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STEAM-ECE: Developing a STEAM Approach for Early Childhood Education in Indonesia

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ABSTRACT
This paper examines the introduction of STEAM (Science, Technology, Engineering, Arts, and Mathematics) education in Early Childhood Education (ECE) in Indonesia, focusing on the 2022 Merdeka Curriculum's (MoECRT, 2022) efforts to incorporate technology and digital literacy into the learning process. Despite some progress, teachers still face challenges implementing STEAM into their teaching practice due to a lack of confidence and resources. The study examines the STEAM-ECE project, a capacity-building initiative led by Maker{Futures} and universities in the UK and Indonesia, which aims to empower pre- and in-service teachers and ECE lecturers with the skills and knowledge necessary to implement STEAM learning. The project included hands-on workshops, where teachers gained skills and confidence in making and implementing a maker approach in their classrooms. Interviews were carried out with seven teachers and six ECE university lecturers who had attended the workshop and had implemented the sessions into their own practice. These interviews aimed to explore the workshop's impact on teaching practice and how the ECE lecturers had assimilated the workshop content into their pre-service curriculum. The findings emphasize the importance of local expertise in sustaining STEAM education and highlight the potential of makerspaces as innovative learning environments. This study contributes new insights into STEAM implementation in ECE within Low- and Middle-Income Countries, offering a scalable professional development model adaptable to diverse cultural contexts.

Keywords: Early Childhood Education, Indonesia, Teacher Professional Development, Makerspaces, STEAM

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1. INTRODUCTION

Over the past two decades, Indonesia has taken several steps to prioritize Early Childhood Education (ECE), and through various educational reforms, policies, and financial investments, policymakers have made a commitment to increase opportunities for children to access higher-quality education and care in the early years (World Bank, 2020; 2023). In 2022, the Merdeka Curriculum was launched by the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia (MoECRT), which aimed to provide a holistic and inclusive approach to education with an emphasis on the development of character, creativity, and critical thinking skills (MoECRT, 2022). The new curriculum reflects a flexible framework designed to meet the diverse needs of students and prepare them to navigate the complexity of the future world. At a global level there has been an increasing emphasis on the importance of engaging young children in Science, Technology, Engineering, and Mathematics (STEM) related activities to ensure that children acquire the related skills, knowledge, and practices to navigate the rapid development of new technologies and contribute to social, virtual, and economic developments (Marsh et al., 2019). This drive is reflected in the Merdeka Curriculum (MoECRT, 2022), and the use of technology and digital literacy skills is presented as a way of improving the learning experience of Indonesian children, preparing them for the challenges of the 21st century by providing them with the skills and knowledge they need to succeed in a changing world (Zidan & Qamariah, 2023).

STEM in ECE can be framed as a way of thinking (Science), a way of doing (Technology), the process of solving problems (Engineering), and the process of applying knowledge (Mathematics) (Vasquez et al., 2020). The inclusion of 'A' in STEAM covers the Arts, including crafting, music, and culture. The development of workforce competencies for the 21st century has been gaining international momentum with a focus on creativity, innovation, problem-solving, critical thinking, and collaboration as a way of achieving a more productive and sustainable economy (Allina, 2018). The 'makerspace' movement is an educational approach that provides children with opportunities to engage in STEAM learning through design and making, driven by their own interests (Author, 2024a). In makerspaces, children can tinker, explore, and create a range of artifacts using various materials and tools, developing multidisciplinary knowledge and skills that are essential for future success (Author, 2024b).

Despite the introduction of learning outcomes that emphasize literacy, science, technology, engineering, art, and mathematics (MoECRT, 2022), support to drive STEAM learning in Indonesian schools remains limited, and teachers lack the necessary skills, knowledge and resources to deliver this approach in their classroom (Prahani et al., 2023). Similar challenges with teacher professional development and the implementation of STEAM in schools have been widely reported in the literature as an international problem (Ng et al., 2022; Wan et al., 2021). Quintana-Ordorika et al. (2024) argue that:

> *"Several previous studies have highlighted the need for further research in the area of maker education, specifically in providing a formal maker training that prepares future teachers to effectively integrate maker pedagogical approaches into educational practices and assume the role of makerspace instructors (p.835)."*

Research focusing on pre-service teacher training and professional development opportunities consistently highlights how educators are underprepared to teach STEM subjects (Çiftçi et al., 2022; Ingleby, 2015; Johnston et al., 2022). Considering the importance placed on these subjects in preparing children for an advanced technological future, it is imperative that teachers possess the skills and knowledge to support children's STEM development in a creative, effective, and playful manner (Author, 2024b). Furthermore, teachers need to have a positive attitude to STEM learning and development, so that children develop their own positive dispositions in these subjects (Johnston et al., 2022).

A scoping review of STEM professional learning in ECE illuminated how workshops and professional learning networks positively influence the STEM confidence, knowledge and skills of early childhood educators (MacDonald et al., 2023). Hughes et al. (2022) assert that "Structured opportunities for hands-on engagement with maker concepts, strategies, and technologies is essential for cultivating confidence, generating alternative assessment strategies, and understanding the curricular relevance of making" (p.3). It is important that teachers can be makers themselves to best support their learners in making activities. Allowing teachers time to create lesson plans that integrate making into their curriculum and professional practice, and then implementing these plans in the classroom, is another effective strategy for 'maker' professional development (Chen & Cao, 2021). A key challenge for schools is that this approach to teacher professional development requires significant investment and support in terms of time and resources to be successful in a sustainable way.

This paper reports on a STEAM-ECE project implemented by Maker{Futures} and the School of Education at the University of Sheffield (UoS) in the United Kingdom, and the Early Childhood Teacher Education Department at Universitas Pendidikan Indonesia (UPI) in Indonesia. Maker{Futures} is a TUoS initiative that helps early years settings, schools, libraries, museums and community spaces develop their maker education provision through workshops, activity days and events, and professional development sessions. The overarching research question is:

> *"How can the implementation of maker space workshops with pre- and in-service teachers support the development of STEAM skills and knowledge for teachers and children in Indonesia?"*

STEAM-ECE was a capacity-building program that aimed to empower ECE pre-service and in-service Teachers and lecturers in Indonesia with the knowledge, skills, and mindsets necessary for teaching STEAM to early learners. The project brought together expertise from both universities to co-develop a new STEAM-based professional development module and resources that were delivered over three days to pre-service teachers and ECE academics in Purwakarta, Indonesia. The work was funded by the British Council's UK-Indonesia Going Global Partnerships (GGP) Teacher Training Grant, with a core commitment to engaging with a diverse range of stakeholders and beneficiaries. This was achieved by inviting a diverse group of participants, including university lecturers, pre- and in-service teachers with differing experiences and socio-economic backgrounds. The project, therefore, worked to benefit a range of stakeholders both directly and indirectly. In the first instance, the workshops provided in-service teachers with knowledge and skills to develop and deliver STEAM-based practices in their Early Years classrooms. The training also helped to enhance pre-service training and standards of practice by connecting and upskilling these future teachers with international, evidence-based STEAM practices in ECE. The inclusion of lecturers in the training workshops also had the potential to benefit future students, as STEAM education can be embedded in future university teaching on ECE modules. By working to improve STEAM skills and knowledge across this group of educators, a core aim was to improve children's outcomes across the STEAM disciplines and support the development of 21st-century competencies highlighted earlier. A final project output was a free website that contained a digital version of the delivered module and teaching ideas for STEAM implementation in ECE classrooms, which was co-produced with the university lecturer participants. An end-of-project webinar event to launch the website was attended by 425 delegates from across Indonesia (i.e., Java, Kalimantan, Sumatra, and Sulawesi).

Whilst the initial project aims were to deliver the three-day workshop and produce a project resource website, we also aimed to capture the impact that the training had on teacher professional development and evidence how the educators applied their new knowledge in the classroom within an Indonesian context. Jones et al. (2020) assert that there is a need to understand teachers' perceptions of the integration of a maker pedagogical approach in the classroom and how to develop

effective professional development opportunities to support maker-centered learning. However, most STEAM/maker research focuses on high-income countries, leaving Low- and Middle-Income Countries (LMIC) underrepresented (Hughes et al., 2022; MacDonald et al., 2023). Our project directly responds to this call and extends current research knowledge about formal maker professional development education opportunities for educators and evidence of classroom-based STEAM implementation in ECE. The study addresses this gap by exploring how teachers and lecturers adapted and delivered STEAM-based education in their own contexts and how professional development opportunities in maker pedagogy can support educators in Indonesia, a participant group underrepresented in current STEAM/maker education research.

What follows is an overview of the project facilitation, detailing the three-day workshop and the delivery of professional development activities. The paper will then discuss findings from 13 post-workshop interviews to explore the following aims: 1) to understand the real-world application by in-service teachers using the skills acquired during the STEAM-ECE workshops. 2) to investigate the adaptation and delivery of STEAM-based teaching modules within ECE departments in Indonesia. 3) to explore the unique challenges presented by the Indonesian context when implementing STEAM education. To conclude, we consider the implications for future professional development opportunities for pre- and in-service teachers and further research opportunities that stem from this study.

2. METHOD

The STEAM-ECE project consisted of 4 phases:

a) Phase One - Needs analysis

In the first phase, a needs analysis was conducted using an online survey to capture the knowledge, skills, beliefs, and attitudes of teachers and ECE academics towards STEAM learning (see Appendices A and B). The purpose of this scoping review was to gain a collective understanding of current STEAM practices in Indonesia, which allowed us to develop and disseminate a training programme based on tangible needs, requirements, and priorities rather than assumptions. We were also keen to cultivate a symbiotic relationship between the University of Sheffield, UPI, and other Indonesian academic and educational institutions, facilitating a knowledge exchange approach that builds on shared expertise. The survey captured data from 153 pre-service teachers from eight universities, 16 lecturers, and 23 in-service teachers. Analysis of the data highlighted a strong interest in project-based learning, existing gaps in knowledge and application of STEAM education, as well as a clear demand for this approach in Indonesia. This exercise identified targeted recommendations for curriculum development, training needs, priorities, and resource allocation to bridge the identified gaps, which informed the development of the 'Training the Trainers' workshop. One of the key findings was the unfamiliarity of many teachers with incorporating stories or storybooks into STEAM lessons, despite their potential to enrich and provide contextual STEAM concepts for young learners. The incorporation of children's literature as a stimulus for classroom discussion and activity ideas became a core element of the planning for the three-day workshop.

b) Phase Two - STEAM-ECE: Training the Trainers workshop

The second phase focused on designing the workshops and their corresponding resources. Nine ECE academics from five Indonesian universities and nine pre- and in-service teachers from nine schools were recruited as workshop participants. The workshop took place in the Purwakarta campus of UPI in July 2023 and was delivered by the UK project team. The workshop took place over three days and focused on developing participants' STEAM knowledge and skills, using a hands-on experiential approach. All PowerPoint presentations and resources were translated into Indonesian.

The workshop included an introduction to the program, presentation of material about maker pedagogy, and maker cycle-based learning practice activities. Over the three days, we focused on activities using simple electronics and working with fabric and cardboard. Attendees had the opportunity to explore the resources, develop skills such as cardboard joining techniques and tie-

dying, and were given the time to 'tinker'. To guide participants through an iterative process of ideas and prototypes, we utilized the Maker{Futures} Maker{Cycle} model, which shifts learning from a linear to a cyclical approach. Drawing from engineering design processes, the cycle encourages participants to look, think, make, and test by iteratively applying the following principles:

1) Find a problem or challenge and look carefully at it.
2) Think of ways to solve or respond to it.
3) Make a model or create a response.
4) Test it out.
5) Look at ways to improve or develop.

We used Indonesian children's stories as a stimulus for the different activities. Using stories to generate activity ideas is common practice in ECE, promoting learning across almost all areas of children's development. In classrooms, stories are often complemented by play-based activities to engage children in experiences related to language and literacy (Cooper, 2005). These activities provide opportunities for children to use their imagination, engage in complex language and thinking, and make inferences and predictions (Williamson et al., 2023).

Activity Example 1 – Simple Electronics

Participants were given resources to make a simple circuit (batteries, LEDs, battery packs, and crocodile clips) and were asked to make the LED light up. We then introduced Play-Doh to the activity, which is salt-based and therefore generates electricity. The participants were challenged to incorporate the playdough into the simple circuit and try to work out why the bulb did not light up if they were not successful the first time. Finally, a switch was added to the circuit. We then extended the activity and gave participants aluminium foil and clothes pegs that can be used as clips, and children are able to manipulate. The challenge was to make a tool that could connect the LED to the battery.

We then used the Indonesian children's story Ketika Listrik Padam, a story about Seruni, a little girl who is in the dark during a power cut and imagines ordinary household items as monsters. We set the brief that participants had to find a way to help Seruni make a light using the skills they had learnt during the previous skill-building sessions.

Activity Example 2 – Materials

On day 2, we worked with cardboard and fabric. We examined various types of cardboard (i.e., corrugated, moulded) and different joining techniques, including the use of tape, glue, string, and split pins, as well as dry joints such as slots, folds, and tabs. We explored various methods of working with fabric, including modifying it (dyeing), joining fabrics (stitching), and embellishing it (enhancing). Using locally sourced spices and fruits (i.e., dragon fruit, jackfruit, turmeric), we created dyes that were then used to tie-dye the fabrics. After each session of making, we held a 'show and tell' session, inviting participants to reflect on the activity, the challenges they faced, and how they overcame them.

On the final workshop day, participants were also given time to develop their own lesson plans and resources that they could implement in their classrooms (Appendix E). At the end of the day participants received a makerspace kit to take back to their classrooms. The kit included a variety of making resources, including wool, playdough, LEDs, battery packs, batteries, masking tape, scissors, split pins, paintbrushes, Blu-Tack, and wax crayons. Resources were included that we knew could be sourced in Indonesia, and we also utilised recyclable products during the workshops that would be easily available (i.e., cardboard, food cartons, plastics).

c) Phase Three - Piloting the module

The third phase involved the ECE academics trialing the professional development module in their own universities with pre-service teachers and in-service teachers implementing 'makerspace' sessions in their classrooms. This was done in a similar way to the professional development workshop, where students were introduced to a picture book during the teaching session and

challenged to solve a problem using the available resources. The in-service teachers conducted the making sessions with the children in their classrooms, and lesson plans, evaluations, and photographs of the children participating in the activities were shared with the research team (Appendix F).

d) Phase 4 - Dissemination

In Phase Four, the module content and supporting lesson plans developed by teachers were digitized to form a newly created web resource. A final webinar was then held for 400 educators across Indonesia to launch the resource and disseminate the project findings.

Data collection

Following the project, the Indonesian team conducted interviews with seven teachers and six ECE university lecturers who had attended the workshop and implemented the sessions in their own practice (See Appendix C and D). These interviews aimed to explore the workshop's impact on teaching practice and how the ECE lecturers had assimilated the workshop content into their pre-service curriculum. Prior to conducting the research, ethical approval was obtained from TUoS. Interviews took place online and in the teachers' first language. Transcripts were then transcribed and professionally translated into English. The interview transcripts were then coded, and key themes were identified that will be reported in the next section, conducting the research.

3. RESULTS AND DISCUSSION

a) The real-world application by in-service teachers using the skills acquired during the STEAM-ECE workshops

In total, seven teachers from different schools across Java were interviewed to explore their previous conceptions of STEAM education, the impact of the workshops on their professional development and classroom practice, the children's engagement in making, and the skills developed, as well as to explore their future aspirations. Several teachers interviewed expressed concerns that a STEAM approach would be "too challenging" for the children, especially in the early years. One teacher commented:

> *"I think STEAM is difficult, especially if it's taught to young children, like in preschool."*
> *"I can't imagine science, maths, engineering, technology, and art being taught at that age."*

Some of the teachers shared how they had tried, prior to the workshops, to implement the STEAM-based curriculum in their classroom, but in a "simple way," and one teacher explained her lack of confidence:

> *"… before attending this workshop, I had problems. I think I lacked additional knowledge. Besides that, I still had doubts because I was afraid that I would miss something or overlook a step."*

Across all the interview data, the teachers recognised the benefits for the children to be taught STEAM subjects through makerspaces:

> *"STEAM education is designed to enhance 21st-century skills such as critical thinking, creative thinking, collaboration, and problem-solving. It is particularly important for early childhood education to prepare students for future careers in the fields of technology, science, and engineering in the long run."*

In my opinion, STEAM learning is important because through STEAM, students can think analytically, creatively, and communicatively, and are able to collaborate with other people to carry out activities or solve problems … There are many other important benefits for students through this

learning. Students can solve problems in creative and innovative ways. The students create works according to their creativity."

One teacher pointed out how STEAM aligns well with the Merdeka Curriculum (MoECRT, 2022), helping to prepare children for the "demands of the 21st century". All the teachers spoke about how the STEAM-ECE workshops had helped support their professional development. One described how attending the workshops had a "huge impact on the knowledge I had," with another explaining:

The workshop has greatly benefited me, improving my understanding and skills. I am now confident and ready to provide full support to my students without any doubts or fears. I have no worries or fears about implementing what I've learned. The teachers enjoyed the "hands-on experience" of making and could see how this could be translated into their own classroom practices. One teacher commented:

"[making] allows students to learn while feeling like they are playing, encouraging them to come up with diverse ideas, solutions, and creative expressions."

There was also a realization that making does not "require complex technology or resources" and can be "implemented in a straightforward manner, yielding maximum outcomes". The importance of 'process not product' was also mentioned by one participant:

Previously, we focused on understanding the process that students followed and the final results they achieved. However, after this workshop, I realized that the work process is more important than the results."

The same teacher also discussed how she had shared her experience of teaching STEAM through making with other teachers at the school.

Several teachers discussed how they used storybooks to introduce provocations and problems to children, stimulating their engagement in making activities. During Phase One (Needs Analysis) only 3% of teachers reported using storybooks in their teaching so this was an interesting development in terms of impact on pedagogical practices in the Indonesian classroom.

"After the workshop, the next theme at our school happened to be birthday parties. For a week, we learned about organizing birthdays. We started by discussing books and watching videos. Then, I introduced the materials I had prepared, such as cardboard boxes, circular boxes, and plastic film, explaining their uses. After that, the students began creating their own designs, and it was great to see the diverse results they came up with. One student makes a gift, someone makes an invitation, and so on. It turns out my students could do it."

It was also reported that children were given more autonomy in the classroom, being able to choose how they worked, either "individually or in groups", and the materials and tools they needed. One teacher talked about how:

"The students preferred hands-on learning in STEAM as it allowed them to think outside the box and come up with unique ideas and designs. They were surprised by the diverse range of outcomes and even learned from each other's solutions. The STEAM approach made learning more enjoyable for the students."

In addition to the teacher's professional development and the changes to their pedagogical practices, a significant impact on the children's learning was also reported. Students were described

as “more active and critical in asking questions,” showing “great enthusiasm” in their work. It was observed that children “worked together as a team,” demonstrating “compassion towards their peers who needed help completing their tasks”. One teacher talked of how her children had “learnt to persevere”, and “engage in discussions and express their opinions”. Practical skills were also observed, including an improvement in cutting and joining skills when working with cardboard. It was observed by one participant that the children:

> *“… used their cognitive abilities to learn to solve problems by using their physical motor skills in the form of tinkering. I observed that they organized their work and discussed how to formulate or put them together. “*

Summarizing, one teacher asserted, “these 21st-century abilities are very apparent in STEAM practice”.

b) The adaptation and delivery of STEAM-based teaching modules within ECE departments in Indonesia

In total, six ECE lecturers were interviewed from six different universities across Java and Sumatra, Indonesia, including Purwakarta, Jakarta, Cirebon,Karawang, Riau, and Lampung. Whilst some of the lecturers had heard of STEAM, their knowledge to date had mainly been derived from English textbooks and YouTube. All the lecturers reported that they found the face-to-face workshops valuable and saw the opportunity as a way of improving their own teaching practice. One lecturer explained:

> *“Not all lecturers get the opportunity to develop at their institutions, so this kind of training is very important. It's not just about teaching; it's about improving our abilities as educators.”*

The practical way in which the workshop was delivered was reported to be a useful way of learning as this helped make links between theory and practice. One participant described how the “hands-on experience” helped to ensure that “the concepts taught are not just understood but applied,” and this enabled her to “better understand and connect it with the theories”. The focus on practical hands-on activities in the CPD workshops influenced how the lecturers taught their own students. One reported that her “way of teaching has changed to an approach that can make Indonesian students more creative”. Another lecturer found it useful to think of the environment as a “great learning resource.” By involving students in the creative process and allowing them the freedom to explore the environment and available tools, they managed to “improve their skills” and “create stunning results” in their making projects. She specified that using practical activities:

> *“… provides a sense of purpose and reflection when deciding how to use the tools and materials later on. It's not just a matter of playing, but rather utilising the instruments and materials around them.”*

It was specified how “Students are encouraged to actively participate and engage rather than passively listening or asking basic questions” and that this allowed “for the development of skills through hands-on experiences”.

There was a significant shift away from a teacher-centered approach to a more student-centered one. The lecturers commented:

> *“[the workshop] emphasized student-centered learning, encouraging students to engage in hands-on activities such as tinkering and project completion, tailored to their individual skills.”*

"It is a change in mindset for future teachers. They now understand the necessary steps to develop and enhance students' competencies as a facilitator. This reflection is based on the practical implementation of the STEAM approach."

This change in mindset involved taking risks. One lecturer explained, "You have to dare to be different from others, you have to take a risk, right?" Meanwhile, another stated that the student-centered approach encouraged them to "take risks and be confident in their individuality, something not typically taught in education."

All lecturers interviewed observed students demonstrating 21st-century skills. One lecturer talked of how a group of students were "united in analyzing the positives and negatives, trying to understand why some devices worked while others did not". Another reported how she had seen students "find solutions through thinking and problem-solving," demonstrating "courage, self-confidence, problem-solving, and collaboration". It was highlighted how students were able to "showcase their creativity and motivation" and that there were "noticeable changes in learning, making it more interesting".

c) The unique challenges presented by the Indonesian context when implementing STEAM education

One of the key challenges reported by the teachers was the language barrier that was faced during the training workshop. The workshop was delivered in English, with slides translated into Indonesian. Additionally, the Indonesian facilitator provided brief, translated summaries of the verbal presentations. However, this is not an ideal strategy, and to ensure teacher professional development is meaningful and specific, it is vital that local expertise is developed in terms of STEAM and making, so language does not continue to be a barrier to learning for the teachers. All the teachers interviewed specified that further training was high on their agenda for their own professional development, so developing local knowledge that is culturally and contextually relevant is imperative.

In terms of delivering the makerspace sessions in the classroom, it was reported that children were not accustomed to this style of learning, and some found it challenging to adapt to the freedom and flexibility offered. The younger children also found it challenging to manipulate certain materials and tools, such as scissors and cardboard. This reflects findings from UK-based research, which highlights the importance of using child-appropriate tools and being aware of challenges with developing fine motor skills, and strength and dexterity in small hands (Author, 2024a). Often, teachers were alone in the classroom, which was a challenge when supporting and managing the different groups of children. One teacher also highlighted the difficulty in "creating a conducive and focused learning environment specifically for STEAM implementation".

For the lecturers, a lack of resources and infrastructure was cited as a significant challenge in delivering sessions in their teaching to university students. This was the result of limited funding from the institutions, with one lecturer explaining how "if we want to practice, we have to pay for it ourselves". Even when there was an opportunity to obtain resources to support the making sessions, the geographical nature of Indonesia meant tools could only be ordered from Jakarta. University teaching spaces were criticized for being "not as conducive to hands-on learning as a kindergarten classroom". Finally, additional training and time were also highlighted as a barrier to implementing a maker approach in the classroom.

Discussion and Implications

This study builds on the current literature on STEAM education and professional development in ECE, particularly in under-researched LMIC contexts. The following discussion situates our findings within existing literature, highlighting new insights.

Firstly, the research highlights the importance of developing educators' skills, knowledge, and STEM confidence, including that of lecturers working with pre-service teachers. Whilst some of the teachers had taught STEAM subjects before the workshops, they lacked confidence in their self-belief about whether they had the necessary skills and knowledge to do this effectively. At a local level, this finding aligns with Prahani et al. (2023), who similarly identified STEM subject knowledge as a barrier to the implementation of STEAM education among Indonesian teachers. However, this also resonates with research from a wider international context (Çiftçi et al., 2022; Ingleby, 2015; Johnston et al., 2022; Author, 2024b), highlighting how initial teacher education and continuing professional development do not always provide teachers with the knowledge and skills they need to implement, with confidence, an effective STEM curriculum. This has significant implications for children's outcomes and reinforces findings from Wan et al.'s (2019) systematic review of international empirical studies focusing on ECE and STEM education, which supports the need for further professional development opportunities for teachers, particularly in LMIC. The findings also highlight the importance of lecturers working with pre-service teachers and having the necessary skills and knowledge to support the delivery of these subjects, so newly qualified teachers are equipped to support children's STEM development in a creative and engaging way.

Recognising the importance of developing children's 21st-century skills was another key finding in this research. Our study reports that all teachers valued the development of the children's 21st-century skills and reported their own observations of children displaying these skills. Participants discussed how children demonstrated critical thinking skills, problem-solving abilities, creativity, teamwork, and perseverance. There were also examples of children showing empathy and compassion towards others, helping them out when they struggled. These findings continue to build on the growing body of literature that exemplifies the skills and knowledge children gain through participating in makerspace sessions in the early years and beyond (Blackley et al., 2018; Forbes et al., 2021; Jones et al., 2020; Author, 2024a). There are significant policy/practice implications here as the makerspace model could inform the practical implementation of the Merdeka Curriculum (MoECRT, 2022). This also emphasises the importance of continuing to develop teacher skills and knowledge in the STEAM domain to ensure the government's goals of preparing children for the challenges of the 21st century by providing them with the skills and knowledge they need to succeed.

There was a consensus among all participants interviewed that the workshop format was effective in helping them understand the makerspace philosophy, develop their making skills, and understand how this approach might work with their own children. This supports the existing literature around developing teacher skills in this area through structured opportunities and hands-on learning, building confidence in themselves as makers (Chen & Cao, 2021; Hughes et al., 2022; MacDonald et al., 2023). As an ongoing endeavour to support teacher professional development, it is essential that local expertise remains a key focus for the development of these workshops, which cater to pre- and in-service teachers and lecturers. This is important to ensure that makerspaces are developed to be culturally relevant for both teachers and children, drawing on local knowledge, diverse contexts, and rich making practices.

The findings also illuminate the importance of incorporating a maker approach to ECE pre-service education as a way of embedding STEAM into future professional practices across Indonesia. Exploring the development of maker practices with the lecturers also provided specific insights, which further reflect the challenges faced when implementing these types of pedagogical practices in universities. The discussion around 'risk-taking' when teaching pre-service teachers marked a shift away from a teacher-directed approach to student-centered learning. Further research is needed to explore how lecturers and those working with pre-service teachers can support and embed these types of pedagogical opportunities in their work with pre-service teachers, ensuring they are confident and prepared to teach STEM subjects in their own classrooms.

The data highlighted significant challenges, including cost implications and resource availability. Again, this is not an issue unique to Indonesia and reinforces that delivering STEM-type subjects in schools is often difficult due to a lack of financial support and resource management, especially for

LMIC. Due to the perceived cost implications for adopting this approach in terms of financing tools and resources, further work needs to be done exploring how makerspaces can be sustainable, with a focus on using materials that are readily available (i.e. recyclables). This work would also feed into an Education for Sustainable Development agenda and align with several of the Sustainable Development Goals (UNESCO, 2015).

4. CONCLUSION

The findings show that the STEAM-ECE workshops effectively strengthened teachers' confidence, creativity, and ability to apply makerspace-inspired, child-centred pedagogies in real classroom settings. In-service teachers observed improvements in children's problem-solving, collaboration, and resilience, and they recognised that effective STEAM learning can be supported using low-cost, everyday classroom materials. The workshops also contributed significantly to teachers' professional growth, enabling them to share new practices with their colleagues.

At the institutional level, lecturers working with pre-service teachers demonstrated a clear shift toward practical, hands-on, and student-centred approaches. They emphasized the importance of developing 21st-century competencies to adequately prepare future teachers to implement STEAM in early childhood settings.

The study also identified several contextual challenges, including resource limitations, sustainability concerns, linguistic barriers, and curriculum integration issues, highlighting the need for localised training, accessible materials, and sufficient staffing to support effective STEAM implementation in Indonesia.

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