specific items

Sub-construct	Item	M	SD	Interpretation
Communication	C1	4.37	.48	Well implemented
	C2	4.40	.49	Well implemented
	C3	4.33	.47	Well implemented
	C4	4.37	.48	Well implemented
	C5	4.30	.46	Well implemented
Collaboration	Colla1	4.28	.45	Well implemented
	Colla2	4.32	.47	Well implemented
	Colla3	4.32	.47	Well implemented
	Colla4	4.30	.46	Well implemented
	Colla5	4.33	.47	Well implemented
Critical thinking	Ct1	4.23	.43	Well implemented
	Ct2	4.28	.45	Well implemented
	Ct3	4.33	.47	Well implemented
	Ct4	4.30	.46	Well implemented
	Ct5	4.40	.49	Well implemented
	Ct6	4.30	.46	Well implemented
Creativity	Cr1	4.07	.25	Well implemented
	Cr2	4.13	.34	Well implemented
	Cr3	4.18	.39	Well implemented
	Cr4	4.17	.38	Well implemented
	Cr5	4.28	.45	Well implemented

Table 5. Mean scores based on factors

Factors	M	SD	Interpretation
Communication	4.35	.48	Well implemented
Collaboration	4.31	.36	Well implemented
Critical thinking	4.30	.25	Well implemented
Creativity	4.17	.36	Well implemented
Implementation of 4C skills	4.30	.36	Well implemented

5. DISCUSSION

Research indicates that mathematics teachers hold a favorable view regarding the integration of 4C skills. Specifically, all four facets are perceived to be well-implemented, signifying teachers' adeptness at incorporating these skills into teaching. With the advent of the IR 4.0, teachers must proficiently deliver problem-solving instruction, emphasizing communication, critical thinking, creativity, intrapersonal and interpersonal skills, scientific acumen, and technological prowess as these competencies are paramount for future employment prospects [42]. Furthermore, teachers must adapt to rapidly evolving technological advancements and integrate new methodologies to prepare students for an increasingly complex and interconnected world.

To meet industry demands, teaching strategies employed by teachers should afford students opportunities to hone 4C skills, fostering early mastery of these proficiencies. Generally, teachers in

Malaysia demonstrate proficiency in integrating these four skills [24], corroborating the present study's findings. This assertion is supported by González-Pérez and Ramírez-Montoya [27] research, which underscores teachers' capacity to cultivate an active learning milieu by prioritizing these skills. Teachers have leveraged the 21st-century, ensuring that students develop essential competencies such as digital literacy, global awareness, and problem-solving abilities. This approach not only fosters a deeper understanding of content but also equips learners with the adaptability and critical thinking skills necessary to thrive in a rapidly evolving technological landscape.

In the realm of mathematics education, teachers should endeavor to deliver effective problem-solving instruction imbued with these skills. Problem-solving endeavors stimulate diverse ideation and innovation, enabling students to explore various solution pathways, thereby enriching their critical thinking, creativity, and innovative aptitude [43]. Within the purview of this study, mathematics teachers can deploy these four skills through problem-solving methodologies. This aligns with Huang and Iksan [28] findings, indicating teachers' adeptness in teaching methods encompassing these skills. Teachers have utilized the 21st-century learning model framework as a roadmap for delivering instruction emphasizing communication skills, advanced cognitive abilities, and technology utilization.

However, some studies discuss the challenges faced by teachers in implementing teaching that involves these skills. For example, the study by Wahyuddin *et al*. [44] found that teachers have moderate skill levels and attitudes in implementing teaching that involves the 4C skills. Teachers should have high knowledge, skills, and attitudes in implementing teaching that involves these skills. The study by Umardiyah and Rohmah [16] found that factors such as knowledge, resources, facilities, and time constraints have caused teachers to have low skills in implementing teaching involving these skills. Both studies also found that teachers have difficulty implementing creative teaching compared to other skills, affecting students' creativity and innovation skills.

Creativity holds particular significance in various domains such as economics, environmental sciences, and humanities [45]. Teachers are urged to adopt creative instructional approaches to nurture students' creativity. In today's job market, creativity ranks among essential competencies. Creative instruction should encourage expansive learning exploration and novel idea generation to address real-world challenges effectively [46]. In the IR 4.0 era, creative instruction increasingly leverages technology as an educational tool for both teachers and learners. This assertion finds support in Ihnatova *et al*. [47] research, where technology-enabled blended instruction facilitated diverse idea generation among students. Learners are encouraged to explore diverse information and ideas before engaging in the learning process.

Creative instruction assumes pivotal importance for teachers in this era. However, contrary to the present study's findings indicating challenges faced by mathematics teachers in delivering technology-infused creative instruction, the creativity factor attained the lowest score compared to other facets. These findings resonate with Khalid *et al*. [48] research, highlighting teachers' struggles in delivering creative instruction. Ineffective technology utilization hampers teachers' ability to create innovative learning experiences for students, consequently diminishing learning effectiveness and comprehension of mathematical concepts.

Moreover, Wijaya *et al*. [49] reported that 50% of mathematics teachers worldwide encounter difficulties in delivering creative mathematics instruction. Many teachers grapple with technology integration in education, resulting in diminished educational quality. Hence, teachers are encouraged to harness technology to foster students' creativity. This issue finds further validation in Sánchez *et al*. [50] research, which underscores creative instruction as a challenge confronting both current and future teachers. Despite this, most teachers continue to prioritize traditional instructional practices, neglecting opportunities for pedagogical enhancement. Sun [51] study concludes that creative instruction assumes pivotal importance in problem-solving instruction, influencing students' cognitive and creative development in mathematics learning.

6. CONCLUSION

In summary, this investigation highlights the integration of the 4C skills, in Malaysian mathematics education, aligning with the demands of the IR 4.0. It praises teachers for effectively incorporating these skills into problem-solving teaching, emphasizing their role in fostering a learning environment that goes beyond traditional methods. However, alongside these positive findings, challenges persist in effectively implementing creative teaching, especially concerning technology utilization. Identified obstacles include teachers' moderate skill levels, resource constraints, and struggles in leveraging technology to enhance creative learning opportunities. These hurdles reflect broader educational concerns, emphasizing the necessity for robust support systems, continuous professional development, and a shift towards innovative teaching approaches.

A limitation of this study is that it primarily focuses on mathematics education within the Malaysian context, which may not fully capture the diverse educational environments and challenges faced by teachers in other regions Additionally, while the study identifies several obstacles and proposes potential solutions, it does not extensively evaluate the effectiveness of these proposed interventions or provide a comprehensive analysis of their long-term impact on teaching practices and student outcomes. Without a thorough assessment of how these interventions perform over time and in varied settings, the study's recommendations may lack the empirical evidence needed to ensure their efficacy and adaptability in different educational contexts.

Given the pervasive nature of these challenges, a collective effort is deemed necessary to address them. Proposals for integrating technology and creative teaching methodologies, such as mobile learning (M-learning) and PBL, are presented as potential solutions to bridge existing gaps and elevate the quality of mathematics education in the IR 4.0 era. Ultimately, this study contributes significantly to ongoing discussions on educational transformation to meet contemporary demands. It celebrates the achievements of mathematics teachers in Malaysia, acknowledges existing challenges, and suggests strategic pathways for collaborative action among teachers, policymakers, and researchers to navigate the evolving landscape of mathematics education in the digital age.

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C : **C**onceptualization	I : **I**nvestigation	Vi : **Vi**sualization
M : **M**ethodology	R : **R**esources	Su : **Su**pervision
So : **So**ftware	D : **D**ata Curation	P : **P**roject administration
Va : **Va**lidation	O : Writing - **O**riginal Draft	Fu : **Fu**nding acquisition
Fo : **Fo**rmal analysis	E : Writing - Review & **E**diting	

CONFLICT OF INTEREST STATEMENT

The author declares that there is no conflict of interest regarding the publication of this study. All procedures and processes have been conducted with integrity and transparency, and no financial, personal, or professional relationships have influenced the outcomes or interpretations of this research.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author, [MIZ], upon reasonable request.

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