Navigating 'the bumpy road' from research to practice: Improving the impact of research on spatial reasoning practice with young children

Catherine Gripton[1]*, Kathryn E. Bates[2], Sue Gifford[3], Katie A. Gilligan-Lee[4,5], Helen J. Williams[6], Alison Borthwick[7], Ashley Y. Williams[5], Andrea Lancaster[6] and Emily K. Farran[5,8]

School of Education, University of Notttingham[1]; Department of Psychology, Institute of Psychology, Psychiatry and Neuroscience, Kings College London[2]; School of Education, University of Roehampton[3]; School of Psychology, University College Dublin[4]; Centre for Educational Neuroscience, University of London[5]; Early Years Mathematics Specialist Consultant[7]; International Mathematics and Education Advisor[7]; School of Psychology, University of Surrey[8].

*catherine.gripton@nottingham.ac.uk

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Abstract

Ensuring that knowledge generated through research has impact in early childhood education practice is a familiar and complex challenge. This article reports on an attempt to bridge the research-practice divide in one area of mathematics, early spatial reasoning, through the development of a practitioner toolkit to aid professional learning. The approach was to research practitioner perspectives on what is needed to support practice in this important and often under-recognised area of mathematics. We conducted questionnaires and focus groups. These showed that practitioners in England desire support in all areas of spatial reasoning, having received little or no training previously, and that multiple professional learning resources are required for a diverse sector. We argue that research dissemination, which is inclusive of the breadth of the early education sector, should provide age-range specific, accessible, practice-focussed, multi-modal resources.

Keywords: research dissemination; professional development; practitioner perspectives; mathematics; spatial reasoning.

Introduction

For early childhood education (ECE) research to have impact in practice, it needs more than translational dissemination. It needs more than making research findings available to practitioners and policymakers, communicating them on the terms, timelines, preferences, modus operandi and modalities of the researchers. This is hardly a controversial statement. The problem is all too familiar to researchers whose efforts to meet this challenge are often less successful than intended due to the financial, systemic and practical obstacles which must be overcome. From close-to-practice and action research to 'what works' and commissioned reviews, efforts to use research findings to improve education are abundant. The sheer number and range of efforts to bridge the

research-practice divide are evidence of just how challenging this is[1]. Despite good intentions from practitioners and researchers, the competing priorities and policies in this busy and complex sector alongside the competitiveness of the research environment make research impact in ECE difficult to achieve. The route from research to practice (and practice to research) is a particularly 'bumpy road' (Sfard, 2005), beset with challenges, barriers, potential stumbling blocks and ultimately points of failure.

Spatial reasoning (SR) is an area of early mathematics education where recent progress in research has achieved limited impact in ECE (Verdine et al, 2014). SR is the ability to mentally manipulate objects and to understand the relations between objects and oneself (Uttal et al., 2013). In a previous study, practitioners in England reported having little confidence in their understanding of SR and provided incomplete definitions of it to researchers (Bates et al., 2023). SR is an area of early mathematics where there is a clear research-practice divide. In this study, we set out to bridge this by asking ECE practitioners what they already know, what they need to know and crucially how this knowledge could be effectively communicated through professional resources. In developing our own professional resources for SR, we sought answers to five research questions:

> RQ1: Which areas of SR are priority areas for professional learning for ECE practitioners?
>
> RQ2: What types of professional resources do ECE practitioners want/need to support their teaching of SR to young children?

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[1] Indeed, this research project received funding provided as targeted support for research impact.

RQ3: What features of our professional resources to support SR practice do ECE practitioners report are the most/least useful?

RQ4: Which of our professional resources do ECE practitioners find most helpful to support their teaching of SR to young children?

RQ5: How do ECE practitioners intend to use our professional resources to support SR practice?

Reporting on these five research questions, this article begins with a summary of why early mathematics is a priority area for addressing the research-practice divide. We then establish the significant disparity between the research evidence on early SR development and current early mathematics practice. Next, we explain the research design, providing a description of the questionnaires and focus groups used to capture practitioner perspectives. This is followed by a summary and discussion of our results. Finally, we broaden our focus to consider the wider potential implications for research and knowledge exchange activities which aim to have impact in ECE.

'The bumpy road' from research to practice in early mathematics education

Sfard's description of knowledge exchange in mathematics education as a 'bumpy road' captures the challenges of making research findings useful and accessible to those in a position to apply them (2005, p.409). Success in this endeavour is, at its heart, a social justice issue as early mathematics is the greatest overall predictor of later school achievement (Duncan et al., 2007). There is an ethical and moral imperative for early mathematics researchers to support application of research to practice, yet this is not straightforward. Applying research conducted with learners under specific conditions to practice with a different group of learners, at a later time and under different conditions, is problematic.

Educational research cannot provide effectiveness guarantees to practitioners because 'everything works somewhere and nothing works everywhere' (Wiliam, 2018). Research can be incredibly useful to aid understanding of how we might improve teaching and learning, i.e., 'the core problem of practice' (Even & Ball, 2003, p.142), but there is further work to do to make this useable for practitioners. Unfortunately, educational research is often 'inaccessible, irrelevant, or impenetrable' for practitioners (Rycroft-Smith & Macey 2021, p.1) with findings not actively, iteratively and useably presented to teachers (Gorard et al., 2020) in outputs that they readily access (Vanderlinde & van Braak, 2013). Additionally, research rarely focusses sufficiently on *how* something works, yet this is important for practitioners. Attention only to 'what works' is not enough (Biesta, 2010), 'examples of how it can be got to work are crucial' (Desforges, 2001, p.3). To narrow the research-practice divide in early mathematics, research findings need to be accessible and directly useful to practitioners, so researchers need to work for and with practitioners, in what Gilmore suggests is a two-way transactional space (2022). In the next section, we outline why achieving this in SR is a particular priority.

The research-practice divide in SR practice with young children

SR (more commonly referred to as spatial thinking in cognitive psychology) is important for STEM and mathematics learning, in particular. SR, the ability to mentally manipulate objects and interpret spatial relations, is correlated with higher mathematics achievement for younger and older children (Gilligan et al., 2019; Sorby & Panther, 2020; Atit et al., 2021). As spatial skills are highly malleable, educational effort to support the development of children's SR is effective and worthwhile (Uttal et al., 2013; Hawes et al., 2022). This means that SR is a promising, whilst currently underutilised, route to raising mathematics achievement (Verdine et al., 2017) which can support

economic growth (OECD, 2010) and access to STEM careers (Wai et al., 2009).

Early childhood is a particularly fruitful time for SR development (Verdine et al., 2017), with significant physical and motor development (such as sitting and walking) affording opportunities for new spatial experiences and navigational systems (Oudgenoeg-Paz et al., 2015; Newcombe, 2019). It is important for children to develop both intrinsic (within-object) and extrinsic (between-object) spatial skills (Uttal et al., 2013) so that they can mentally manipulate objects (interpreting and using their spatial features) as well as being able to interpret the spatial relationships between objects (or between themselves and objects). It is also important to develop spatial language (and other symbolic tools such as gesture, sketches and analogy) for them to think and reason spatially (what Newcombe, 2018, terms 'spatializing'). In the youngest years, spatial skills typically develop rapidly with a broad range of areas developing from birth to 7 years (Figure 1). Some children, particularly girls (Newcombe, 2020; Clerkin & Gilligan, 2018) and children from 'low-income homes' (Verdine et al., 2014; Verdine et al., 2017; Bower et al., 2020), can miss out on important mathematical development because they are less likely to be provided with some important spatial learning opportunities (Sarama & Clements, 2009). These can be provided in ECE where research suggests that effective pedagogies to support spatial development include learning with concrete materials (Hawes et al., 2022b) and adult use of spatial talk, supplemented by gesture (Pruden et al., 2011; Bower et al., 2020). There is also evidence that block and puzzle play as well as children's books with spatial elements offer spatially rich early learning activities (e.g. Schmitt et al., 2018; Bower et al., 2020; Ferrara et al., 2011; Verdine et al., 2014; Szechter & Liben, 2004).

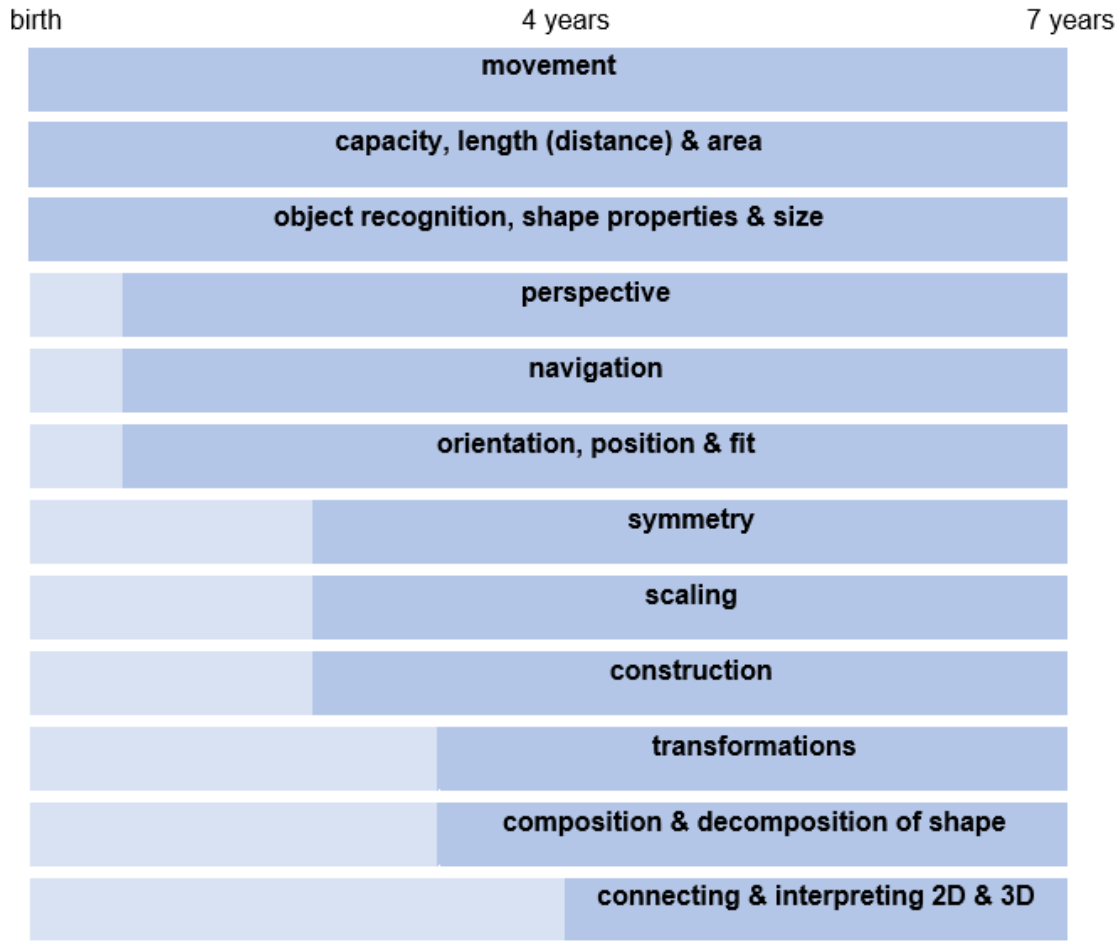

Figure 1. Areas of spatial reasoning and ages where skills in this area typically begin to emerge (from Gripton & Farran, 2022)

With limited time for practitioner professional development in ECE, focussing on what is likely to make the greatest difference to children is the priority. The wealth of SR research offers a compelling case that developing practice in this area is highly likely to lead to learning gains for many children (e.g. Clements & Sarama, 2011; Bower et al., 2020; Gilligan et al., 2019, Verdine, 2017). This makes SR development what Coe et al. characterise as a 'best bet' from research for practice (2020).

In our earlier research (Bates et al., 2023), we found that ECE practitioners in England have little or no confidence in their definitions of SR and tend to include either intrinsic spatial features (within-object) or extrinsic spatial relations (between object)

but not both. We found that they are typically able to identify spatial activities but that they use these less often than non-spatial activities. A focus on SR in ECE in England has perhaps been hampered by minimal attention in national curricula and policy. Whilst SR does now feature in the statutory educational programme for birth to five-year-olds in England, 'shape, space and measures' was removed from the statutory early learning goals in mathematics for the end of this phase of a child's education (DfE, 2021), something which is likely to 'reduce the emphasis' in practice, according to a finding from the pilot study of the new goals (Husain et al., 2019, p.22). It is therefore unsurprising that in another study (N=104), we found that practitioners working with 4-5-year-olds perceive spatial and numeracy activities as less important than literacy and life skills and completed these activities less frequently (Gilligan-Lee et al., 2023). Our previous findings indicate that research evidence on the potential of SR to raise mathematical attainment, the types of SR that are important for young children to develop and the most useful pedagogies for SR development have not yet reached practice in ECE settings. In this article, we report on efforts to narrow this gap by working with practitioners in the development of a toolkit of research evidence-based professional resources.

Methods

Researchers need to understand the practice community which they hope to influence (Farley-Ripple et al., 2018). Premised firmly on the assumption that practitioners are the experts in their own practice and in the way they learn as professionals, the research-design process sought to gain knowledge of practitioner perspectives on how SR research findings could be communicated effectively. The process followed Burkhardt & Schoenfeld's (2020) engineering approach to turning research insights into improved education practice including prototyping, rich feedback and iterative refinement of

resources which they identified as key features. The aim was to develop a toolkit to support practitioner knowledge, collecting data in each iterative design cycle to utilise practitioner feedback and make successive improvements. Initially, the research team undertook a literature review[2] of SR development from birth to 7 years. This provided a starting point for the design process, informing the toolkit content as well as the questions asked of practitioners in the data collection cycle 1.

Data collection methods

This mixed methods study comprised of two online questionnaires (conducted in cycles 1 and 3) and a series of focus groups conducted at three points of toolkit development, each with a different focus (cycles 1, 2 and 3). The focus group findings from cycle 1 have been reported previously in Bates et al. (2023). Table 1 shows the number of participants in each activity. Cycle 1 sought information on current understanding and training needs of practitioners. Cycle 2 aimed to find the features and types of our professional resources that practitioners found most useful and included a review of the initial toolkit (designed following cycle 1). The toolkit resources were then re-designed for cycle 3 to ascertain what amendments were needed for the final version, what elements of the toolkit were most helpful and intentions for how these would be used. There was a further final cycle which focussed on evaluation and use of the toolkit one year later which is not reported in this article.

Table 1. Participation in data collection

[2] The final version of the Spatial Reasoning Toolkit (Gifford, 2022) includes a references list.

Design cycles	Data collection methods	N	Age range of children the practitioners work with		
			Birth to years	4 to 7 years	Other
Cycle 1	Questionnaire	94	35	51	8
	Focus groups*	9	5	4	0
Cycle 2	Focus groups	11	5	6	0
Cycle 3	Focus groups	9	5	4	0
	Questionnaire	74	22	34	18

**The cycle 1 focus group data are reported in detail in Bates et al. (2023)*

Participants

Having obtained the necessary ethics approvals[3], participants for the cycle 1 questionnaire were recruited using social media. They were asked if they would volunteer for focus group participation, with responses collected separately to retain anonymity in the questionnaire data. Cycle 3 questionnaire participants were recruited via a link in the published Spatial Reasoning Toolkit in order to gain responses from practitioners who had engaged with it. Where they indicated that they had not engaged with a specific resource, their evaluation of this resource was discounted in the analysis. For each questionnaire and set of focus groups, participants were divided into two groups based upon the children they worked with in their main role, 'birth to 4 years'

[3] The research team gained the necessary approvals under the Author's university research ethics approval process and all ECE practitioners included in this study consented to participation. Responses to the two questionnaires were kept anonymous so it is impossible for the research team to know how many participants responded to both, although overlap in these participant groups is very likely.

(i.e. children not in statutory schooling) and ‘4 to 7 years’ (i.e. children in statutory schooling). This was an attempt to seek representation and hear voices from across the birth to 7 years ECE sector. Practitioners in the ‘birth to 4 years’ group worked in preschools, private day nurseries, nursery classes, nursery schools or as child-minders. Practitioners in the ‘4 to 7 years’ group worked in mainstream or special schools with Reception (4-5 years) or Key Stage One (5-7 years) classes. Practitioners who did not state an age-range or worked across both (e.g. advisors and drama therapists) were coded as ‘other’ and not included in analyses by practitioner group. Responses from practitioners working outside of England were also not included.

Data analysis

Quantitative analysis was conducted on the questionnaire responses to three questions from the cycle 1 questionnaire. Practitioners were asked to select yes/no in response to the question, ‘have you received training on the following?’ for 11 areas of practice with responses calculated as percentages. They selected a level of priority on a four-point scale (low, little, some, high) for each of the same 11 areas of practice, ‘how much of a priority would it be for you to gain resources/information each of the following? The number of responses for each level of priority was calculated as a percentage. Practitioners were also asked to select all that apply out of six options for ‘what format of content would you find most accessible and informative?’ with a seventh open text response option. The percentage for each format was calculated and open text responses were collated but not coded as they were small in number.

Four questions were analysed from the cycle 3 questionnaire where practitioners were asked to report on the five sets of resources from the final draft of the toolkit. These were rated for usefulness on a five-point scale (not at all, somewhat, neutral, very,

extremely) with a sixth ‘not applicable’ option, calculated as percentages for each resource type. On a five-point scale (strongly disagree, disagree, neither, agree, strongly agree), each participant provided a response to a statement that they had learnt something from reviewing the resources and these were calculated as percentages. Practitioners were asked to indicate how they intend to use the toolkit out of four non-exclusive options (own professional development, professional development with colleagues, assessment, planning) with a fifth open text response for ‘other’. These were calculated as percentages with open text responses collated but not coded as they were small in number. Finally, practitioners had the opportunity to use an open text response to tell us something that they may do differently in their practice having reviewed the toolkit resources. These were coded qualitatively using inductive analysis to group similar items.

Focus group data in all three cycles were analysed using inductive thematic analysis with researcher triangulation where themes were independently derived and then cross-checked in order to identify patterns of shared meaning (Braun & Clarke, 2019). For the cycle 1 focus group, these were first presented in Bates et al. (2023).

Results

Cycle 1

Practitioner training in SR practice

Less than a quarter (22%) of the practitioners surveyed in cycle 1 had previously received professional development on the importance of spatial reasoning in learning mathematics and this was the highest of all areas of SR practice that we asked about with others being lower (1-14%, table 2). These areas were ‘high’ priority (39% to 65%) or at least ‘some’ priority (80% to 97%) for their professional learning (table 2).

A theme in the focus group data from the 'Birth to 4 years' practitioners was the limited opportunities for pre- and in-service professional development in SR (Table 3). Emma (this and subsequent names are pseudonyms), a practitioner from the 'Birth to 4 years' focus group explained,

> 'I know when I initially did my level three then went on and did my foundation degree and teacher training and everything, spatial reasoning wasn't mentioned very much.'

In the focus groups, both practitioner groups reported a need for professional resources about SR (cycle 1 theme, table 3).

Table 2. Practitioner responses to the questions, 'have you received training on the following?' and 'how much of a priority would it be for you to gain resources/information each of the following?

Areas of spatial reasoning practice	Practitioners who had received training	'High' priority for practitioners	'High'/'some' priority for practitioners
Nature of SR	12%	40%	92%
Supporting children's SR using gesture and spatial language	7%	55%	97%
Importance of SR for STEM	14%	39%	86%
Supporting SR across the curriculum	3%	65%	97%
Implementing a learning trajectory for SR	2%	40%	92%
How SR abilities might differ for individuals and groups	5%	40%	86%
Importance of SR in learning mathematics	22%	52%	94%
How families can support SR at home	1%	41%	94%
Developing learning environments that encourage SR	9%	41%	96%
Using children's books to encourage SR	1%	61%	91%
Technology resources to aid SR	3%	44%	80%

Table 3. Focus group themes

	Practitioners	Themes	Definition
Cycle 1 focus group*	All practitioners	Mixed terminology	Limited familiarity with spatial terminology and partial definitions of spatial reasoning
		Need for resources	Importance of children having access to the resources and activities that promote spatial reasoning development
	Birth to 4 practitioners	Importance of learning through experience	Association between spatial experiences, in a range of contexts, and spatial reasoning development
		Motor skills as an opportunity to develop spatial reasoning	Physical and spatial development are connected
		Limited opportunities for professional development	Lack of focus on spatial reasoning in practitioner professional development (pre- and in-service)
	4 to 7 practitioners	Inflexibility in the curriculum	Lack of time to teach spatial reasoning and a lack of focus in the mathematics curriculum
		Impact of poor spatial reasoning	Recognition that poorer spatial reasoning can limit children's holistic development
		Incidental spatial reasoning	Spatial reasoning development opportunities are embedded in everyday activities and routines
Cycle 2 focus group	All practitioners	Multi-modal professional resources	Use of photographs, videos and text to communicate and exemplify spatial reasoning practice
		Research evidence-based subject knowledge	The credibility and quality of the messages about spatial reasoning
		Accessible and user-friendly resources	Presentation of resources is important for practitioners to access and navigate content. They should use simple language and be brief
	Birth to 4 practitioners	Practitioners with different roles, experience and training	Practitioners are a diverse group requiring different information and resources depending on their role, experience and prior training
		Age-specific	Professional learning should be specific to the age-range and settings that the practitioner is working with
		Links with curriculum	Using curriculum document structures aids familiarity and connection-making
	4 to 7 practitioners	Developmental progression in spatial reasoning	Practitioners need to understand the sequence of children's spatial reasoning development
		Application to practice	Professional learning resources need to be directly relevant to practice including examples of what this looks like in practice
Cycle 3 focus group	All practitioners	Use in planning, teaching and professional development	Spatial reasoning toolkit resources can be used to support different professional activities, over time and in combination with each other
		Multiple multi-modal resources	Posters, videos, trajectories and written documents support practitioner understanding of spatial reasoning practice
		Presentation of information	Practitioners need resources that are presented well, organised, divided into sections and written in plain English with key information and terminology highlighted
		Research evidence-based subject knowledge	The credibility and quality of the messages about spatial reasoning
		Grounded in practice	Content is authentic as it is communicated through and set within practice which reflects practitioners' experiences
		Age-specific	Professional learning should be specific to the age-range (and setting-type for this age-range) that the practitioner is working with
		Practitioners with different roles, experience and training as well as parents	Practitioners are a diverse group requiring different information and resources depending on their role, experience and prior training
	4 to 7 practitioners	Links with curriculum	Using curriculum document structures aids familiarity and connection-making

*previously reported in Bates et al. (2023)

Practitioner preferences for the format of professional learning resources

In the cycle 1 questionnaire, practitioners selected a range of different resource formats as most accessible and informative, with 65% choosing three or more options. 'Birth to 4 years' and '4 to 7 years' practitioner groups made broadly similar choices in the questionnaire, although webinars were less popular with 'birth to 4 years' practitioners. Text responses provided under 'other' suggested that the choices offered in the questionnaire were appropriate with only three alternatives suggested, each by one practitioner (an audit tool, in person training and professional book recommendations).

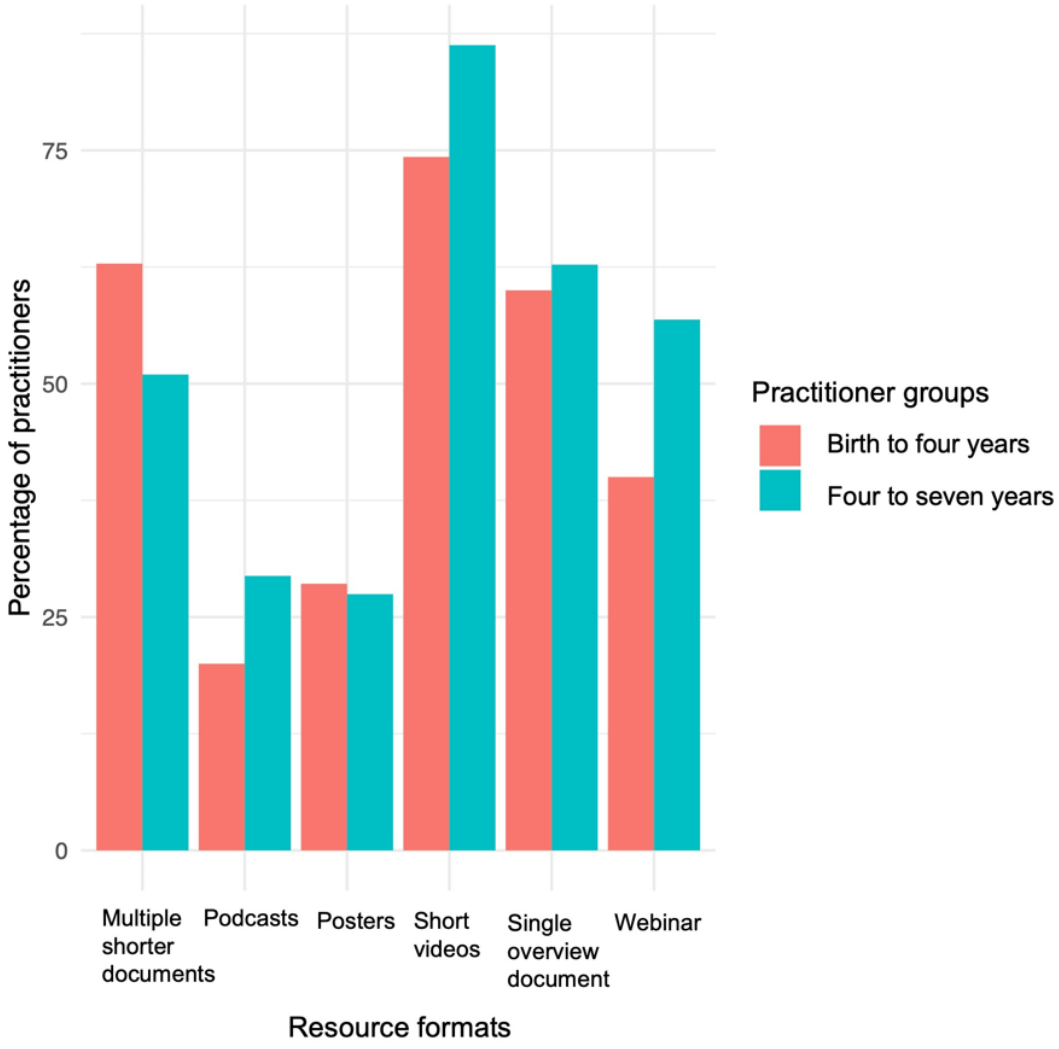

Figure 2. Resource format preference by practitioner group (N in brackets)

Cycle 2

Features of professional resources

Two focus group themes common to both practitioner groups in cycle 2 were that professional resources should be 'research-based' and 'accessible and user-friendly' (theme in Table 3). For text resources, focus group contributions indicated that subheadings and text boxes provide this along with brevity and simple language. The guidance document needed to be 'written in a different way' for a practitioner audience than a researcher audience (Kasia, 'birth to 4 years' group). The '4-7 years' group reported that alignment of layouts with familiar curriculum documents also aids

accessibility ('Links with curriculum' theme in Table 3). Practitioners in the 'birth to 4 years' practitioner group suggested separate 'age-specific' resources (theme in Table 3).

Alternatives to guidance documents

A third focus group theme common to both practitioner groups was that 'multi-modal' professional resources (with photographs, video and text used to communicate information and exemplify practice) are preferred (Table 3). These are necessary for the range of colleagues working with birth to 4 years according to focus group participants such as Uma (cycle 2, 'birth to 4 years' group) who explained, "I think [it is important] because we've all got different people at different levels of ability and different skill levels". A trajectory (developmental progression) was a preference for the '4 to 7 years' group (Table 3).

Cycle 3

Usefulness of the Spatial Reasoning toolkit resources

Of the 74 respondents to the cycle 3 questionnaire 60% strongly agreed and 94% agreed/strongly agreed that they had learned something useful for the future from the Spatial Reasoning toolkit. For the different resource types in the toolkit, the videos (93%), posters (96%), trajectory (96%), research summary (94%) and book lists (95%) were judged very/extremely useful to practitioners. There were no notable differences in toolkit resource preferences between the 'birth to 4 years' and '4 to 7 years' practitioner groups in the questionnaire responses (figures 3 and 4) or the focus group responses (6 of the 7 themes in common in Table 3).

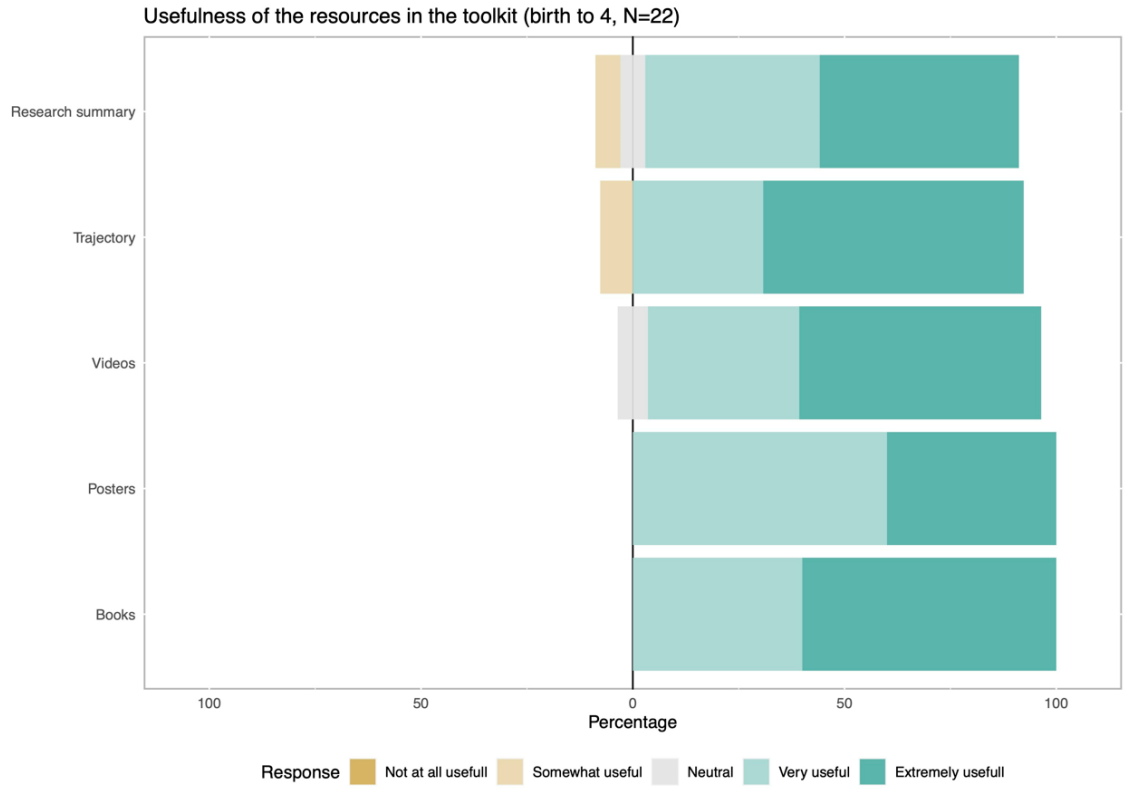

Figure 3. Usefulness of different resource types in the Spatial Reasoning Toolkit.

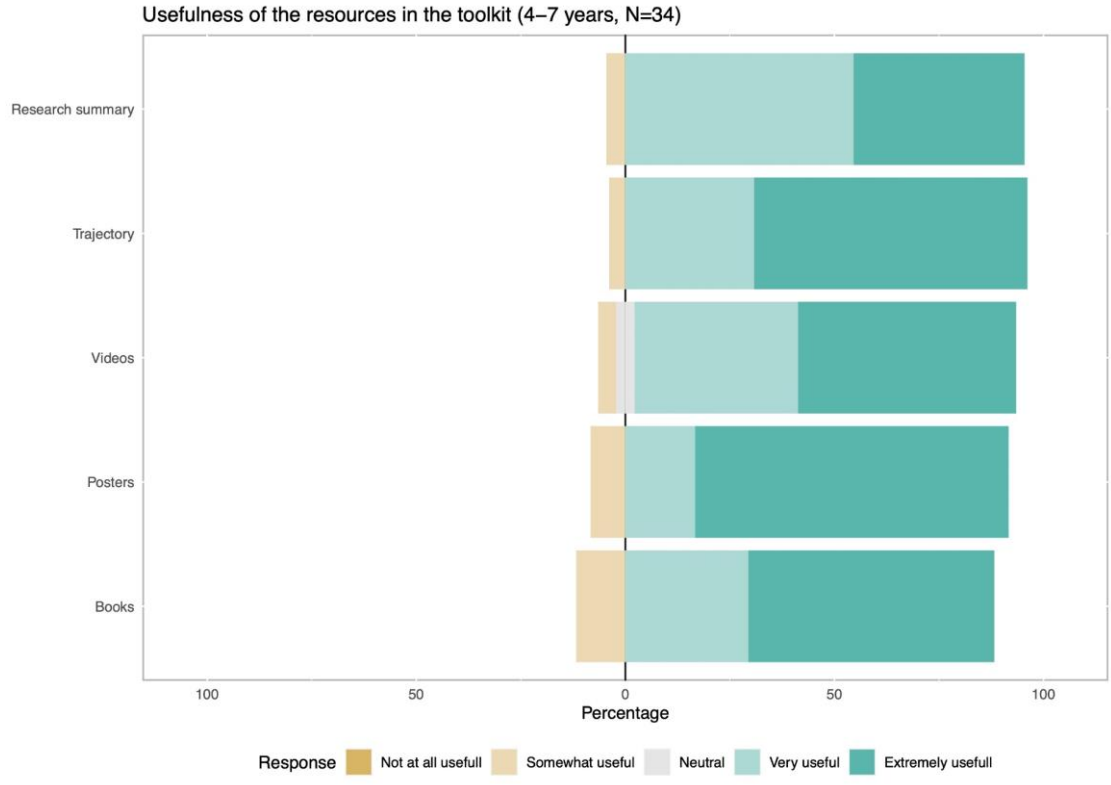

Figure 4. Usefulness of different resource types in the Spatial Reasoning Toolkit.

Seven of the eight themes in the cycle 3 focus group data for both practitioner groups (table 3) are broadly common with themes from cycle 2. Both practitioner groups made comments on the age-specificity and research-based nature of the professional resources as well as their appropriateness for practitioners with different roles and training, developed following cycle 2 feedback from the Birth to 4 years practitioner group. Kelly's comment ('birth to 4 years' group) about the posters linked age-specificity to practitioner understanding:

> The other fact that I really like was that there were four different ones with different age groups. That really helps us to understand. Okay, when we have the younger children, when we have babies, when we have toddlers and when we get the older ones, this is what to do, because there are differences.

Two of the cycle 3 themes were slightly extended from cycle 2 with comments that *multiple* multi-modal resources were preferred ('multi-modal resources' in cycle 2) and that resources could be used by children's *parents* as well as practitioners ('practitioners with different roles and training' in cycle 2).

Focus group discussions included limitations to usefulness, making suggestions for refinements to the toolkit resources. Responses included the need for practice examples (in photographs, video and text resources) which authentically represent real practice ('Grounded in practice' theme, Table 3). Rachel explained the importance of this in the communication of research findings:

> There's nothing like seeing it. You can read the words and imagine and when you read the words but everybody imagines their own way, of what that means…Seeing something gives you that feeling, 'oh yeah, yeah, that's what that really means'!

There were comments that images and video should include ethnically diverse practitioners. Beth explained:

> The only little disappointing thing I think about the posters is the staff didn't feel represented in the pictures so there was some children from different cultural backgrounds, but I work with a really, really diverse staff team and the first thing they said to me was there's no black adults in these pictures.

Intended uses of the professional resources

In the cycle 3 questionnaire, 64 out of 67 respondents (96%) provided a text response to the question, 'how do you intend to use the toolkit in the future'. These included specific types of activities (such as map work and small world play), resources (such as children's books and jigsaws), pedagogies (such as using gesture and modelling language) and assessment (including photographs and documentation of specific spatial skills). The responses also included professional activities such as planning, auditing provision and training colleagues. Almost half of the practitioners intended to use the toolkit resources for professional development with colleagues (Figure 5). Focus group contributions coded as 'multiple multi-modal resources' (table 3) included the importance of multiple resource types so that they would be used over time and in combination with each other ('Use in planning, teaching and professional development' theme, Table 3). Caroline (4-7 years practitioner group) explained that she would begin with the videos with a staff group then use the posters as prompts for interactions with children in the setting, then extend this further using the trajectory as a staff group again.

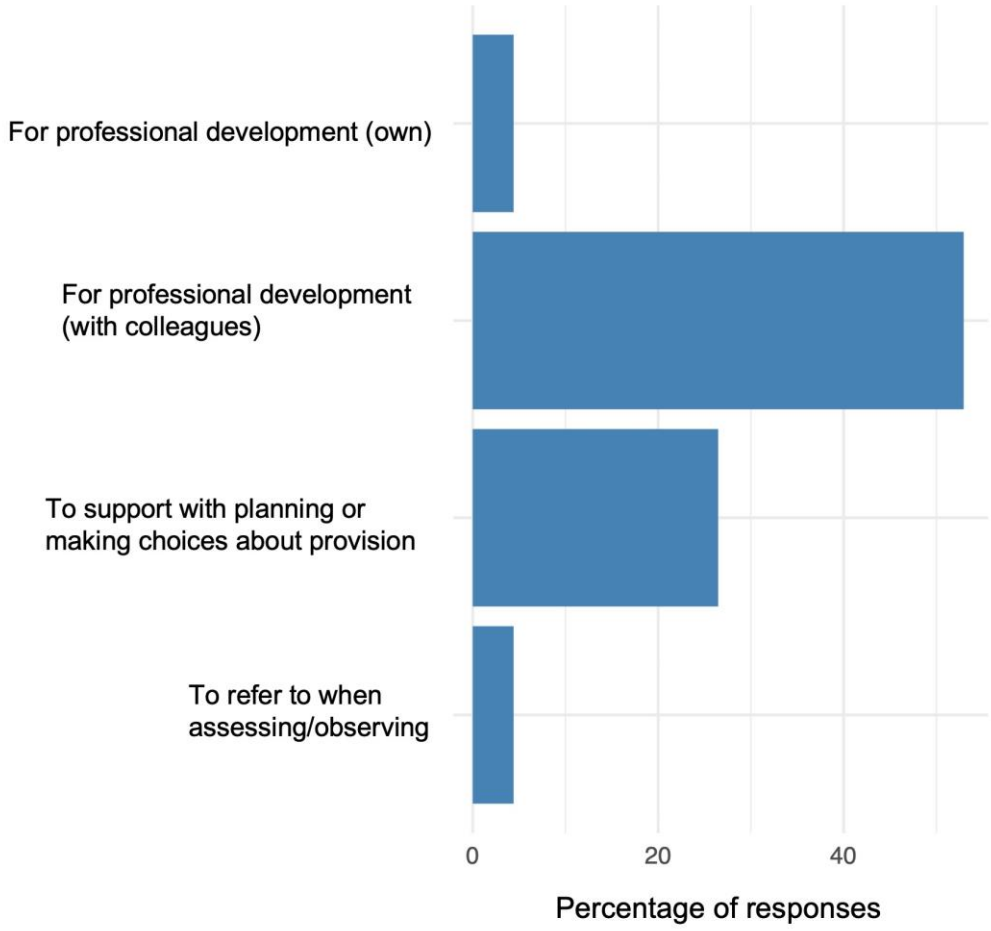

Figure 5. Practitioner intentions for how to use the Spatial Reasoning Toolkit

Discussion

The ECE practitioners in England that participated in our research report having received little or no training on how to develop young children's SR and felt this was a priority in all areas of SR practice (RQ1). Research-based tools for practitioners can address this, helping to narrow the research-practice divide in this area (Burkhardt & Schoenfeld, 2003). These tools need to be accessible, not just in terms of being published and written in plain English but available in the spaces that practitioners readily access in their everyday professional work (Vanderlinde & van Braak, 2013). For busy practitioners, professional resources need to present key information swiftly and succinctly. In the Spatial Reasoning Toolkit (Gifford et al., 2022) this meant

restricting the length of videos and using large captions with key terminology. In the guidance document, one-page summaries, key information boxes and bold text were added to aid skim reading. Some practitioners in the focus groups expressed finding it helpful when tools had a familiar format, for example the same layout as familiar curriculum documents. It seems that taking steps to draw attention to and emphasise key information supports the likelihood of it being taken forwards into practice.

Findings suggest that ECE practitioners typically require multiple multi-modal professional resources which are accessible to the broad range of practitioners in this diverse sector in England. ECE practitioners have varied roles and training so different access points and ways to engage seems important. Multiple resources means that practitioners are more likely to return to the information over time, using them iteratively which supports research-based ideas to become embedded in practice (Gorard et al., 2020). A key finding of this study is that multiple, multi-modal resources enable practitioners to use them in combination, offering potential for use in planning, practice, assessment and crucially in professional development with colleagues. Posters, videos and the learning trajectory seem to be the most important tools in impacting ECE practice from the Spatial Reasoning Toolkit, according to the practitioners in this study, but practitioners expressed quite individual preferences and indicated that they would use these varied resource-types in different ways. Multiple, multi-modal resources seem to support active engagement with research evidence.

Professional resources need to be age-specific in ECE in England which spans practice with children at very different stages of development (birth to 7 years). The data indicates that in addition to having separate resources for different age-groups, resources need to exemplify authentic practice for these age-groups. This includes descriptions of activities and images/video of children that are the correct age and in

age-appropriate setting-types. This aligns with the need for resources to be practice-focussed, using images and video of real children and practitioners in real settings. These are essential communicators of research findings, not just decoration, showing practitioners how to enact research insights in practice. Because these have enormous explanatory power, it is important for ethnically diverse practitioners to be represented so that all practitioners can see themselves using the practices recommended.

The strength and credibility of the research basis underpinning the resources seems important to practitioners. The inclusion of citations to empirical research articles and syntheses is important as the authority of the authors/presenters. We wonder if the human connection supports practitioners to apply research insights to practice, narrowing the perceived gap between professionals working in research and practice spaces, something that Dagenais et al. (2012) suggests is a powerful predictor of use.

Overall, practitioner involvement enabled the production of age-specific, accessible, practice-focussed and multi-modal research-based professional resources which are likely to gain traction in ECE practice according to our data. In Figure 6 we provide our recommendations for supporting research impact in ECE practice as a list of 5 key considerations.

Figure 6. List of recommendations arising from this study

<FIGURE 6>

Conclusion

Helen, a practitioner in the cycle 2 focus groups, summarised the issue of the research-practice divide when she explained that researchers and teachers have quite different

perceptions on the utility of professional resources for practice when she reviewed the first draft of the SR toolkit.

> I think it's a bit of a misleading word [toolkit] for teachers. Although it may be okay for researchers to call this [text document] a kit, I feel like it needs to feel a bit more practical.

Bridging the research-practice divide in SR practice posed two significant challenges to the research team: 1) The distance between research and practice in this area is less of a gap and more of a wide ravine; 2) The practice context is hugely varied with a wide range of setting contexts, types, opening hours, adult-child ratios and sizes in ECE, which means that bridging the divide involves building a complex bridge to a highly varied landscape. Our approach was to consult the experts, those in practice in a diverse range of settings, in order to develop a research-based toolkit. In the final questionnaire, 73% of respondents strongly agreed that they would recommend the toolkit to others (94% agreed or strongly agreed in total). As Burkhardt & Schoenfeld point out, 'the research-based development of tools and processes for use by practitioners, common in other applied fields, is largely missing in education' (2003, p.3), as are the prototyping, feedback and iterative development processes used in this study (Burkhardt & Schoenfeld, 2021). The evidence from this study suggests the potential of this approach in diverse sectors of education such as ECE. Our recommendations (Figure 6) are, however, no guarantee of impact in practice. There are many factors outside of researchers' control such as funding and practitioner agency (Gorard et al., 2020).

There are, of course, alternative approaches to bridging the research-practice divide than producing research-based resources. Practitioner research and practitioners as co-researchers are two examples. As Jaworski (2003) points out we need both insider (practitioner research) and outsider (enhance knowledge in a generalised sense) research

approaches to generate knowledge that is authentic and usable as well as innovative and challenging to the status-quo. Dagenais et al.'s (2012) conceptualisation of general and local research knowledge may be helpful, pointing to the value and contribution of both in ensuring that research findings have traction in practice. In this way dissemination is perhaps an unhelpful term in that it suggests a unidirectional translational approach which fails to acknowledge the local research knowledge generated through practice. We argue that bidirectional transactional knowledge exchange is needed in mathematics education if it is to bridge the research-practice divide.

Researchers need to do the work of ensuring their research has 'practical significance' (Daniel & De Bruyckere, 2021) with findings reported in terms of practicality of implementation as well as strength of findings (statistical significance). Biesta (2010) points out, this is a question of research epistemology as well as research reporting. We need epistemologies which frame knowledge as dynamic and evolving, rather than static, constant and readily transplanted to practice. Recognition of the change and fluidity of knowledge generated through research supports researchers to prepare for and work with practitioners who progress this knowledge change journey as they continually reform and reshape new knowledge through educational practice. This acknowledges the values about the purposes of education that are inherent in selecting and apply research to practice (Biesta, 2010). There is potential for smoothing the bumpy road from research to practice in the provision of knowledge in appropriate formats. These need to be presented not as solutions but as possible ways of working and thinking about practice, recognising that practitioners will evolve and shape this knowledge into something workable in their setting with their children. In doing so we can consciously avoid positioning practitioners as passive enactors or deliverers of research findings, taking deliberate steps so that they are democratically positioned as

agents of knowledge who change it through their reflection, values, critical engagement and problem solving. This requires research-practice transactions that are practice-focussed, where findings are not a threat to professional judgement but are reliant upon it.

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