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Research Article

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STEM education in early primary years: Teachers' views and confidence

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ABSTRACT

Pre-school and first years of primary school provide the basis for future learning in STEM, and teachers' views-confidence are important for effective classroom practices. This study investigated teachers' views and confidence in implementing STEM education in early primary years. The participants were 140 Greek teachers who completed an online 35-item questionnaire. Teachers expressed positive-strong perceptions and confidence in implementing STEM education in early primary years. Over 80% of the sample expressed agreement in that they feel comfortable-confident when they facilitate inquiry-based learning activities within mathematics or science topics. The practical obstacles of resources-material and time to explore STEM topics and implement learning activities were reported. The findings have implications for educational policy and practice.

Keywords: STEM, early primary years, teacher views, perceptions, confidence

INTRODUCTION

STEM (science, technology, engineering, and mathematics) education is an approach that presents science, technology, engineering, and mathematics fields in an integrated way, rather than as discrete subjects to be taught separately (MacDonald & Huser, 2020; Yelland & Waghorn, 2020; Yong-yi, 2022). STEM has been pursued internationally since the mid-2000s, while relevant research grew rapidly within the last decade (Irwanto et al., 2022). Researchers highlighted the importance of early exposure to STEM (e.g., Clements et al., 2021; Gozum et al., 2022; Kalogiannakis & Papadakis, 2020; Nikolopoulou, 2022a; Papadakis & Kalogiannakis, 2022; Wan et al., 2021). Pre-school and first years of primary school provide the basis for future learning in STEM since, for example, science and mathematical skills acquired in early years predict later academic performance (Campbell et al., 2018). For example, inquiry-based learning activities/interventions facilitate STEM learning (Ješková et al., 2022; MacDonald et al., 2021).

The purpose of this study is to investigate teachers' views and confidence regarding STEM education in early primary years. Examining teachers' views is important, since these are associated with (and influence) their STEM classroom practices (Margot & Kettler, 2019) and teaching behaviour; understanding teachers' perspectives and confidence will help in building teacher competencies. Negative beliefs and low levels of confidence often limit educators' efforts to implement classroom practices (Gialamas & Nikolopoulou, 2010; Nikolopoulou & Gialamas, 2015). Perceived self-efficacy is a significant determinant of performance (Bandura, 1986), and consequently teachers who have higher levels of confidence (self-efficacy) are more likely to implement STEM education in classrooms. For the purpose of this paper, as the age-boundaries between pre-school and primary school differ among different countries, the terms *pre-school*, *early childhood education* (*ECE*) and *kindergarten* are treated synonymously. Similarly, the terms (teacher) *views*, *beliefs*, and *perceptions* are used as synonyms. It is noted that 'technology' within the acronym STEM is not confined to the use of digital technologies (ICTs) or electronic devices (McClure et al., 2017).

LITERATURE REVIEW

STEM Education in Early Primary Years

The goals-objectives of a STEM education program for young children are associated with knowledge, skills, dispositions, and feelings; for example, STEM skills include problem solving, creativity, hypothesizing, self-investigating, critical thinking, and computational thinking (Nikolopoulou, 2022a; Papadakis et al., 2022). During integrated STEM learning, children are expected to handle information from

different disciplines at the same time. When STEM approach is used, young children can, for example, carry out hands-on activities in science to explore and observe different materials; explore patterns and shapes, and build blocks (e.g., in mathematics); build on their confidence levels and develop social learning skills. Inquiry-based STEM activities provide young children with opportunities to develop/practice various skills (Greca Dufranc et al., 2020), including 21st century skills such as problem-solving, creativity and innovation, cooperation, communication, critical thinking, self-direction and scientific process skills (Yildirim, 2020).

In parallel, digital technology tools offer young children the possibility to develop and integrate knowledge-skills about STEM subjects and facilitate the development of early science skills-practices (Kalogiannakis & Papadakis 2020; Papadakis, 2020). For example, educational robotics provides a learning environment where young children can exercise programming skills (Papadakis & Kalogiannakis, 2020), mathematical skills and scientific skills-processes, as well as hands-on experimental work (Nikolopoulou, 2022b). STEM curricula in the early primary years of education can facilitate children's natural curiosity through appropriate, and playful experiments, as well as inquiry-based learning (MacDonald et al., 2020). The role of the teachers is important since they can provide young children with the opportunities, resources, and support, in order to be engaged in high-quality STEM experiences (Bagiati et al., 2015; Gozum et al., 2022; Li et al., 2021).

Teachers' Views and Confidence Regarding STEM Rducation

Research into early childhood STEM is limited (Campbell et al., 2022), and with regard to teachers' views and confidence when implementing STEM education with early primary years there is a relatively small number of studies (e.g., MacDonald et al., 2021; Margot & Kettler, 2019; Wan et al., 2021). A recent review of 24 studies from 2009-2019 (Wan et al., 2021) reveals that teachers' views of STEM education in early years mainly regard hands-on experiences, and STEM as discrete subjects, while practical obstacles (e.g., resources, time, administrative support,) and concerns (e.g., children's interest, safety) are also expressed. Another review on preK-12 teachers' perceptions of STEM integration and education (Margot & Kettler, 2019), between 2000 and 2016, indicates that teachers value STEM education, but they also report obstacles such as pedagogical and curriculum challenges, concerns about students, and lack of teacher support. Research highlighted the importance of teacher confidence in the delivery of STEM in early years' settings (Larkin & Lowrie, 2022); while ECE teachers' beliefs towards STEM are relatively positive, self-efficacy and confidence are rather low (Campbell et al., 2018).

MacDonald et al. (2021) reveals Australian ECE teachers' beliefs and confidence regarding STEM education. Participants indicated positive perceptions-dispositions toward STEM education; for example, the majority of participants express the view that STEM activities can facilitate children's interest in STEM subjects when they attend upper education levels, and they believe pre-school help foster children's interest in science, technology, engineering, and mathematics in later grades, and they believe it is appropriate to explore STEM topics from a young age. Although, they believe they have sufficient capabilities in mathematics and are confident in engaging in small inquiry activities with the children, they reported less confidence in the disciplines of science, technology and engineering.

In Turkey, Yildirim (2020) reports on teachers' perceived problems when implementing STEM in ECE settings (poor time management, easily distracted students, and lack of material), while Ultay and Ultay (2020) indicate ECE teachers' perceived limitations (lack of tools-infrastructure, limited teacher training, and time problems).

According to Swedish and Spanish pre-school teachers, robotics contributes to teachers' planning of STEM teaching, increases children's enthusiasm, and stimulates children's knowledge and agency (Fridberg et al., 2022). Teachers describe the great interest aroused among children for the chosen STEM activities, emphasizing their improvements in their understanding of science, mathematics and robotics concepts. Teachers' self-efficacy of STEM teaching was improved during the project.

A few studies regarded teachers' views on STEAM (inclusion of Arts as well). In Saudi Arabia, ECE teachers had overall positive views, but STEAM implementation was viewed with caution (Albahar & Alammari, 2022; Alghamdi, 2022); teachers felt they required additional training and professional development for classroom practices (Albahar & Alammari, 2022). Voicu et al. (2022) indicated that teachers from six countries in S. Europe had positive perceptions of the STEAM approach (they believed that it increases children's motivation, engagement in learning, creativity, and self-confidence), while main difficulties were related to curriculum limitations, lack of resources, experience, and training in the STEAM approach.

Findings regarding the association between teachers' self-efficacy and/or attitudes toward STEM teaching with teachers' characteristics are inconclusive. In Tao's (2019) study, teachers' years of teaching experience and level of education were not found to be associated with their attitudes toward or confidence with STEM education. However, in another study (Park et al., 2017) teaching experience and teacher awareness of the importance of STEM were shown to positively influence ECE teachers' perceived confidence and readiness for teaching STEM. Pedagogy and content self-efficacy were found to be positively correlated with early childhood teachers' working status, age, occupational commitment, and interest in ECE (Yang et al., 2021).

Within the Greek context there is a small number of studies on the topic (e.g., Ampartzaki et al., 2022; Nikolopoulou, 2022a; Papadakis et al., 2021). A recent study by Ampartzaki et al. (2022) indicated that although ECE teachers knew about the STEAM approach, only a few had the experience of implementing it; the major difficulties reported relate to understanding the methodology of STEAM approach and the lack of educational resources. Teachers' views were associated with the enrichment of the curriculum (with hands-on and active learning), a positive impact on children's critical thinking and communication skills, as well as their overall development. Teachers had received limited support by stakeholders (policymakers, advisers). Nikolopoulou (2022a)

Table 1. Demographic characteristics of the sample (n=140)

Category	Frequency	Percentage (%)
Gender		
Female	120	85.71
Male	20	14.29
School level		
Pre-school	68	48.57
Primary	72	51.43
Years of teaching experience		
1-10	9	6.43
11-20	48	34.29
21+	83	59.28
Years of STEM use in class		
<1	21	15.00
1-5	59	42.14
6-10	40	28.57
>10	20	14.29
Years of ICT use in class		
1-5	24	17.14
6-10	28	20.00
>10	88	62.86
Pedagogical ICT training		
Yes	101	72.14
No	39	27.86

investigated teachers' practices and views of STEM activities for children aged four-seven years old. STEM activities implemented in class are programming, robotics and interdisciplinary activities, as well as experiments and exploration of materials. Teachers' perceived challenges mainly regard experiential learning, children's interest and active participation, while main problems include limited time, infrastructure, and teacher training. Another study (Tzagaraki et al., 2022) explored primary school teachers' views on the contribution of robotics in improving the learning process, the development of skills, and opportunities to enhance involvement with robotic activities; teachers are optimistic about its use, recognizing its contribution to developing technological, mathematical, social, and language skills. Teaching experience, age and technological competence were associated with ECE teachers' attitudes towards robotics (Papadakis et al., 2021).

The aforementioned literature reveals some studies, but the topic of teachers' views and confidence on STEM education in early primary years is still under-researched, and the evidence derives from a few countries. Thus, there is a need for further empirical findings from other countries. The findings of this study are expected to enhance the emerging body of research evidence on ECE teachers' views and confidence.

THE STUDY

As stated in the introduction, the purpose/aim of the study was to investigate teachers' views and confidence about STEM education in early primary years.

Sample

The participants were 140 pre-school and primary school teachers, across Greece. **Table 1** displays the demographic characteristics of the sample (gender, school level, years of teaching experience, years of STEM use in class, years of ICT use in class, pedagogical training in ICT). The majority of participants were female (85,71%) and more than half of the sample (59.28%) had 21 or more years of teaching experience. The years of using STEM in classroom varied from less than one year to more than 10 years. With regard to STEM education in the Greek context, it is noted that STEM is not officially included within the official curriculum. However, the Ministry of Education announced the commencement of STEM inclusion in some pre-school settings from the next year, in order for the children to develop technology and science skills; among them, a new topic will be STEM-Educational Robotics.

Procedure and Research Instrument

The data were collected via an online questionnaire in October and November 2022. The authors' professional networks, social media, and e-mails were used to distribute the survey. Teachers' participation was voluntary and ethical issues were considered. Informed consent was obtained from all subjects involved in the study. All participants were assured that, should they wish to participate in the research, their responses would remain anonymous; in addition, teachers could end the survey at any time.

The questionnaire was consisted of two sections. Section A included 35 statements-items aiming to investigate teachers' views and confidence on STEM education in early primary years. The statements were adapted from MacDonald et al. (2021). These statements aimed to explore teachers' views about STEM education (e.g., views about STEM benefits, about STEM equipment and materials) and teachers' confidence in implementing STEM in classrooms (e.g., confidence when they facilitate inquiry-based learning activities within science and/or mathematics topics). In the questionnaire, the 35 items were presented in mixed order, and the teachers were asked to rate their views on a 5-point Likert-type scale (1=strongly disagree, 2=disagree, 3=not sure, 4=agree, 5=strongly agree). Section B aimed to collect data on teachers' demographic and individual characteristics (shown in **Table 1**). The instrument was piloted with nine teachers (who did not participate in the main survey) to ensure that there was no ambiguity in interpreting the wording of the items.

RESULTS

Regarding data analysis, R programming language (version 4.2.2) and RStudio (version 2022.12.0+353) were used for managing the data and conducting the statistical analyses (descriptive statistics, factor analysis).

Descriptive Measures for Teachers' Views-Confidence

To explore teachers' views and confidence on STEM education, a descriptive analysis was performed. **Table 2** shows teachers' response percentage frequencies on the 35 items (n=140 teachers). The last column of **Table 2** has added together the percentages of those who "agree" and "strongly agree". The majority of the teachers expressed strong perceptions and high levels of confidence with regard to STEM education.

Table 2. Teachers' response percentage frequencies on the 35 items (n=140 teachers)

Responses	SD	D	U	A	SA	ASA
S28. I feel comfortable facilitating inquiry-based learning activities related to mathematics topics (e.g., shapes, numbers).	0.0	0.0	0.0	51.4	48.6	100.0
S13. Young children are curious about STEM concepts and phenomena.	0.0	0.0	0.7	51.4	47.9	99.3
S29. I feel comfortable facilitating inquiry-based learning activities related to earth science topics (e.g., sun, weather).	0.0	0.0	0.7	62.1	37.1	99.3
S16. I get ideas for hands-on activities from what my students do, say, and ask.	0.0	0.0	3.6	67.9	28.6	96.4
S05. Experimenting hands-on with materials and objects is how children learn best.	0.7	2.1	0.7	30.7	65.7	96.4
S18. I enjoy doing STEM activities with students.	0.0	0.0	5.7	40.0	54.3	94.3
S24. I feel comfortable facilitating inquiry-based learning activities related to life science topics (e.g., living things, plants, animals).	0.0	0.0	5.7	59.3	35.0	94.3
S10. STEM-related activities help improve students' mathematics skills.	0.0	0.7	5.7	50.7	42.9	93.6
S17. STEM-related activities help improve children's social skills.	0.7	2.1	3.6	59.3	34.3	93.6
S01. Early-primary years STEM activities help foster children's interest in science, technology, engineering, and mathematics in later grades.	0.7	2.9	5.0	29.3	62.1	91.4
S22. I feel comfortable facilitating inquiry-based learning activities related to physical and energy science topics (e.g., force of gravity, gas, liquids, solids).	0.0	0.7	7.9	59.3	32.1	91.4
S03.It is important for my classroom to have a STEM area that can be freely explored by young children/students.	0.0	0.7	8.6	53.6	37.1	90.7
S06. STEM-related activities help improve students' approaches to learning.	0.0	3.6	7.9	32.1	56.4	88.6
S33. I am certain that I can recognize scientific, technical, engineering and mathematical learning opportunities for children in everyday life.	0.7	2.1	8.6	57.1	31.4	88.6
S08. I use all kinds of materials (e.g., blocks, toys, boxes) for STEM activities.	0.0	3.6	7.9	46.4	42.1	88.6
S19. I demonstrate experimental procedures (e.g., comparing objects to see if they will sink or float) with my students.	0.0	0.7	10.7	48.6	40.0	88.6
S34. I find it easy to engage in small inquiry activities with the children.	0.0	2.9	11.4	57.1	28.6	85.7
S32. I feel confident in being able to explore STEM topics in a manner that the children can understand the content.	0.0	0.7	19.3	47.9	32.1	80.0
S23. I feel comfortable facilitating inquiry-based learning activities related to optics (e.g., light, color).	0.0	0.7	19.3	54.3	25.7	80.0
S14. I collect materials and objects to use in STEM activities.	2.9	3.6	16.4	37.1	40.0	77.1
S20. I do not mind the messiness created when doing hands-on STEM activities.	0.0	5.7	17.1	40.0	37.1	77.1
S31. I feel emotional to explore topics from fields of science, technology, engineering, & mathematics.	0.7	5.0	20.0	42.9	31.4	74.3
S12. STEM-related activities help improve children's language skills.	0.0	3.6	25.0	48.6	22.9	71.4
S35. I am certain that I can answer most scientific, technical, engineering, and mathematical questions of the children.	0.7	5.7	22.1	42.9	28.6	71.4
S07. I discuss ideas and issues of STEM learning with other educators.	0.7	5.0	23.6	37.1	33.6	70.7
S25. I feel comfortable facilitating inquiry-based learning activities related to engineering topics.	0.7	5.7	27.9	40.0	25.7	65.7
S02. More science, technology, engineering, and mathematics topics should be explored in early-primary years.	0.0	12.1	25.0	26.4	36.4	62.9
S30. I find it easy to prepare STEM learning programs for the children.	2.9	9.3	30.7	39.3	17.9	57.1
S04. Given other demands, there is not enough time in a day to explore STEM topics.	3.6	13.6	26.4	33.6	22.9	56.4
S09. Preparation for STEM learning activities takes more time than other subject areas.	3.6	16.4	28.6	34.3	17.1	51.4
S21. I do not have enough materials to do STEM activities.	6.4	33.6	37.1	22.1	0.7	22.9
S26. I feel uncomfortable using scientific tools such as scales, rulers, and magnifying glasses.	42.1	42.9	8.6	6.4	0.0	6.4
S27. I feel uncomfortable talking with young children about the scientific inquiry method (e.g., making hypotheses, predicting, experimenting).	39.3	45.7	8.6	3.6	2.9	6.4
S11. It is not appropriate to introduce STEM topics to children at an early age.	65.0	28.6	5.7	0.7	0.0	0.7
S15. Young children cannot learn about STEM topics until they are able to read.	62.1	37.1	0.7	0.0	0.0	0.0

Note. SD: Strongly disagree; D: Disagree; U: Undecided/not sure; A: Agree; SA: Strongly agree; & ASA: Agree & strongly agree

It is noteworthy that over 80% of the sample "agree and strongly agree" with most of the items. More specifically, the items with the highest percentage of agreement were: "I feel comfortable facilitating inquiry-based learning activities related to mathematics topics (e.g., shapes, numbers)" (for S28: 100%), "young children are curious about STEM concepts and phenomena" (for S13: 99.3%), "I feel comfortable facilitating inquiry-based learning activities related to earth science topics (e.g., sun, weather)" (for S29: 99.3%). Indicative items with lower percentage of agreement (and higher percentage of uncertainty) were, S21: 22.9% of the teachers agree in that there is not enough materials to do STEM activities; S09: 51.4% of the sample mentioned that preparation for STEM learning activities takes more time than other subject areas; S04: 56.4% agree that there is not enough time in a day to explore STEM topics (due to other curricular demands). Such views are related to barriers obstructing the use of STEM in classrooms.

Factorial Structure of the Questionnaire

An exploratory factor analysis was performed, using the principal axis factoring method accompanied by the varimax rotation method, in order to investigate the factorial validity of the 35 item beliefs-confidence questionnaire. The analysis results support a three-factor solution, which we retain for interpretation. The first factor (F1), labelled "confidence with

Table 3. Factor loadings, mean, & SD per item (34 items)

	F1	F2	F3	Mean	SD
S20	0.76			4.09	0.88
S24	0.71			4.29	0.57
S30	0.70			3.60	0.98
S12	0.67			3.91	0.79
S19	0.59			4.28	0.68
S16	0.59			4.25	0.51
S34	0.59			4.11	0.71
S29	0.58			4.36	0.50
S35	0.56			3.93	0.89
S28	0.54			4.49	0.50
S07	0.38			3.98	0.92
S15	-0.33			1.39	0.50
S06		0.77		4.41	0.79
S01		0.76		4.49	0.78
S02		0.74		3.87	1.04
S31		0.68		3.99	0.89
S05		0.67		4.59	0.69
S10		0.64		4.36	0.62
S13		0.60		4.47	0.52
S08		0.59		4.27	0.76
S11		-0.58		1.42	0.64
S14		0.58		4.08	0.98
S18		0.58		4.49	0.61
S17		0.55		4.24	0.69
S03		0.49		4.27	0.64
S21		-0.37		2.77	0.89
S27			-0.81	1.85	0.93
S25			0.67	3.84	0.90
S33			0.67	4.16	0.73
S26			-0.62	1.79	0.85
S22			0.59	4.23	0.62
S32			0.56	4.11	0.73
S23			0.49	4.05	0.69
S04			-0.39	3.59	1.09
CA	0.85	0.82	0.85		

Note. SD: Standard deviation; CA: Cronbach's alpha; All responses ranged from 1 (strongly disagree) to 5 (strongly agree); Factor 1 (F1): "Confidence with inquiry learning activities"; Factor 2 (F2): "Beliefs"; Factor 3 (F3): "General confidence"; Extraction method: Principal axis method; & Rotation method: Varimax

inquiry learning activities", was associated with 12 items: S20, S24, S30, S12, S19, S16, S34, S29, S35, S28, S7, and S15. The second factor (F2), labelled "beliefs", was associated with 14 items: S6, S1, S2, S31, S5, S10, S13, S8, S11, S14, S18, S17, S3, and S21. The third factor (F3), labelled "general confidence", was associated with 8 items: S27, S25, S33, S26, S22, S32, S23, and S4. Item S9 was not associated with any factor.

Table 3 displays the loadings and the Cronbach's alpha coefficient for internal consistency for each factor (F1 to F3), as well as the means and standard deviations per item. All factors show an acceptable internal consistency: Cronbach's alpha coefficient ranged from 0.82 to 0.85.

DISCUSSION

This study explores teachers' views and confidence in implementing STEM education in early primary years and adds to the body of empirical evidence in the field. The findings reflect a situation in a micro-level. It was shown that teachers' perceptions and confidence in implementing STEM education in early primary years were, in general, positive. The majority of the sample expressed strong perceptions-confidence for most of the questionnaire items. There is an agreement with other studies in different countries/cultures (e.g., MacDonald et al., 2021; Voicu et al., 2022; Wan et al., 2021). Initially, there is an agreement with research reviews (Margot & Kettler, 2019; Wan et al., 2021), which highlighted positive teachers' beliefs on early exposure to STEM and experimenting hands-on with materials. Indicatively, the view that young children are curious about STEM topics-phenomena (S13: 99.3% agreement) is in line with earlier research (Fridberg et al., 2022), while the belief on getting ideas from their young students-children for experimental and hands-on tasks (S16: agreement 96.4%) is in accordance with a recent study in Greece (Nikolopoulou, 2022a). The findings are also line with MacDonald et al. (2021) with regard to positive views on early exposure to STEM and confidence in facilitating inquiry-based learning activities (mainly) in mathematics and science topics (a smaller percentage expressed confidence for engineering topics). Our study reveals that teachers' confidence beliefs were positive as over 80% of the sample expressed agreement (i.e., they feel comfortable-confident) for the relevant items; S28, S29, S24, S22, S32, S23, S26, and S27, indicated in **Table 2**. An exception was the item S25 (agreement 65.7%), which reveals confidence when teachers facilitate-assist inquiry-based learning activities within the engineering subject. The item "I find it easy to prepare STEM learning programs for the children" (for S30, agreement 57.1% and uncertainty 30%) indicates that not all teachers find it easy, and this has implications for teacher training. In parallel, items with lower percentage of agreement reveal specific obstacles in implementing STEM education such as limited resources/materials and lack of time in preparing STEM activities. Earlier research has also indicated the practical obstacles of resources-material (Ampartzaki et al., 2022; Nikolopoulou, 2022a; Voicu et al., 2022; Wan et al., 2021; Yildirim, 2020) and time to explore STEM topics and implement learning activities (Ultay & Ultay, 2020; Wan et al., 2021; Yildirim, 2020). School principals are suggested to be aware of teachers' perceptions, in order to plan for provision of STEM materials and appropriate infrastructure.

The findings (though not generalizable) have implications for educational policy and practice. Educational policy makers need to be aware of teachers' perspectives on STEM education. This may facilitate the design of appropriate in-service STEM training programs. For example, more attention could be given in facilitating inquiry-based learning activities related to engineering topics. Professional development programs/interventions positively impact on pre-school teachers' beliefs and confidence towards teaching STEM (Chen et al., 2021; Lange et al., 2022). Policy makers may need to review the curriculum so that new ways of teaching-learning can be explored. Teachers may need to review aspects of their current practices/interventions/pedagogies that will improve children's learning outcomes. Greek early primary STEM initiatives and teacher training constitute an issue for future research.

The limitations of this study include the size of the sample and the use of a quantitative inquiry only. The sample cannot

be considered as representative of the Greek population, since those teachers who use STEM activities may possess more positive views-confidence. Teachers' perspectives can be further explored with larger population and by also using open-ended questions to provide deeper insight. Additionally, the impact of teachers' demographic characteristics on their perceptions could be investigated. Future research is suggested to replicate the study with other teacher groups and to examine possible similarities and differences among different populations.

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Declaration of interest: The authors declare that they have no competing interests.

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Availability of data and materials: All data generated or analyzed during this study are available for sharing when appropriate request is directed to corresponding author.

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