International Journal of Evaluation and Research in Education (IJERE)
Vol. 14, No. 2, April 2025, pp. 1488~1495
ISSN: 2252-8822, DOI: 10.11591/ijere.v14i2.29568

Identifying challenges of cultivating creativity in product design

Salwa Suradin, Mohamad Sattar Rasul, Marlissa Omar
STEM Enculturation Research Centre, Faculty of Education, Universiti Kebangsaan Malaysia, Bangi, Malaysia

Article Info

Article history:

Received Dec 11, 2023
Revised Sep 30, 2024
Accepted Oct 30, 2024

Keywords:

Creativity challenge
Creativity cultivation
Design and technology
Motivation
Product design
Systematic literature review
Teacher competence

ABSTRACT

Creativity, a crucial skill in the fourth industrial revolution (IR4.0) is highly demanded in the workforce to drive innovation in product design. Therefore, it is important to cultivate creativity in product design through design and technology (D&T) education. However, many past studies encountered challenges regarding D&T teachers' teaching creativity which might affect creativity cultivation among students. Thus, this article aims to identify the challenges faced by D&T teachers in cultivating student creativity within product design development. Utilizing the systematic literature review (SLR) method using reporting standards for systematic evidence syntheses (ROSES) in three databases, Web of Science, Scopus, and Google Scholar. Based on thematic analysis, this SLR leads to three themes: i) lack of pedagogical competence; ii) different thinking styles; and iii) lack of motivation. Addressing these challenges highlights the importance for educational institutions to align their curricula with current industry demands, ensuring students are well-prepared to tackle the complexities of contemporary product design. This effort requires collaboration among educators, industry leaders, and policymakers to update teaching methods, incorporate practical experiences, and enhance an environment that cultivates creativity.

Corresponding Author:

Marlissa Omar
STEM Enculturation Research Centre, Faculty of Education, Universiti Kebangsaan Malaysia
Bangi-43600, Selangor, Malaysia
Email: marlissa@ukm.my

1. INTRODUCTION

Creativity is a crucial skill in the fourth industrial revolution (IR4.0) in a highly challenging work environment [1]. By 2025, it will be positioned within the top five [2], highlighting it is high demand in the workforce. It is also a key component of 21st century skills, which includes technical, information, communication, collaboration, creativity, critical thinking, and problem-solving [3]. Cultivating creativity in product design education helps students develop innovation skills [4]. Creativity involves generating novel solutions for design challenges [5], emphasizing its importance in addressing real-world issues.

Design and technology (D&T) also known as technology education [6] is an academic discipline that requires students to develop creativity through product design with technology [7], [8]. Creativity is cultivated by the social environment and significantly influenced by teachers [9], via instruction and practice. Teachers' enthusiasm, dedication, and capacity for learning significantly affect student performance [10], making their competence essential for cultivating creativity in product design.

In previous study [11], interviews with 12 Latvian D&T teachers whose students scored in the Olympiad design competition 24.5 to 26 points out of 26, showed their expertise in creative design. These teachers gained knowledge from peers and industry for design ideas. This collaboration utilizes the combined knowledge and expertise of education and industry [12], allowing teachers to gain the required skills as they need strong spontaneous skills to handle unpredictable situations during the learning process. In England, D&T teachers foster collaboration by encouraging students to work together on product design [13], allowing them to share ideas from diverse perspectives and potentially nurturing specific talents in the future.

Cultivating students' creativity in product design is a significant concern for researchers. Many past studies encountered numerous challenges, with teachers' competence being a major one. In the Kirovohrad region, teachers often rely on intuition over informed practices and a lack of awareness about product-based teaching technology requirement [14]. They neglected to generate ideas for conceptualization [15], failing to enhance students' understanding of product design. Moreover, teachers struggle to balance cultivating creativity with technical skills [16], as D&T is a subject that encompasses both technical and creative elements.

The existence of a large volume of studies necessitates a systematic literature review (SLR) to collect and understand the findings of previous studies. There are studies, like [8] that look at SLR issues related to creativity in D&T education, but these studies are mostly focused on Hong Kong, while D&T education occurs in other countries as well. So, SLR is necessary because it is a comprehensive, transcendent, structured, and systematic literary highlighting technique [17]. To construct a relevant systematic review, the article was guided by the main research question: what are the challenges of cultivating creativity in product design among D&T teachers?

2. METHOD

This systematic literature review used the reporting standards for systematic evidence syntheses (ROSES) guideline, developed by Haddaway *et al.* [18]. ROSES is particularly suitable for reference as it assists researchers in developing a thorough and well-structured SLR due to it is adaptability to various research approaches and applicability across multiple fields [18]. Following ROSES' guidance, the SLR process began with the research questions using the PICo method: 'P' for population or problem, 'I' for interest, and 'Co' for context. Followed by a systematic search strategy (identification, screening, and eligibility) and data abstraction and analysis. The research question, based on PICo, helps the researchers analyze extracted data to find the relevant evidence from the database [19]. The review included three main aspects namely D&T teachers (population), cultivating creativity challenge (interest), and product design (context) formulating the main objective of the study: "What are the challenges of cultivating creativity in product design among D&T teachers?"

2.1. Systematic searching strategies

This section describes three sub-processes of systematic strategies: identification, screening, and eligibility. The study followed this procedure. The researchers aimed to efficiently locate and synthesize relevant information essential for conducting a comprehensive SLR.

2.1.1. Identification

The first step in the SLR process involves identification, wherein the researchers systematically search predetermined databases for relevant literature. This step enhances the importance of keywords and increases the probability of finding more relevant articles [20]. Keywords related to cultivating creativity challenges, product design, and teachers were identified by referencing previous studies and thesaurus, followed by utilizing the three databases: Web of Science (WoS), Scopus, and Google Scholar. WoS and Scopus were chosen for their high-quality databases [21], advanced search functions, and surpassing other databases [22], ability to support complex queries and filters to refine search results [23], making them suitable for systematic review and evidence synthesis. Despite Google Scholar's quality control [24], its strengths are the number of articles and reference diversity [25], therefore it can serve as a supplementary database.

Advanced searching techniques applying basic functions such as Boolean operators (AND, OR), phrase searching, truncation, wild card, and field codes functions were applied in WoS and Scopus, while manual searches using the handpicking method on Google Scholar and the snowballing on the selected articles. Table 1 shows the keywords used to find related articles. This search yielded 174 articles for the screening.

2.1.2. Screening

Screening is the second process that includes or excludes articles from the review [26]. The first criterion is publication year, focusing on the last six years (2018-2023) due to the significant rise in articles since 2018. Only empirical research articles providing primary data, written in English were considered to ensure the quality to avoid translation problems as shown in Table 2. Articles on product design in the D&T context were included, excluding 126 articles and the remaining 48 articles. However, five duplicate records were identified, making the total number of 43 articles for the next selection stage.

Table 1. The search string used for the systematic review process

Databases	Keywords used
Scopus	TITLE-ABS-KEY ((“design and technology” OR “engineer* education” OR “technology* education”) AND (“product* design*” OR “design* process*” OR “project*” OR “design*”) AND (“creative*” AND “challenge*” OR “barrier*” OR “obstacle*”) AND (“teacher*” OR “educator*” OR “practitioner*”))
Web of Science	TS = ((“design and technology” OR “engineer* education” OR “technology* education”) AND (“product* design*” OR “design* process*” OR “project*” OR “design*”) AND (“creative*” AND “challenge*” OR “barrier*” OR “obstacle*”) AND (“teacher*” OR “educator*” OR “practitioner*”))
Google Scholar	Using specific keywords from Scopus and WoS, as well as Boolean operators, phrase searches, and field code functions (either together or individually) as appropriate

Table 2. The inclusion and exclusion criteria

Criterion	Inclusion	Exclusion
Literature category	Journal (research article)	Book, book series, chapter in book, systematic review articles, conference proceeding
Language	English	Non-English
Timeline	2018 to 2023	2017 and earlier
Country	World	

2.1.3. Eligibility

Eligibility is a manual screening process that involves analyzing the articles that enable researchers to minimize the glitches possibly caused by the database [27]. After careful examination, 28 articles were excluded due to the focus on art and craft, and pure science subjects rather than D&T subjects. Overall, there were only 15 articles selected in this study as shown in Figure 1.

2.2. Data abstraction and analysis

The remaining articles were evaluated and analyzed, focusing on specific studies that addressed the formulated questions. The data were extracted by thoroughly reading the abstracts and full articles to identify relevant themes. The thematic analysis employed content analysis to identify themes related to D&T teachers’ challenges in cultivating creativity in product design.

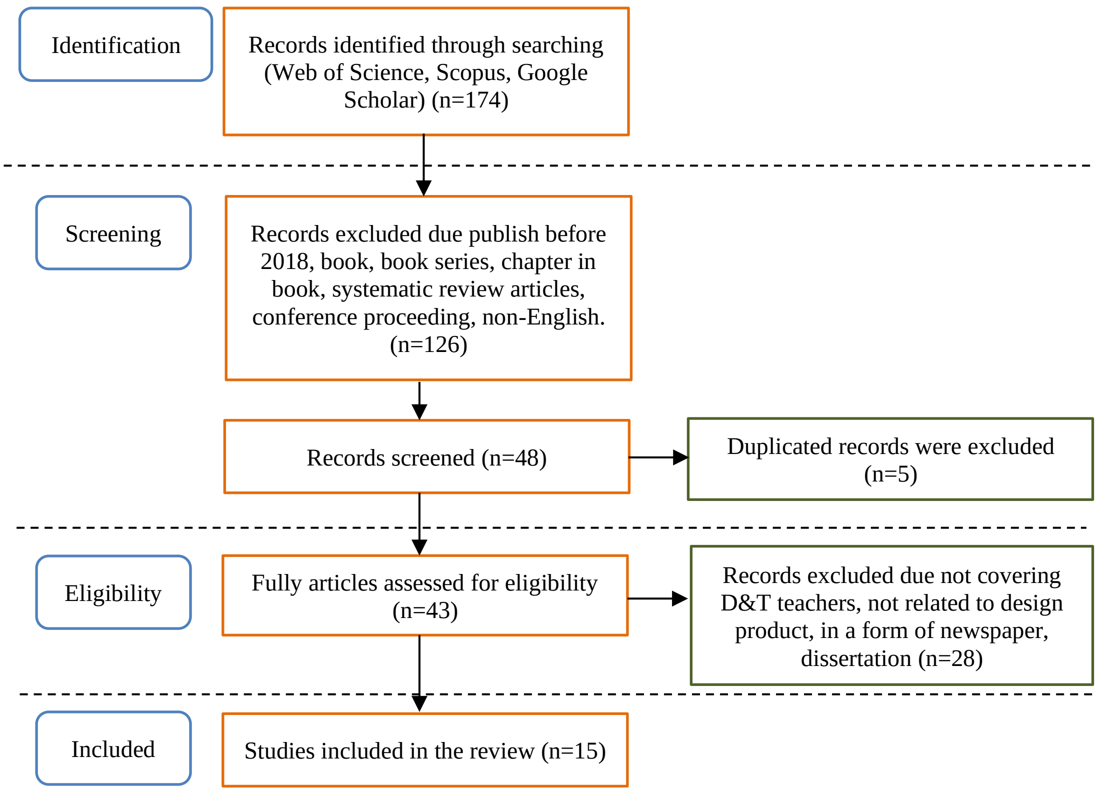

Figure 1. Diagram of the article selection procedure

3. RESULTS AND DISCUSSION

3.1. Background of the selected study

Among the 15 selected articles, two were published in 2023, two in 2022, five in 2021, three in 2020, and others in 2019. Five articles appeared in the International Journal of Technology and Design Education, three in the Journal of Technical Education and Training, and one each in archives of design research, Asia-Pacific Education Researcher, British Educational Research Journal, FormAkademisk, International Journal of Training Research, Journal of Creative Behavior, and Journal of Vocational Education Studies.

3.2. The developed themes

The thematic analysis was undertaken on 15 selected articles identifying three themes of key challenges: i) lack of pedagogical competence; ii) different thinking styles; and iii) lack of motivation, as shown in Table 3. These three key challenges address the main research question of this SLR.

3.2.1. Challenge 1: lack of pedagogical competence

The first challenge identified was a lack of pedagogical competence among teachers. Many struggle to deliver effective feedback that cultivates creativity, due to unable to adapt their input to diverse students' needs [6], [11], [28]–[30]. In product design, insufficient knowledge and skills of inventive problem-solving impede their effectiveness in teaching [7]. The problem is exacerbated by many D&T teachers having non-specialist backgrounds, which are in creative arts rather than engineering and technology [31], [32], struggling them to create innovative learning experiences, and limiting students' creativity.

They have a limited ability to facilitate learning. An important challenge lies in properly implementing collaborative learning [33]–[35], essential for teamwork and ideas sharing among students. They often lack the skills to create a conducive learning environment [28]. Guiding students in design processes is challenging, as it requires a deep understanding of iterative problem-solving and creative exploration. Moreover, inadequate digital tools [36] hinder their pedagogical effectiveness. Additionally, time constraints in preparation [32], restricting their ability to pose students to diverse problem-solving approaches.

They lack training in contemporary pedagogical approaches, such as constructivism, that cultivate creativity, leading them to use established practices over encouraging an exploration environment [28], [33]. Dependence on routines limits students' engagement in creative problem-solving in product design. Moreover, D&T teachers were shaped by past experiences and mentors [32] causing them to resist change. Consequently, the curriculum misaligned with the changing demands of product design in D&T, limiting students' creativity.

The deficiency affects many aspects of the educational process. While students are adept at conceptualizing ideas, they face difficulties transforming these concepts into tangible and feasible designs [37]. Their ideas were hindered due to the teachers' ineffective guidance [38]. Teachers from non-specialist backgrounds who lack the essential pedagogical competence struggle to overcome this gap [39] in creating innovative learning experiences in product design. Consequently, students receive insufficient exposure to the various problem-solving approaches in cultivating creativity in product design.

3.2.2. Challenge 2: different thinking style

The second theme identified the difference in thinking styles in students' creative performance. Most students in product design applied a risk-averse thinking style [33], [35], [36], [40], relying on established solutions without questioning them. A study by Tan *et al.* [30] found that students depended on teachers for problem-solving. While they do generate initial design ideas, they often stick to these without exploring alternative ideas [11]. This reluctance to move beyond initial ideas prevents them from discovering more creative solutions, as they prioritize safe and familiar approaches.

However, some students take responsibility for their learning [34]. Independent-thinking students contribute diverse ideas but potentially cause conflicts or misunderstandings [15], [30], challenging teachers to handle differing viewpoints while maintaining learning objectives. Different thinking among them [6], [41] leads to different ability levels [11], posing a challenge for teachers to support all students. Teachers must balance providing guidance and allowing students the autonomy for idea exploration.

These findings underscore the significance of acknowledging and accommodating different thinking styles in product design education. A structured environment with predictable outcomes fosters risk-averse thinking [42], but teachers' reliance on rubrics can limit students from generating creative ideas [43], despite rubrics guiding teaching effectively. This rigidity inhibits creativity [44], which pressures independent thinkers to meet specific benchmarks instead of thinking outside the box.

Table 3. The findings

No	Authors (country)	Lack pedagogical competence	Different thinking style	Lack of motivation
1	Kola [6] (South Africa)	Teachers struggle to adapt feedback on design processes.	Students' diverse thinking styles need varied teaching methods.	Students diminishes willingness to explore creative solutions
2	Hashim *et al.* [28] (Malaysia)	Traditional teachers lack the skills to facilitate learning	-	Teachers feel overwhelmed by the demands of their job
3	Uyub *et al.* [29] (Malaysia)	Teachers' difficulty facilitating discussion and student-led inquiry.	Students rely on teachers' solutions.	Students show little drive and low cooperation
4	Urdziņa-Deruma [11] (Latvia)	Teachers struggle to encourage students to explore ideas	Students are firm to initial ideas and have differing ability	Students discourage peers from engaging in the process.
5	Tan *et al.* [30] (Malaysia)	Teachers' difficulty providing constructive feedback	Communication barrier among students	Students' reluctance to share ideas
6	Tee *et al.* [7] (Malaysia)	Teachers' lack inventive problem-solving skills	-	Teachers experience workloads.
7	Ahmad *et al.* [31] (Malaysia)	Non-specialist backgrounds teachers	-	Teachers need intensive training.
8	Jones *et al.* [32] (United Kingdom)	Non-specialist teachers lack time and resist change.	-	Lack of student engagement and enthusiasm for the design.
9	Christensen *et al.* [40] (Denmark)	Teachers rely on established methods	Students favor established solutions.	Students afraid of failure
10	Delahunty *et al.* [33] (Ireland)	Traditional teachers struggle with collaborative learning	Students favor structured learning	Students fail to see the relevance or application
11	Han *et al.* [34] (United Kingdom)	Teachers find hard to balance individual and group work	Students take ownership of learning	Students felt peer pressure from dominant members.
12	Kim [15] (Korea)	-	Diverse ideas lead to conflicts	-
13	Enochsson *et al.* [36] (Sweden)	Limited knowledge teachers	Students adhere strictly to instructions	Lack of student engagement in the design product
14	Mou [35] (Taiwan)	Teachers' difficulty in providing structured guidance	Students prefer a single solution over more exploration	Students' difficulty in problem-solving
15	Weng *et al.* [41] (China)	-	Students' diverse levels of understanding of new concepts	Students have low confidence in their abilities

3.2.3. Challenge 3: lack of motivation

Encouraging student motivation is a significant challenge for teachers, especially when they lack personal investment in product design. Disinterest in completing product design in D&T [29] results in disengagement and refusal to exert effort [6], [32], [36]. They fail to see the relevance of their learning [33], and a belief in "right" and "wrong" answers in design [40] foster a cautious approach and stifling creativity.

Peers' dynamics further complexity, as disengaged students influence others, while dominant members create pressure and reluctance to idea contribution [11], [30], [41]. This leads to problem-solving issues, frustration, and decreased motivation [35]. As a result, teachers often interfere by proposing ideas and guiding students to complete the design, disrupting other students' learning. Consequently, teachers who feel overburdened [7], [28] develop negative attitudes and lead to burnout [28] due to excessive workload.

Motivating students is challenging, especially without personal investment in the subject [45]. Previous research [36] showed a positive correlation between students' design interest and motivation, suggesting the benefits of cultivating creativity. Nevertheless, teachers' guidance significantly boosts students' creativity, as seen in a study with low academic achieving Singaporean students [46], highlighting the crucial role of teachers' involvement and support through motivation. Moreover, hands-on experiences enhance students' understanding [13], articulating their needs while gaining insights into others' experiences.

Overall, these findings emphasize the pivotal role of student interest in cultivating creativity within product design. Teachers should prioritize engaging students' design interests [47], [48] by providing opportunities for hands-on experiences in 3D fabrication such as including 3D printing and computer [49] to explore creative possibilities. Moreover, a study by Park and Lee [50] stated that teachers who foster an environment of learning by encouraging experimentation, recognizing small achievements, and promoting a growth mindset can help students overcome their comfort zone and participate in the creative process.

4. CONCLUSION

This SLR identified challenges, such: i) lack of pedagogical competence; ii) different thinking styles; and iii) lack of motivation, are significantly impact the cultivation of students' creativity in product design. These findings are critical in D&T education, emphasizing the importance of providing D&T teachers with specialized training and pedagogical support, allowing them to gain more exposure to the content to effectively cultivate creative problem-solving skills in students. By addressing these challenges, educational institutions can synchronize their curriculum with current demands, ensuring students are more proficient in navigating the complexity of contemporary design. The implications for the community are significant. Since creativity is a fundamental aspect of innovation, improving students' inventiveness may drive advancement across various industries. A more creatively skilled workforce can lead to the development of innovative products, boosting economic growth and improving quality of life. Thus, stakeholders in education, industry, and policymaking should work together to revise teaching methods, integrate practical experiences, and create an environment that promotes exploration and experimentation. Further study is required to explore how technology, such as digital tools and 3D fabrication, can be integrated into teaching to overcome the gap between conceptualization and realization in product design, ultimately cultivating students' creative potential.

ACKNOWLEDGEMENTS

The authors acknowledge the Universiti Kebangsaan Malaysia (UKM) for funding under Geran Galakan Penyelidik Muda (GGPM) under the grant number GGPM-2022-019.

REFERENCES

[1] F. M. Kamaruzaman, R. Hamid, A. A. Mutalib, and M. S. Rasul, "Determination of 4IR generic skills constructs for engineering graduates," *Journal of Positive School Psychology*, no. 3, pp. 243–257, 2021.

[2] World Economic Forum, "The Future of Jobs Report 2020," Geneva, 2020.

[3] E. van Laar, A. J. A. M. van Deursen, J. A. G. M. van Dijk, and J. de Haan, "Determinants of 21st-century skills and 21st-century digital skills for workers: a systematic literature review," *Sage Open*, vol. 10, no. 1, Jan. 2020, doi: 10.1177/2158244019900176.

[4] O. I. Higuera-Martinez and L. Fernández-Samacá, "Fostering creativity in engineering through PBL," *International Research Symposium on PBL*, pp. 414–423, 2020.

[5] D. McInerney, "Insights into product design students' perception of, and engagement with, creativity in design education," *International Journal of Technology and Design Education*, vol. 33, no. 3, pp. 1199–1219, Jul. 2023, doi: 10.1007/s10798-022-09766-x.

[6] I. M. Kola, "Using analytical rubrics to assess technological solutions in the technology classroom," *International Journal of Technology and Design Education*, vol. 32, no. 2, pp. 883–904, Apr. 2022, doi: 10.1007/s10798-020-09635-5.

[7] T. K. Tee *et al.*, "Design and technology teacher in TVET: A view on thinking style and inventive problem-solving skill," *Journal of Technical Education and Training*, vol. 12, no. 1, pp. 197–203, 2020, doi: 10.30880/jtet.2020.12.01.021.

[8] Y. L. Wong and K. W. M. Siu, "Is there creativity in design? From a perspective of school design and technology in Hong Kong," *Asia Pacific Education Review*, vol. 13, no. 3, pp. 465–474, Sep. 2012, doi: 10.1007/s12564-012-9208-y.

[9] T. M. Amabile and M. G. Pratt, "The dynamic componential model of creativity and innovation in organizations: Making progress, making meaning," *Research in Organizational Behavior*, vol. 36, pp. 157–183, 2016, doi: 10.1016/j.riob.2016.10.001.

[10] H. Serin, "The role of passion in learning and teaching," *International Journal of Social Sciences and Educational Studies*, vol. 4, no. 1, 2017, doi: 10.23918/ijsses.v4i1p60.

[11] M. Urdziņa-Deruma, "The preparing pupils for textile technology Olympiads," *FormAkademisk*, vol. 16, no. 1, Jun. 2023, doi: 10.7577/formakademisk.4624.

[12] M. Omar and F. M. Kamaruzaman, "Technical and vocational education training and industry collaboration: a bibliometric review," *Journal of Education and Learning (EduLearn)*, vol. 18, no. 4, pp. 1582–1592, Nov. 2024, doi: 10.11591/edulearn.v18i4.21120.

[13] H. Demetriou and B. Nicholl, "Empathy is the mother of invention: Emotion and cognition for creativity in the classroom," *Improving Schools*, vol. 25, no. 1, pp. 4–21, Mar. 2022, doi: 10.1177/1365480221989500.

[14] L. Chystiakova, "The project method at design and technology lessons in terms of reforming the new Ukrainian school," *Science and Education*, vol. 25, no. 5, pp. 61–66, May 2017, doi: 10.24195/2414-4665-2017-5-12.

[15] H. Kim, "Learning from two types of class projects in interactive physical prototyping: comparison between technology-driven and experience-driven project results," *Archives of Design Research*, vol. 33, no. 3, pp. 75–87, Aug. 2020, doi: 10.15187/adr.2020.08.33.3.75.

[16] M. McLain, D. Irving-Bell, D. Wooff, and D. Morrison-Love, "How technology makes us human: cultural historical roots for design and technology education," *The Curriculum Journal*, vol. 30, no. 4, pp. 464–483, Dec. 2019, doi: 10.1080/09585176.2019.1649163.

[17] H. A. M. Shaffril, S. E. Krauss, and S. F. Samsuddin, "A systematic review on Asian's farmers' adaptation practices towards climate change," *Science of The Total Environment*, vol. 644, pp. 683–695, Dec. 2018, doi: 10.1016/j.scitotenv.2018.06.349.

[18] N. R. Haddaway, B. Macura, P. Whaley, and A. S. Pullin, "ROSES reporting standards for systematic evidence syntheses: pro forma, flow-diagram and descriptive summary of the plan and conduct of environmental systematic reviews and systematic maps," *Environmental Evidence*, vol. 7, no. 1, Dec. 2018, doi: 10.1186/s13750-018-0121-7.

[19] H. A. M. Shaffril, A. A. Samah, and S. Kamarudin, "Speaking of the devil: a systematic literature review on community preparedness for earthquakes," *Natural Hazards*, vol. 108, no. 3, pp. 2393–2419, Sep. 2021, doi: 10.1007/s11069-021-04797-4.

[20] H. A. M. Shaffril, A. A. Samah, and S. F. Samsuddin, "Guidelines for developing a systematic literature review for studies related to climate change adaptation," *Environmental Science and Pollution Research*, vol. 28, no. 18, pp. 22265–22277, May 2021, doi: 10.1007/s11356-021-13178-0.

[21] S. R. M. Yusop, M. S. Rasul, R. Mohamad Yasin, H. U. Hashim, and N. A. Jalaludin, "An assessment approaches and learning outcomes in technical and vocational education: a systematic review using PRISMA," *Sustainability*, vol. 14, no. 9, Apr. 2022, doi: 10.3390/su14095225.

[22] M. Gusenbauer and N. R. Haddaway, "Which academic search systems are suitable for systematic reviews or meta-analyses? Evaluating retrieval qualities of Google Scholar, PubMed, and 26 other resources," *Research Synthesis Methods*, vol. 11, no. 2, pp. 181–217, Mar. 2020, doi: 10.1002/jrsm.1378.

[23] A. Martín-Martín, M. Thelwall, E. Orduna-Malea, and E. Delgado López-Cózar, "Google Scholar, Microsoft Academic, Scopus, Dimensions, Web of Science, and OpenCitations' COCI: a multidisciplinary comparison of coverage via citations," *Scientometrics*, vol. 126, no. 1, pp. 871–906, Jan. 2021, doi: 10.1007/s11192-020-03690-4.

[24] H. A. Mohamed Shaffril, N. Ahmad, S. F. Samsuddin, A. A. Samah, and M. E. Hamdan, "Systematic literature review on adaptation towards climate change impacts among indigenous people in the Asia Pacific regions," *Journal of Cleaner Production*, vol. 258, Jun. 2020, doi: 10.1016/j.jclepro.2020.120595.

[25] G. Halevi, H. Moed, and J. Bar-Ilan, "Suitability of Google Scholar as a source of scientific information and as a source of data for scientific evaluation-review of the literature," *Journal of Informetrics*, vol. 11, no. 3, pp. 823–834, Aug. 2017, doi: 10.1016/j.joi.2017.06.005.

[26] L. Affengruber *et al.*, "Characteristics and recovery methods of studies falsely excluded during literature screening-a systematic review," *Systematic Reviews*, vol. 11, no. 1, Nov. 2022, doi: 10.1186/s13643-022-02109-w.

[27] H. A. M. Shaffril, S. F. Samsuddin, and A. Abu Samah, "The ABC of systematic literature review: the basic methodological guidance for beginners," *Quality and Quantity*, vol. 55, no. 4, pp. 1319–1346, Aug. 2021, doi: 10.1007/s11135-020-01059-6.

[28] S. Hashim, S. H. Zakariah, F. A. Taufek, N. N. Zulkifli, N. H. Che Lah, and D. E. Murniati, "An observation on implementation of classroom assessment in technical and vocational education and training (TVET) subject area," *Journal of Technical Education and Training*, vol. 13, no. 3, Sep. 2021, doi: 10.30880/jtet.2021.13.03.019.

[29] N. Uyub, N. H. Noh@Seth, N. S. A. Alhassora, N. A. Mohd Ahyan, H. Jambari, and M. R. Pairan, "Factors contributing to students' attainment in design and technology project work," *Journal of Technical Education and Training*, vol. 13, no. 1, Mar. 2021, doi: 10.30880/jtet.2021.13.01.007.

[30] C. Tan, X. Lau, and L. Lee, "The mediating role of creative process engagement in the relationship between shyness and self-rated creativity," *The Journal of Creative Behavior*, vol. 53, no. 2, pp. 222–231, Jun. 2019, doi: 10.1002/jocb.173.

[31] N. A. Ahmad, R. C. Ros, A. Kamis, and H. N. Makmor, "Need analysis: development of Lk-D&T sketch module for form one design and technology (D&T) subject in secondary school," *Journal of Vocational Education Studies*, vol. 2, no. 2, 2019, doi: 10.12928/joves.v2i2.708.

[32] L. C. R. Jones, H. J. McDermott, J. R. Tyrer, and N. P. Zanker, "The effect of teacher's confidence on technology and engineering curriculum provision," *International Journal of Technology and Design Education*, vol. 31, no. 1, pp. 117–137, Mar. 2021, doi: 10.1007/s10798-019-09542-4.

[33] T. Delahunty and R. Kimbell, "(Re)framing a philosophical and epistemological framework for teaching and learning in STEM: Emerging pedagogies for complexity," *British Educational Research Journal*, vol. 47, no. 3, pp. 742–769, Jun. 2021, doi: 10.1002/berj.3706.

[34] J. Han, D. Park, M. Hua, and P. R. N. Childs, "Is group work beneficial for producing creative designs in STEM design education?" *International Journal of Technology and Design Education*, vol. 32, no. 5, pp. 2801–2826, Nov. 2022, doi: 10.1007/s10798-021-09709-y.

[35] T.-Y. Mou, "Students' evaluation of their experiences with project-based learning in a 3D design class," *The Asia-Pacific Education Researcher*, vol. 29, no. 2, pp. 159–170, Apr. 2020, doi: 10.1007/s40299-019-00462-4.

[36] A.-B. Enochsson, N. Kilbrink, A. Andersén, and A. Ådefors, "Obstacles to progress: Swedish vocational teachers using digital technology to connect school and workplaces," *International Journal of Training Research*, vol. 20, no. 2, pp. 111–127, May 2022, doi: 10.1080/14480220.2021.1979623.

[37] P. Goodyear, "Design and co-configuration for hybrid learning: Theorising the practices of learning space design," *British Journal of Educational Technology*, vol. 51, no. 4, pp. 1045–1060, Jul. 2020, doi: 10.1111/bjet.12925.

[38] M. S. Fredagsvik, "The challenge of supporting creativity in problem-solving projects in science: a study of teachers' conversational practices with students," *Research in Science & Technological Education*, vol. 41, no. 1, pp. 289–305, Jan. 2023, doi: 10.1080/02635143.2021.1898359.

[39] P. Hanley and R. Thompson, "'Generic pedagogy is not enough': Teacher educators and subject-specialist pedagogy in the Further Education and Skills sector in England," *Teaching and Teacher Education*, vol. 98, Feb. 2021, doi: 10.1016/j.tate.2020.103233.

[40] K. S. Christensen, M. Hjorth, O. S. Iversen, and R. C. Smith, "Understanding design literacy in middle-school education: assessing students' stances towards inquiry," *International Journal of Technology and Design Education*, vol. 29, no. 4, pp. 633–654, Sep. 2019, doi: 10.1007/s10798-018-9459-y.

[41] C. Weng, C. Chen, and X. Ai, "A pedagogical study on promoting students' deep learning through design-based learning," *International Journal of Technology and Design Education*, vol. 33, no. 4, pp. 1653–1674, Sep. 2023, doi: 10.1007/s10798-022-09789-4.

[42] R. Harris, "Risk aversion in a performativity culture-what can we learn from teachers' curriculum decision making in history?" *Journal of Curriculum Studies*, vol. 53, no. 5, pp. 659–674, Sep. 2021, doi: 10.1080/00220272.2021.1884294.

[43] E. Panadero and A. Jonsson, "A critical review of the arguments against the use of rubrics," *Educational Research Review*, vol. 30, Jun. 2020, doi: 10.1016/j.edurev.2020.100329.

[44] K. van Broekhoven, D. Cropley, and P. Seegers, "Differences in creativity across art and STEM students: We are more alike than unalike," *Thinking Skills and Creativity*, vol. 38, Dec. 2020, doi: 10.1016/j.tsc.2020.100707.

[45] L. K. Fryer, H. N. Bovee, N. Witkin, and P. Matthews, "Nudging students' interest in learning a new language: An experimental proof of concept for an online informational-nudge," *System*, vol. 119, 2023, doi: 10.1016/j.system.2023.103162.

[46] N. Amir, "Strengthening the science-D&T interaction through simple maker-centred projects in a Singapore classroom," *Physics Education*, vol. 55, no. 4, Jul. 2020, doi: 10.1088/1361-6552/ab9212.

[47] M. L. Aranda, R. Lie, S. S. Guzey, M. Makarsu, A. Johnston, and T. J. Moore, "Examining teacher talk in an engineering design-based science curricular unit," *Research in Science Education*, vol. 50, no. 2, p. 469, 2020, doi: 10.1007/s11165-018-9697-8.

[48] E. Vrieling-Teunter, R. Hebing, and M. Vermeulen, "Design principles to support student learning in teacher learning groups," *Teachers and Teaching*, vol. 27, pp. 64–81, May 2021, doi: 10.1080/13540602.2021.1920909.

[49] K. Jones and J. D. Mendez, "Enhancing learning with 3D print technology: A case study of problem based learning," *Journal of Education for Business*, vol. 96, no. 3, pp. 187–194, Apr. 2021, doi: 10.1080/08832323.2020.1774735.

[50] E. J. Park and S. Lee, "Creative thinking in the architecture design studio: bibliometric analysis and literature review," *Buildings*, vol. 12, no. 6, Jun. 2022, doi: 10.3390/buildings12060828.

BIOGRAPHIES OF AUTHORS

Salwa Suradin is a doctoral candidate in the Faculty of Education, Universiti Kebangsaan Malaysia, Bangi, Malaysia. Her research concentrates on creativity in designing products in TVET education. She can be contacted at email: p121279@siswa.ukm.edu.my.

Mohamad Sattar Rasul is a professor in the Faculty of Education, Universiti Kebangsaan Malaysia since 2012. His research interests include STEM education, career development, quality assurance, qualification and skills certification systems, and TVET policy and curriculum. He was awarded the Top Researcher Award Receiving External Research Grants in 2018. He holds the position of Professor in TVET and STEM Education at the university level, Chairman of the STEM Cultivation Study Center for almost seven years, and Fellow of the Engineering Education and Research Center. He received the honor of "Most Published in Indexed Journal (WoS/Scopus/ERA)" in 2018. He can be contacted at email: drsattar@ukm.edu.my.

Marlissa Omar is a senior lecturer at Centre for STEM Enculturation, Faculty of Education, Universiti Kebangsaan Malaysia. She obtained her Doctor of Philosophy in Technical and Vocational Education (TVET) from Universiti Teknologi Malaysia (UTM). Besides teaching, she is actively involved in research activities. Her current research interests include vocational education, digitization in TVET, Mobile apps in TVET education, and other issues in TVET education. She can be contacted at email: marlissa@ukm.edu.my.