4C skills teaching activities for mathematics teachers: application of modified nominal group technique

Mohamad Ikram Zakaria[1], Chuzairy Hanri[1], Sri Hastuti Noer[2], Mella Triana[2], Widyastuti[2]
[1]Department of Science, Mathematics and Multimedia Creative, School of Education, Faculty of Social Sciences and Humanities, Universiti Teknologi Malaysia, Johor, Malaysia
[2]Department of Mathematics Education, Faculty of Teacher Training and Education, Universitas Lampung, Lampung, Indonesia

Article Info

Article history:

Received May 23, 2023
Revised Jun 27, 2024
Accepted Jul 3, 2024

Keywords:

4C skills
Mathematics teachers
Nominal group techniques
Problem solving
Teaching activities

ABSTRACT

Education 4.0 strongly promotes the development of communication, collaboration, critical thinking, and creativity (4C) skills among students. Consequently, it is crucial for mathematics teachers to integrate activities that facilitate the cultivation of these skills. However, the scarcity of resources, such as recommended instructional activities, poses a challenge for mathematics teachers striving to effectively impart 4C skills through problem-solving methods. This research aims to develop a set of teaching activities designed to enhance the delivery of 4C skills through problem-solving methods, thereby supporting mathematics teachers in improving their pedagogical strategies. Utilizing the modified nominal group technique (mNGT), the study engaged 11 experts from diverse fields, including mathematics education, pedagogy, curriculum development, and primary and secondary education. Data collection was conducted through expert discussions between January 2024 and February 2024. Descriptive statistics (percentages) were employed to analyze the data, prioritizing and ranking each teaching activity. The findings identified 19 pertinent teaching activities that emphasize 4C skills through problem-solving methods. The highest-ranked activity was motivating students to explore various learning resources, including information and communication technology (ICT) tools (98%), while guiding students through problem-solving questions received the lowest ranking (75%). In conclusion, the comprehensive list of teaching activities provides a valuable guide for mathematics teachers to effectively incorporate 4C skills into their instructional practices.

This is an open access article under the CC BY-SA license.

Corresponding Author:

Mohamad Ikram Zakaria
Department of Science, Mathematics and Multimedia Creative, School of Education
Faculty of Social Sciences and Humanities, Universiti Teknologi Malaysia
Sultan Ibrahim Chancellery Building, St. Iman, 81310 Skudai, Johor, Malaysia
Email: mohamad.ikram@utm.my

1. INTRODUCTION

Industrial revolution 4.0 (IR 4.0) refers to the current automation and data exchange trends in manufacturing and other industries. It is characterised by the integration of advanced technologies such as the Internet of things (IoT), artificial intelligence (AI), and cloud computing, which has led to greater efficiency, customisation, and connectivity in production processes [1]. This revolution has also brought about significant changes in how humans work and live and is expected to continue shaping the future of industry and society. According to Faizal *et al*. [2], IR 4.0 has brought more significant changes than in previous eras of revolution. Subsequently, the focus of many disciplines, including the education system, has changed to meet the demands of IR 4.0. Undeniably, education is essential in preparing the workforce for the IR 4.0 era. It is important that students and workers are equipped with the necessary skills and knowledge to work with and operate the advanced technologies that are driving Industry 4.0 [3]. Education system should focus on developing soft skills such as creativity, problem-solving, and critical thinking, as these skills will be increasingly valuable in the IR 4.0 era [4]. Thus, the national education system must evolve to develop human resources that can meet the demands of IR 4.0 [5].

The national education system should focus on developing students with these essential skills for the IR 4.0 era. Creativity, communication, critical thinking, and collaboration (4C) are all important skills that will be in high demand in the future workforce. These skills will allow prospective employees to adapt to new technologies and work effectively in teams to solve complex problems [6]. In this regard, teachers play an essential role by providing them with the necessary skills and knowledge to succeed in the future workforce. Teachers act as facilitators of learning, creating a meaningful learning experience for students by engaging them in activities that challenge them to think critically and creatively [7]. For teachers to effectively meet the job demands of the future, they must be equipped with the necessary knowledge and skills to teach students about advanced technologies and other emerging technologies. They also need to be familiar with new teaching methods, such as project-based learning and problem-based learning that fosters creativity, communication, critical thinking, and collaboration [8].

In mathematics education, teachers can cultivate 4C skills through problem-solving task [9]. Problem-solving tasks can inspire students to generate a wide range of new ideas and innovations, which can be applied to real-world situations. Through problem-solving activities, students can be taught to explore various alternative answers and encouraged to think creatively and critically. This can be done by providing students with open-ended problems with multiple solutions or by having them work on real-world projects that require them to apply their mathematical knowledge to solve problems [10]. When students are presented with a problem, they are forced to think beyond the known routine and develop new ideas and approaches to solve the problem [11]. Additionally, when students work on problem-solving tasks in groups, they learn to collaborate and communicate effectively with their peers.

However, applying the 4C skills to problem-solving presents challenges [12], [13]. Inadequate training and support [14], along with limited resources such as suggested teaching activities, hinder mathematics teachers from effectively conveying mathematical concepts [15], [16]. These limitations also prevent teachers from connecting lesson content to real-life situations, providing structured guidance, and achieving desired goals [17]. Therefore, offering teachers continuous professional development and ongoing support is crucial. This equips them with the necessary skills to effectively incorporate 4C skills into their teaching methods [9], [14]. Providing these resources ensures they can enhance their instructional practices

With this goal in mind, this study focused on creating a set of teaching activities that align with the 4C skills, intended for mathematics teachers to enhance their teaching practices. While earlier studies have focused more on the readiness and constraints of teachers with the implementation of 4C skills [18]–[22], they have not explicitly addressed the teaching activities that align with the 4C skills in mathematics education. Integrating these activities into teaching methods may aid teachers in refining their instructional strategies and enhancing their students' learning journeys. To pinpoint pertinent teaching activities, the researchers formulated the following research questions: What teaching activities, in line with the 4C skills, can mathematics teachers employ to improve their teaching practices based on expert consensus?

2. LITERATURE REVIEW

2.1. Review of 4C skills

The development of the IR 4.0 has created many challenges in education. In this era, the education system plays an important role in developing a knowledgeable and capable generation in terms of communication, collaboration, critical thinking, and creativity (4C) [23]. To meet these challenges, teachers must adapt their teaching methods to provide students with the skills they need to succeed in the IR 4.0 era [24]. Mathematics teachers must ensure that 4C skills are included in problem-solving activities. This is because problem-solving is one of the most effective ways to cultivate these skills in students, as it encourages them to generate a wide range of new ideas and innovations [25]. Teachers can effectively cultivate these skills during their lessons by designing problem-solving activities that require students to work on real-world problems. This can include group projects, case studies, or design challenges that require students to use their critical thinking and problem-solving skills to develop solutions. Additionally, teachers should incorporate technology through digital tools into their teaching such as interactive whiteboards, tablets, and online resources. These tools can present mathematical concepts visually, interactively and provide students with immediate feedback and support on their problem-solving skills [26], [27].

In the context of implementation, the 21st century learning model framework has been used as a guide to be achieving effective teaching in the classroom. The 21st Century Learning Model framework is a comprehensive approach to teaching and learning that emphasises developing 21st-century skills such as 4C skills. This framework is based on the idea that students need to be able to apply their knowledge and skills in real-world contexts to be successful in the 21st century [28]. One of the main goals of this framework is to prepare students for the challenges of the digital age and the IR 4.0 era. The framework encourages the integration of real-world problem-solving tasks, which can support students in developing their problem-solving skills and preparing them for the IR 4.0 era. A study by González-Pérez and Ramírez-Montoya [29] found that most teachers used this framework as a guide to implement the teaching methods that promote 21st-century skills in their classrooms. This is supported by another study by Huang and Iksan [30] which found that mathematics teachers have used the 21st Century Learning Model framework to teach problem-solving skills. By using this framework, teachers can design lessons and activities that promote the development of the 4C skills and provide students with opportunities to apply them in real-world contexts.

After examining several past studies, the researchers found that there were still fewer studies that explored the teaching activities that align with the 4C skills in mathematics education [31]–[33]specifically through problem-solving teaching methods. This is because past studies have focused more on the readiness and constraints of teachers with the implementation of 21st-century learning in other institutions [18]–[22]. Consequently, recognizing this research gap, the researchers posit the necessity to design teaching activities that align with the 4C skills through problem-solving teaching methods. This research is intended to address existing gaps in the literature and elucidate the practical application of 4C skills in the specific context of mathematics education. This endeavor is anticipated to pinpoint areas where teachers may use the activities as additional support, facilitating the effective implementation of these methods in their classrooms and, ultimately, fostering improvements in students' learning outcomes.

2.2. Conceptual framework

To support the execution of this research, the researchers conducted comprehensive literature reviews focused on the core principles of 4C skills specifically through problem-solving teaching methods. This step aimed to reinforce the conceptual foundation of the study, ensuring it was thoroughly informed and rooted in established knowledge before advancing further. The subsequent section delineates these four foundational elements of 4C Skills, which were instrumental in crafting the framework for this research.

- Communication: Teachers facilitate the development of this skill by encouraging oral discussions, written explanations, and the use of various visual aids like charts, graphs, and diagrams, fostering a deeper understanding and application of mathematical concepts among students [34], [35].
- Collaboration: Teachers nurture the growth of this skill by cultivating a collaborative atmosphere, guiding students in assuming collective responsibilities, encouraging respect and appreciation for each other's contributions, and fostering the development of interpersonal skills [34], [35].
- Critical thinking: Teachers cultivate this skill by fostering inquiry, presenting complex challenges, endorsing analytical thinking, offering support as needed, facilitating discussions, and delivering constructive feedback [34], [35].
- Creativity: Teachers nurture this skill by encouraging students to explore different problem-solving methods and by providing opportunities for experimentation and imaginative thinking. They also support students in applying creative strategies to solve mathematical problems [34], [35].

3. METHODOLOGY

3.1. Research design

The study, conducted from January 2024 to February 2024, employed a literature review followed by a modified nominal group technique (mNGT) consensus process. This involved convening a consensus meeting with experts from diverse fields [36]. The mNGT facilitated the compilation of a list of teaching activities focusing on 4C skills via problem-solving methods for mathematics teachers. This method was selected for its effectiveness in connecting generated ideas to specific issues or problems [37]. Additionally, it is well-suited for situations where a panel of experts holds differing perspectives, as it allows for the integration of these varying opinions based on priority.

3.2. Group expert

Regarding the mNGT, expert groups were purposefully selected [38]. The selection of these experts is crucial as the outcomes hinge on their perspectives [39]. Thus, expert selection aligns with the guidelines proposed by Berliner [40] and Rejab *et al.* [41], emphasizing a minimum of 5 years of experience in their respective fields to ensure the credibility of the results. The established criteria for experts in this study [37] include: i) possessing at least 5 years of expertise in their field, ii) specializing in mathematics pedagogy, and iii) have expertise in the field of 4C skills and have conducted research before. Moreover, careful consideration was given to the number of experts involved. Various recommendations from prior research suggest expert group sizes ranging from 4 to 8 individuals [42], 5 individuals [43], and 6 to 12 individuals

[44]. Following these suggestions, the researcher selected 11 experts in mathematics education, encompassing individuals experienced in teaching and learning mathematics at primary and secondary levels, as well as curriculum and pedagogy experts.

3.3. Research procedure

The researchers implemented the mNGT procedure outlined by Ridzuan *et al.* [37]. Initially, expert groups were presented with a question, problem, or issue, with slight adjustments made to the process compared to the traditional NGT. These alterations, detailed in the study, may affect the time required for idea generation, as the classic NGT typically demands ideas at a fundamental level [37]. To mitigate potential delays in idea generation, the researcher prepared a preliminary draft of suitable activities for 4C skills teaching activities, informed by the literature review. This facilitated the expert groups in focusing their discussion scope and consequently reducing discussion time from 240 to 90 minutes [38].

Subsequently, each expert contributed their ideas and opinions, responding to the preliminary draft by expressing agreement or disagreement with the proposed activities and offering suggestions for additional activities. Thirdly, ideas were shared among the experts, and modifications were made during discussions. Upon conclusion, a comprehensive list of teaching activities was presented to the expert groups for decisions regarding the final selection of activities for inclusion in teaching materials.

Finally, expert groups rated each teaching activity on a scale of 1 (strongly disagree) to 5 (strongly agree) to determine its priority, based on scales utilized by previous researchers [38], [45]. Through voting, the researchers established the priority value of each activity, resulting in a final list of activities based on expert consensus. Activities were prioritized based on the highest percentage value, with the most crucial activities ranked highest and vice versa [46].

4. RESULTS

We found 19 appropriate and pertinent activities to include in 4C skills teaching activities for mathematics teachers, as presented in Table 1. These activities are based on expert views gathered during discussions using the mNGT. The findings show that teachers motivate students to explore a range of learning resources, including information and communication technology (ICT) tools (98%) was ranked first, followed by other activities, while the teachers guide the students to solve the problem-solving questions (75%) was ranked last.

Table 1. 4C skills teaching activities through problem solving

No.	Activities	Total score	Percentage (%)	Ranking
1.	Teachers provide an opportunity for students to rephrase the questions using their own language.	51	93	3
2.	Teachers encourage students to engage in group discussions about problem-solving approaches.	49	89	5
3.	Teachers prompt students to share their ideas during collaborative activities.	46	84	8
4.	Teachers guide the students to solve the problem-solving questions.	42	76	12
5.	Teachers encourage students to provide feedback on their peers' problem-solving strategies within groups.	45	82	9
6.	Teachers arrange group activities that involve students with diverse skill levels.	46	84	8
7.	Teachers promote mutual appreciation among group members for each other's contributions and suggestions.	43	78	11
8.	Teachers involve all students in group work by assigning tasks based on individual capabilities.	44	80	10
9.	Teachers encourage students to explore various alternatives for solving problems.	52	95	2
10.	Teachers allocate time and space for students to consider different problem-solving techniques.	51	93	3
11.	Teachers motivate students to explore a range of learning resources, including ICT tools.	54	98	1
12.	Teachers conduct a variety of hands-on activities to enrich students' learning experiences.	52	95	2
13.	Teachers integrate ICT tools with appropriate instructional strategies.	48	87	6
14.	Teachers utilize a range of problem-solving strategies to enhance students' comprehension	50	91	4
15.	Teachers present a variety of question formats to stimulate problem-solving ideation.	49	89	5
16.	Teachers develop learning materials tailored to students' individual abilities.	47	85	7
17.	Teachers provide an opportunity for students to rephrase the questions using their own language.	51	93	3
18.	Teachers encourage students to engage in group discussions about problem-solving approaches.	49	89	5
19.	Teachers prompt students to share their ideas during collaborative activities.	46	84	8

5. DISCUSSION

The findings reveal that experts have pinpointed 19 teaching activities available to mathematics teachers for integrating 4C skills into problem-solving contexts. These strategies are aligned with the 4C framework, emphasizing 4C. All identified activities were considered suitable by the experts and were ranked accordingly. The top-ranked activity involved teachers motivate students to explore a range of learning resources, including ICT tools. The lowest-ranked activity involved the teachers guide the students to solve the problem-solving questions was ranked last.

The findings of this study do not align with [47] study, where exploration activities through ICT tools in mathematics learning did not affect students' achievement. This occurs because the time allocated for using mobile devices in learning is limited [48]. As a result, students' learning becomes meaningless even though they are given the opportunity to explore various learning resources. Therefore, teachers need to ensure that students have sufficient time to access various learning resources for the purpose of seeking information and new ideas. However, studies conducted by [49]–[51] indicate that exploration activities through ICT tools can create a constructivist learning environment. This is because students are given the opportunity to actively engage in the information-seeking process. Through this process, students can build knowledge by making meaningful connections between ideas. Furthermore, new information acquired by students can be linked to past information to complete tasks given by the teacher.

This viewpoint is supported by Mitsea *et al*. [52], where new knowledge is built through an active process involving cognitive structures and cognitive functions in adapting to past information. This can occur when students are given the opportunity to go through a learning process involving critical thinking, motivation, self-directed learning, feedback, dialogue, explanation, questioning, contextual learning, experimentation, and problem-solving in daily life [53]. Through mobile technology, students have the opportunity to go through this process. This can be evidenced by the study of Pires *et al*. [54], where exploration activities through ICT tools help disabled students to master skills in counting, labeling, and comparing differences in mathematics. This group of students has been given the opportunity to use learning applications to build knowledge through activities tailored to their abilities. This clearly indicates that exploration activities through learning applications can promote active learning among students [55].

After examining all discussions, exploration activities through ICT tools are deemed crucial to be conducted according to experts' and past researchers' views. Similarly, activity 4, which involves teachers guide the students to solve the problem-solving questions, is important. In this context, teachers need to play the role of facilitators to ensure that teaching in the 4C activities can be carried out effectively [56]. The guidance provided also aims to bridge the gap in learning approach changes. Therefore, it can be understood that such changes require teachers to take on the role of guides and facilitators. Teachers need to guide by explaining misunderstood learning concepts, sharing perspectives, and posing questions that enhance students' understanding of the given tasks [57]. As a result, the interaction between students and teachers will increase throughout the learning process. Consequently, the process of transferring responsibility and accountability for learning from the teacher to the student will occur [58].

However, it cannot be denied that the guidance provided by teachers indirectly may have a negative impact on students. This is because such guidance can limit students' creative and critical thinking and hinder them from using new ideas to solve given tasks [59]. Ideally, in problem-solving, students should be given the opportunity to explore learning without restricting their thinking. Thus, they can build knowledge and develop creativity and critical thinking skills in the process. At the same time, they can also utilize new ideas obtained from various exploration sources to complete tasks assigned by the teacher [60]. If students make mistakes during the exploration process, they have the opportunity to learn a new skill [61] while making those mistakes.

In conclusion, all of the suggested 4C teaching activities are deemed appropriate according to expert views and consensus. In this section, the discussion only involves activities 4 and 11. Both of these teaching activities are examples of relevant activities to be conducted when teachers want to implement problem-solving teaching through the 4C approach. Therefore, teachers can use this list of activities as a guide to conduct problem-solving teaching involving the 4C skills.

6. CONCLUSION AND FUTURE RESEARCH

In summary, the research meticulously delineates a comprehensive array of 19 activities designed specifically for mathematics educators seeking to embed 4C skills within problem-solving instruction, drawing upon expert guidance. These activities were distilled from the insights and analysis of the expert panel. Notably, the results underscore the prioritization of encouraging student exploration of diverse learning resources, particularly ICT tools, which emerged as the most prominent aspect. Conversely, the guidance provided by teachers in problem-solving questions received the lowest ranking. These findings underscore the imperative of integrating diverse instructional approaches to foster holistic skill development in mathematics education. In essence, the study concludes that mathematics teachers can utilize the comprehensive list of teaching activities as a valuable roadmap for infusing 4C skills into their teaching practices. By leveraging these activities, teachers stand to catalyze a transformative shift in their instructional methods, promoting active participation, exploration, and innovation among students. However, it is crucial to acknowledge a study limitation, namely the lack of real-world implementation of the identified teaching activities. This gap raises questions regarding their practical applicability and effectiveness in authentic classroom settings. Looking ahead, future researchers can build upon the identified teaching activities as a springboard for crafting innovative instructional models. These models could further enrich the integration of 4C skills principles principles within educational contexts. These findings signal the beginning of ongoing exploration and innovation in instructional methodologies, urging educators and researchers alike to continue advancing teaching practices that align with the dynamic landscape of education.

ACKNOWLEDGEMENTS

This work was supported by the international research grant between Universiti Teknologi Malaysia (UTM) and Universitas Lampung under grant number R.J130000.7353.1U033.

REFERENCES

[1] S. H. Halili, S. Sulaiman, H. Sulaiman, and R. Razak, "Embracing industrial revolution 4.0 in universities," *IOP Conference Series: Materials Science and Engineering*, vol. 1088, no. 1, p. 012111, Feb. 2021, doi: 10.1088/1757-899X/1088/1/012111.

[2] S. Mohd Faizal, N. Jaffar, and A. S. Mohd nor, "Integrate the adoption and readiness of digital technologies amongst accounting professionals towards the fourth industrial revolution," *Cogent Business & Management*, vol. 9, no. 1, Dec. 2022, doi: 10.1080/23311975.2022.2122160.

[3] K. Matsumoto-Royo, M. S. Ramírez-Montoya, and P. Conget, "Opportunities to develop lifelong learning tendencies in practice-based teacher education: getting ready for Education 4.0," *Future Internet*, vol. 13, no. 11, p. 292, Nov. 2021, doi: 10.3390/fi13110292.

[4] A. Aziz Hussin, "Education 4.0 made simple: ideas for teaching," *International Journal of Education and Literacy Studies*, vol. 6, no. 3, p. 92, Jul. 2018, doi: 10.7575/aiac.ijels.v.6n.3p.92.

[5] R. Tandon and S. Tandon, "Education 4 . 0 : A new paradigm in transforming the future of education in," *International Journal of Innovative Science, Engineering & Technology*, vol. 7, no. 2, pp. 32–54, 2020.

[6] A. Hariharasudan and S. Kot, "A scoping review on digital English and Education 4.0 for Industry 4.0," *Social Sciences*, vol. 7, no. 11, p. 227, Nov. 2018, doi: 10.3390/socsci7110227.

[7] R. A. Karim, A. H. M. Adnan, M. S. A. M. Salim, S. Kamarudin, and A. Zaidi, "Education innovations through mobile learning technologies for the industry 4.0 readiness of tertiary students in Malaysia," *IOP Conference Series: Materials Science and Engineering*, vol. 917, no. 1, p. 012022, Sep. 2020, doi: 10.1088/1757-899X/917/1/012022.

[8] C. S. Lai, U. Chundra, and M. F. Lee, "Teaching and learning based on IR 4.0: readiness of attitude among polytechnics lecturers," *Journal of Physics: Conference Series*, vol. 1529, no. 3, p. 032105, Apr. 2020, doi: 10.1088/1742-6596/1529/3/032105.

[9] X. Weng, Z. Cui, O.-L. Ng, M. S. Y. Jong, and T. K. F. Chiu, "Characterizing students' 4C skills development during problem-based digital making," *Journal of Science Education and Technology*, vol. 31, no. 3, pp. 372–385, Jun. 2022, doi: 10.1007/s10956-022-09961-4.

[10] V. V. Utemov *et al.*, "Solving math problems through the principles of scientific creativity," *EURASIA Journal of Mathematics, Science and Technology Education*, vol. 16, no. 10, p. em1887, Aug. 2020, doi: 10.29333/ejmste/8478.

[11] E. H. Mohd Shahali, L. Halim, M. S. Rasul, K. Osman, and M. A. Zulkifeli, "STEM learning through engineering design: impact on middle secondary students' interest towards STEM," *EURASIA Journal of Mathematics, Science and Technology Education*, vol. 13, no. 5, Dec. 2016, doi: 10.12973/eurasia.2017.00667a.

[12] F. Fitriati, R. Rosli, Z. Iksan, and A. Hidayat, "Exploring challenges in preparing prospective teachers for teaching 4C skills in mathematics classroom: a school-university partnership perspectives," *Cogent Education*, vol. 11, no. 1, Dec. 2024, doi: 10.1080/2331186X.2023.2286812.

[13] M. Nawawi, M. Laili, and A. Christanti, "Analysis of students' 4C skills based on the pedagogy multiliteracies model," *Jurnal Scientia*, vol. 10, no. 2, pp. 233–241, 2022.

[14] H. Mohamad Alakrash and N. Abdul Razak, "Education and the fourth industrial revolution: lessons from COVID-19," *Computers, Materials and Continua*, vol. 70, no. 1, pp. 951–962, 2022, doi: 10.32604/cmc.2022.014288.

[15] V. T. Le, N. H. Nguyen, T. L. N. Tran, L. T. Nguyen, T. A. Nguyen, and M. T. Nguyen, "The interaction patterns of pandemic-initiated online teaching: how teachers adapted," *System*, vol. 105, p. 102755, Apr. 2022, doi: 10.1016/j.system.2022.102755.

[16] S. Venkatraman, F. Benli, Y. Wei, and F. Wahr, "Smart classroom teaching strategy to enhance higher order thinking skills (HOTS)—an agile approach for Education 4.0," *Future Internet*, vol. 14, no. 9, p. 255, Aug. 2022, doi: 10.3390/fi14090255.

[17] M. Cáceres, M. Nussbaum, and J. Ortiz, "Integrating critical thinking into the classroom: a teacher's perspective," *Thinking Skills and Creativity*, vol. 37, p. 100674, Sep. 2020, doi: 10.1016/j.tsc.2020.100674.

[18] P. Ye and X. Xu, "A case study of interdisciplinary thematic learning curriculum to cultivate '4C skills," *Frontiers in Psychology*, vol. 14, Mar. 2023, doi: 10.3389/fpsyg.2023.1080811.

[19] H. Boholano, "Smart social networking: 21st Century teaching and learning skills," *Research in Pedagogy*, vol. 7, no. 2, pp. 21–29, Mar. 2017, doi: 10.17810/2015.45.

[20] P. H. Tyan, F. A. Rahman, and M. S. Sarvestani, "Teachers' readiness in implementing and facilitating 21st century learning," *Universal Journal of Educational Research*, vol. 8, no. 1A, pp. 24–29, Jan. 2020, doi: 10.13189/ujer.2020.081304.

[21] K. Karatas and I. Arpaci, "The role of self-directed learning, metacognition, and 21st century skills predicting the readiness for online learning," *Contemporary Educational Technology*, vol. 13, no. 3, p. ep300, Mar. 2021, doi: 10.30935/cedtech/10786.

[22] S. D. Orak and J. İnözü, "Teachers' awareness and actual practices of 21 st century learning and innovation skills," *International Online Journal of Education and Teaching*, vol. 8, no. 2, , pp. 975-997, 2021.

[23] B. Thornhill-Miller *et al.*, "Creativity, critical thinking, communication, and collaboration: assessment, certification, and promotion of 21st century skills for the future of work and education," *Journal of Intelligence*, vol. 11, no. 3, p. 54, Mar. 2023, doi:

10.3390/jintelligence11030054.
[24] O. S. Tan, "Technology, future learning and flourishing thinking," *International Journal of Chinese Education*, vol. 6, no. 1, pp. 81–104, Aug. 2017, doi: 10.1163/22125868-12340075.
[25] M. Baars, T. van Gog, A. de Bruin, and F. Paas, "Effects of problem solving after worked example study on secondary school children's monitoring accuracy," *Educational Psychology*, vol. 37, no. 7, pp. 810–834, Aug. 2017, doi: 10.1080/01443410.2016.1150419.
[26] M. C. Borba, P. Askar, J. Engelbrecht, G. Gadanidis, S. Llinares, and M. S. Aguilar, "Blended learning, e-learning and mobile learning in mathematics education," *ZDM*, vol. 48, no. 5, pp. 589–610, Aug. 2016, doi: 10.1007/s11858-016-0798-4.
[27] A. Barana, M. Marchisio, and M. Sacchet, "Interactive feedback for learning mathematics in a digital learning environment," *Education Sciences*, vol. 11, no. 6, p. 279, Jun. 2021, doi: 10.3390/educsci11060279.
[28] D. Kostons and B. B. de Koning, "Does visualization affect monitoring accuracy, restudy choice, and comprehension scores of students in primary education?," *Contemporary Educational Psychology*, vol. 51, pp. 1–10, Oct. 2017, doi: 10.1016/j.cedpsych.2017.05.001.
[29] L. I. González-Pérez and M. S. Ramírez-Montoya, "Components of Education 4.0 in 21st century skills frameworks: systematic review," *Sustainability*, vol. 14, no. 3, p. 1493, Jan. 2022, doi: 10.3390/su14031493.
[30] J. X. Huang and Z. Hj Iksan, "Understanding of teacher in pekan district on 21st century learning," *International Journal of Modern Education*, vol. 1, no. 2, pp. 01–12, Sep. 2019, doi: 10.35631/ijmoe.12001.
[31] K. Mangaroska, K. Sharma, D. Gašević, and M. Giannakos, "Exploring students' cognitive and affective states during problem solving through multimodal data: Lessons learned from a programming activity," *Journal of Computer Assisted Learning*, vol. 38, no. 1, pp. 40–59, Feb. 2022, doi: 10.1111/jcal.12590.
[32] I. Irham, I. Tolla, and B. Jabu, "Development of the 4C teaching model to improve students' mathematical critical thinking skills," *International Journal of Educational Methodology*, vol. 8, no. 3, pp. 493–504, Aug. 2022, doi: 10.12973/ijem.8.3.493.
[33] F. Umardiyah, Z. Rohmah, and K. A. W. Hasbullah, "Development of teaching materials on geometry uaterials to develop students' critical thinking skills according to the criteria for critical thinking 4C's," *APPLICATION: Applied science in Learning Research*, vol. 1, no. 2, pp. 71–76, 2021.
[34] D. P. Hafizhah, F. S. Maharani, and S. Salamah, "The role of digital technology in enhancing 4C competencies in 21st century mathematics learning: systematic literature analysis," *Discourse: Journal of Multidisciplinary Studies*, vol. 1, no. 1, pp. 21–32, 2024, doi: 10.1234/discourse.v1i1.35.
[35] A. Saad *et al.*, "Exploring of the gender variations in 4Cs skills among primary students," *Thinking Skills and Creativity*, vol. 52, p. 101510, Jun. 2024, doi: 10.1016/j.tsc.2024.101510.
[36] J. Hugé and N. Mukherjee, "The nominal group technique in ecology conservation: application and challenges," *Methods in Ecology and Evolution*, vol. 9, no. 1, pp. 33–41, Jan. 2018, doi: 10.1111/2041-210X.12831.
[37] F. Ridzuan, G. K. L. Rao, R. M. A. Wahab, M. M. Dasor, and N. Mokhtar, "Enabling virtual learning for biomechanics of tooth movement: a modified nominal group technique," *Dentisry Journal*, vol. 11, no. 2, 2023, doi: 10.3390/dj11020053.
[38] M. Mousa, H. J. Teede, B. Garth, I. M. Winship, L. Prado, and J. A. Boyle, "Using a modified Delphi approach and nominal group technique for organisational priority setting of evidence-based interventions that advance women in healthcare leadership," *International Journal of Environmental Research and Public Health*, vol. 19, no. 22, 2022, doi: 10.3390/ijerph192215202.
[39] G. J. Skulmoski, F. T. Hartman, and J. Krahn, "The Delphi method for graduate research," *Journal of Information Technology Education: Research*, vol. 6, pp. 001–021, 2007, doi: 10.28945/199.
[40] D. C. Berliner, "Describing the behavior and documenting the accomplishments of expert teachers," *Bulletin of Science, Technology & Society*, vol. 24, no. 3, pp. 200–212, Jun. 2004, doi: 10.1177/0270467604265535.
[41] M. M. Rejab, S. Chuprat, and N. huda F. M. Azmi, "Proposed methodology using design development research (DDR) Improving Traceability Model with Test Effort Estimation," *I International Journal of Academic Research in Business and Social Sciences*, vol. 8, no. 8, Aug. 2018, doi: 10.6007/IJARBSS/v8-i8/4625.
[42] N. Harvey and C. A. Holmes, "Nominal group technique: an effective method for obtaining group consensus," *International Journal of Nursing Practice*, vol. 18, no. 2, pp. 188–194, Apr. 2012, doi: 10.1111/j.1440-172X.2012.02017.x.
[43] A. Dobbie, M. Rhodes, J. W Tysinger, and J. Freeman, "Using a modified nominal group technique as a curriculum evaluation tool," *Family Medicine*, vol. 36, no. 6, pp. 402–406, 2004.
[44] P. L. Williams, N. White, R. Klem, S. E. Wilson, and P. Bartholomew, "Clinical education and training: using the nominal group technique in research with radiographers to identify factors affecting quality and capacity," *Radiography*, vol. 12, no. 3, pp. 215–224, Aug. 2006, doi: 10.1016/j.radi.2005.06.001.
[45] T. Pastrana *et al.*, "Outcome indicators in palliative care—how to assess quality and success. focus group and nominal group technique in Germany," *Support Care Cancer*, vol. 18, no. 7, pp. 859–868, Jul. 2010, doi: 10.1007/s00520-009-0721-4.
[46] A. De Leon, J. N. Roemmich, and S. L. Casperson, "Identification of barriers to adherence to a weight loss diet in women using the nominal group technique," *Nutrients*, vol. 12, no. 12, p. 3750, Dec. 2020, doi: 10.3390/nu12123750.
[47] F. M. Mwaniki, F. K. Nyamu, and F. M. Waititu, "An exploration of the integration of ict in mathematics lessons in secondary schools, garissa county, Kenya," *Journal of Education*, vol. 4, no. 1, pp. 12–22, 2024.
[48] R. Thapa, N. Dahal, and B. P. Pant, "GeoGebra integration in high school mathematics-an experiential exploration on concepts of circle," *Mathematics Teaching-Research Journal*, vol. 14, no. 5, pp. 16–33, 2022.
[49] E. Nzaramyimana, "Effectiveness of GeoGebra towards students' active learning, performance and interest to learn mathematics," *International Journal Of Mathematics And Computer Research*, vol. 09, no. 10, Oct. 2021, doi: 10.47191/ijmcr/v9i10.05.
[50] E. Skordialos, "Empowering mathematics education in Greek primary schools: bridging the divide through ICT integration and interactive boards for enhanced teacher ICT literacy," *European Journal of Education and Pedagogy*, vol. 5, no. 2, pp. 59–63, Mar. 2024, doi: 10.24018/ejedu.2024.5.2.779.
[51] L. Nungu, E. Mukama, and E. Nsabayezu, "Online collaborative learning and cognitive presence in mathematics and science education. Case study of university of Rwanda, college of education," *Education and Information Technologies*, vol. 28, no. 9, pp. 10865–10884, Sep. 2023, doi: 10.1007/s10639-023-11607-w.
[52] E. Mitsea, A. Drigas, and C. Skianis, "ICTs and speed learning in special education: high-consciousness training strategies for high-capacity learners through metacognition lens," *Technium Social Sciences Journal*, vol. 27, pp. 230–252, 2022, doi: 10.47577/tssj.v27i1.5599.
[53] O. K. T. Kilag *et al.*, "ICT Integration in primary school classrooms in the time of pandemic in the light of Jean Piaget's cognitive development theory," *Int. J. Eme. Iss. Ear. Childhood Education*, vol. 4, no. 2, pp. 42–54, Nov. 2022, doi: 10.31098/ijeiece.v4i2.1170.
[54] A. C. Pires *et al.*, "Learning maths with a tangible user interface: lessons learned through participatory design with children with visual impairments and their educators," *Int. J. Child-Computer Interaction*, vol. 32, p. 100382, Jun. 2022, doi: 10.1016/j.ijcci.2021.100382.
[55] L. K. S. Abiatal and G. R. Howard, "Constructivism-led assistive technology: an experiment at a Namibian special primary school,"

South African Journal of Childhood Education*, vol. 10, no. 1, Jul. 2020, doi: 10.4102/sajce.v10i1.794.

[56] N. C. Burbules, G. Fan, and P. Repp, "Five trends of education and technology in a sustainable future," *Geography and Sustainability*, vol. 1, no. 2, pp. 93–97, Jun. 2020, doi: 10.1016/j.geosus.2020.05.001.

[57] M. Pouta, E. Lehtinen, and T. Palonen, "Student teachers' and experienced teachers' professional vision of students' understanding of the rational number concept," *Edu. Psychology Review*, vol. 33, no. 1, pp. 109–128, Mar. 2021, doi: 10.1007/s10648-020-09536-y.

[58] J. Kim, H. Lee, and Y. H. Cho, "Learning design to support student-AI collaboration: perspectives of leading teachers for AI in education," *Education and Information Technologies*, vol. 27, no. 5, pp. 6069–6104, Jun. 2022, doi: 10.1007/s10639-021-10831-6.

[59] J. Chen, X. Wang, and X. Zheng, "The Investigation of critical thinking disposition among Chinese primary and middle school students," *Thinking Skills and Creativity*, vol. 51, p. 101444, Mar. 2024, doi: 10.1016/j.tsc.2023.101444.

[60] S. İ. Asigigan and Y. Samur, "The effect of gamified STEM practices on students' intrinsic motivation, critical thinking disposition levels, and perception of problem-solving skills," *International Journal of Education in Mathematics, Science and Technology*, vol. 9, no. 2, pp. 332–352, Mar. 2021, doi: 10.46328/ijemst.1157.

[61] Y. Hacioğlu and F. Gülhan, "The effects of STEM education on the 7th grade students' critical thinking skills and STEM perceptions," *Journal of Education in Science, Environment and Health*, Jan. 2021, doi: 10.21891/jeseh.771331.

BIOGRAPHIES OF AUTHORS

Mohamad Ikram Zakaria earned his Ph.D. in mathematics education from Universiti Kebangsaan Malaysia, Bangi, Selangor. With over one year of experience, he serves as a Senior Lecturer in the School of Education, Faculty of Social Sciences and Humanities at Universiti Teknologi Malaysia (UTM). His current focus in research revolves around students' learning and development across various educational levels and domains. His published works encompass topics such as problem-solving, problem-based learning, mobile learning (m-learning), and the heutagogical approach within the field of mathematics education. He can be contacted at email: mohamad.ikram@utm.my.

Chuzairy Hanri is a senior lecturer at Universiti Teknologi Malaysian. His expertise in chemistry education includes scientific argumentation, scientific creativity, and STEM education. He can be contacted at email: chuzairy@utm.my.

Sri Hastuti Noer presently holds the position of Lecturer in the Faculty of Teacher Training and Education at Universitas Lampung, Indonesia. Her research focuses on mathematics education, with specific interests in higher order thinking skills and geometric thinking skills. She can be contacted at email: sri.hastuti@fkip.unila.ac.id.

Mella Triana holds the position of Lecturer in the Faculty of Teacher Training and Education at Universitas Lampung, Indonesia. Her research focuses on mathematics education, Mathematics reasoning, as well as motivation and attitudes towards mathematics. She can be contacted at email: mella.triana93@fkip.unila.ac.id.

Widyastuti holds the position of Lecturer in the Faculty of Teacher Training and Education at Universitas Lampung, Indonesia. Her research focuses on mathematics education, as well as mathematical thinking. She can be contacted at email: widyastuti.1986@fkip.unila.ac.id.