# STEM Practices:<br>A Reconceptualization of STEM in the Early Years

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The symposium provides an overview of the Early Years STEM Australia (ELSA) program. The conceptual underpinnings of the program are framed within STEM practices, rather than traditional thinking concerning the integration of discipline content knowledge. We will argue that our focus on practices is more aligned with the play-based and intentional teaching objectives of the Early Years Learning Framework (EYLF). The symposium describes the approach we have undertaken, the extent to which some of the practices align well to mathematics thinking, and the pedagogical framework used to stimulate play and create activities for the six learning apps that form part of the program.

## Paper 1: Tracy Logan, Tom Lowrie, & Claudette Bateup

### *Early Learning STEM Australia (ELSA): Developing a learning program to inspire curiosity and engagement in STEM concepts in preschool children*

Understanding the skills, knowledge and dispositions needed for work of the future is a sustained focus of the Australian Government, with initiatives such as the National Innovations and Science Agenda at the core of Policy. The Early Learning STEM Australia (ELSA) project seeks to develop and pilot an innovative digital-based STEM learning program to be delivered within Australian preschools. This paper reports on the theoretical underpinnings of the ELSA program and describes the design framework.

## Paper 2: Tom Lowrie, Tracy Logan, & Kevin Larkin

### *The "math" in STEM practices: The role of spatial reasoning in the early years*

The paper describes the conceptual framework of the Early Years STEM Australia (ELSA) program. The conceptual framework is developed from STEM practices, rather than from play-based investigations derived from traditional understandings of content within the four STEM disciplines. One of these core STEM practices is spatial reasoning—a practice that not only has strong associations with mathematics but is also the best predictor of an individual choosing a STEM-related profession beyond schooling.

## Paper 3: Kevin Larkin and Caroline Kinny-Lewis

### *ELPSA and Spatial Reasoning: A design based approach to develop a "mapping" app*

ELSA apps will extend beyond the screen to encourage active play that supports STEM practices, such as exploring location, patterns and problem solving. Here, we present current research into spatial reasoning apps for mathematics, suggest ELPSA as a pedagogical framework to underpin mathematics learning using "mapping" as an exemplar, and then discuss the use of a design based approach to create mathematics apps.

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# Early Learning STEM Australia (ELSA): Developing a Learning Program to Inspire Curiosity and Engagement in STEM Concepts in Preschool Children

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Early Learning STEM Australia (ELSA) is a play-based digital learning program for children in preschool to explore Science, Technology, Engineering and Mathematics (STEM). The initiative is framed within the Australian Government's National Innovation and Science Agenda. The central aims of the program are to: (1) develop a learning program to inspire curiosity and engagement in STEM concepts in preschool children, (2) provide a comprehensive and holistic set of resource materials and learning apps that enhance play-based experiences for children as part of their STEM learning, and (3) establish a community of practice network for early years learning that heightens the sustainability of the initiative beyond the scope of the three-year project timeline.

Consequently, our vision for the ELSA pilot program is to design, develop and deliver quality play-based apps and integrated resources that allow children, educators and families to explore and experience powerful STEM ideas and practices in ways that are connected to the children and their environments. The intent of the ELSA program is to:

- Embed a play-based use of technology in the early years through the presentation of STEM-focused learning experiences in an online, play-based environment;
- Provide meaningful opportunities for preschool children to explore a variety of online, play-based learning environments that are rich in STEM practices;
- Engage effectively with the early learning sector to raise awareness of the importance of STEM; and
- Support early childhood educators to understand the multiple points of connection between the STEM practices and how they connect to the EYLF and Australian Curriculum.

## Our Theoretical Approach to Early Learning

Building on the Early Years Learning Framework (EYLF; DEEWR, 2009) and other successful early learning programs, we acknowledge and prescribe to play- and investigation-based pedagogical approaches to early learning. Through such play and investigation, the intention is to develop positive dispositions and a range of skills and knowledge in STEM literacy for children, educators, and families. These dispositions

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include curiosity, cooperation, confidence, creativity, commitment, enthusiasm, imagination, and persistence. The skills and knowledge include the powerful STEM practices at the core of our program design, namely; spatial reasoning and problem solving through inquiry. For young children three to five years of age), there are a number of appropriate pedagogies, including play-based learning and intentional teaching, which support the construction of purposeful and thoughtful learning environments (DEEWR, 2009).

### *Play-Based Learning Experiences*

Within early childhood, the notion of play-based learning has been a constant element. Dockett and Perry (2010) indicated that the important features of play "include the exercise of choice, non-literal approaches, multiple possible outcomes and acknowledgement of the competence of players" (p. 716). The ELSA pilot program will utilise such features within the learning apps. The overall ELSA learning program, and embedded learning apps within the program, will provide children with opportunities to develop their cognitive skills through an emphasis on reasoning and thinking skills, with core STEM practices as the foundation. The children will experience success through supported challenges, thereby developing persistence and resilience as they undertake the activities stimulated by the apps. Many of the activities will promote movement through exploration of the children's environments as well as developing the fine motor skills that will be needed in order to interact with the technology incorporated in the apps.

Interaction is central to young children's learning—through ideas, challenges, stimulating materials, peers, and learned others. Importantly, ELSA learning apps will extend beyond the screen to encourage active play that supports STEM practices, within the learning centre and home environments. The apps will support learning through play, and act as a springboard for children to explore the natural world through investigation and inquiry. According to the American Association for the Advancement of Science (1993), "students should be actively involved in exploring phenomena that interest them. These investigations should be fun and open the door to…more things to explore" (p. 10).

The learning apps will enable children to engage with the concepts multiple times, over an extended period of time. The activities within the apps will draw on themes that reflect everyday life and familiar objects. This approach will enable a richer understanding and playful exploration of learning concepts and will transfer to off screen activities in actual physical environments. This is important since effective learning in the early years requires repeated exposure to materials and concepts to acquire knowledge. The activities will encourage interaction among the preschool children and with their educators and family members in recognition of the importance of such interactions for the children's learning. The apps can be used individually, in groups and via educator led discussions to encourage social interactions. Such discussions will enable "sustained shared thinking" to solve problems and clarify concepts (Siraj-Blatchford, 2010, p.155). However, research has found that play on its own may not be enough to consolidate learning; as the educators' ability to notice learning opportunities is critical to facilitate children's learning (Dockett & Perry, 2010; van Oers, 1996).

### *Intentional Teaching*

As indicated in the EYLF, intentional teaching is purposeful, thoughtful and deliberate teaching (DEEWR, 2009). An intentional educator thinks carefully about their actions and the potential effects of those actions (Epstein, 2007). According to Gronlund and Stewart (2011), excellent educators "are intentional in all they do with and for children. They do not assume that children's development will happen without support, encouragement, and scaffolding or without presenting appropriate challenges for the children" (p. 28). Educators deliberately plan the types of materials and equipment and carefully consider where to place them so children will discover them and use them. They use a range of teaching techniques including demonstrating, describing, modelling, co-constructing, problem solving, documenting and scaffolding (MacNaughton & Williams, 2008). However, the focus of learning remains child-centred, with the educator designing environments around a learning goal to spark children's curiosity and exploration and providing learning materials to play with. The child is an active participant in constructing their knowledge rather than a passive recipient. All concepts can be developed into inquiry projects in the centre that allow for intentional teaching and open-ended play opportunities. Thus, the ELSA learning apps will use a play-based approach that affords intentional teaching opportunities. The activities available in the apps will allow children to discover and learn concepts as well as provide opportunities for educators to plan learning experiences that reinforce and consolidate new knowledge.

## The Design Framework

Our framework involves four interrelated elements, namely: program design, service delivery, the pilot study, and ongoing communication (see Figure 1). The *program design* is situated within STEM literacy and the STEM practices that make up the core learning program. The theoretical and practical knowledge of the ELSA team have ensured that early years STEM practices in the program are closely aligned to curriculum expectations. The EYLF will provide the overarching connectivity for this initiative and is designed around the engagement elements of *Being, Becoming and Belonging*. All learning app production, resource materials and professional development opportunities will make explicit reference to the EYLF to increase the likelihood of sustained use of the ELSA pilot program. The content and discipline knowledge of STEM understandings will recognise the respective school STEM disciplines to enhance smooth transitions from preschool to school. The resources developed for the educator and families apps will have appropriate levels of theoretical rigour and practical applicability to promote knowledge of STEM literacy and STEM practices. The *service delivery* element will utilise user centric and agile approaches to design that will provide the team with feedback from the target audience throughout development. Users will inform the design of every feature. Such a design affords opportunities for productive refinement and adaptation of the apps and related resource materials through conceptually-meaningful and technically-sound feedback loops. This aspect of the framework is a feature of the ELSA design and exemplifies the important relationship between quality design principles, specific STEM practices, and authentic applications in early years contexts. The important interplay between the focus groups, educator PD, and family engagement will be situated within a research design. *The pilot study* design will direct the formation of supplementary materials and resources that can maximise the holistic STEM experiences of all stakeholders—since the apps themselves are only one aspect of the project's sustainable success. This *communication* strategy will complement and enhance the other elements of the framework—through a range of physical artefacts and virtual interactions. We will create a community of practice network (CPN), which will comprise the research and design team; the learning centre educators, interested families and other stakeholders. The

CPN will afford opportunities for all stakeholders to collectively solve educational problems they have in common, especially those related to STEM.

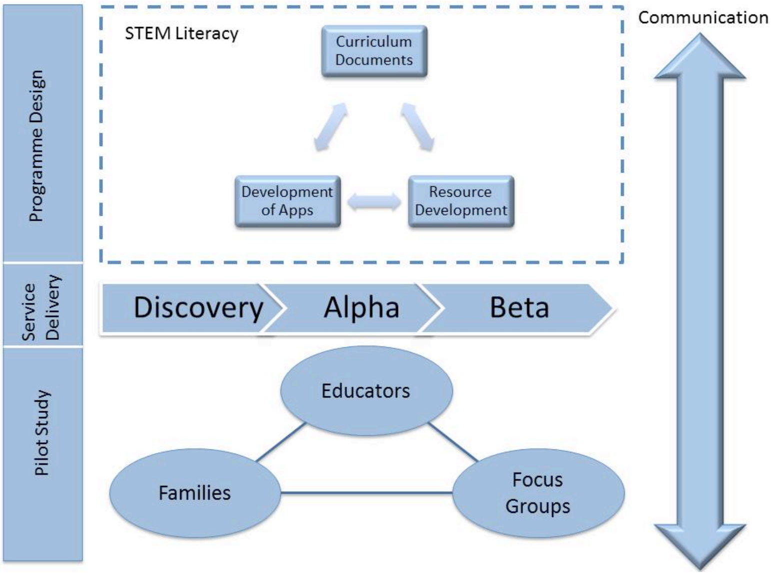


*Figure 1*. A representation of our overarching framework.

# References


American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York, NY: Oxford University Press.

Australian Government Department of Education, Employment and Workplace Relations. (2009). *Belonging, being and becoming: The early years framework for Australia.* Canberra: Commonwealth of Australia.

Bishop, A., FitzSimons, G., & Seah, G. W. T. (1999). Values in mathematics education: Making values teaching explicit in the mathematics classroom. *Proceedings of the Annual Conference of the Australian Association for Research in Education.* Retrieved from http://www.aare.edu.au/99pap/bis99188.htm

Dockett, S., & Perry, B. (2010). What makes mathematics play? In L. Sparrow, B. Kissane, & C. Hurst (Eds.), *Shaping the future of mathematics education: Proceedings of the 33rd Annual Conference of the Mathematics Education Research Group of Australasia* (pp. 715-718). Fremantle, WA: MERGA.

Epstein, A. (2007). *The intentional teacher. Choosing the best strategies for young children's learning.* Washington, DC: NAEYC.

Gronlund, G., & Stewart, K. (2011). Intentionality in action. A strategy that benefits preschoolers and teachers. *Young Children, 66*(6), 28-33.

MacNaughton, G., & Williams, G. (2008). *Techniques for teaching young children: Choices for theory and practice*. Melbourne: Pearson Education Australia.

Siraj-Blatchford, I. (2010). A focus on pedagogy: Case studies of effective practice. In K. Sylva, E. Melhuish, P. Sammons, I. Siraj-Blatchford, & B. Taggart (Eds.), *Early childhood matters: Evidence from the effective pre-school and primary education project* (pp. 149-165). London, England: Routledge.

van Oers, B. (1996). Are you sure? Stimulating mathematical thinking during young children's play. *European Early Childhood Education Research Journal*, *4*(1), 71-87.

# The "Math" in STEM Practices: The Role of Spatial Reasoning in the Early Years

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This paper describes the conceptual framework of the Early Years STEM Australia (ELSA) program. The conceptual framework is developed from STEM practices, rather than from play-based investigations derived from traditional understandings of content within the four STEM disciplines. One of these core STEM practices is spatial reasoning—a practice that not only has strong associations with mathematics but is also the best predictor of an individual choosing a STEM-related profession beyond schooling.

Most advocates of Science, Technology, Engineering and Mathematics (STEM) education highlight the need to purposely integrate the various disciplines in situations that promote real-world problem solving. To some degree, the integration involves using a combination of the four disciplines as a cohesive entity (Breiner, Harkness, Johnson, & Koehler, 2012), although there has been a recent push by specialists outside these four disciplines to consider other domains as part of the STEM movement (e.g., The Arts and even Medicine). In early years settings, and in most real-world situations outside of school, it is unhelpful to consider learning within disciplines—whether integrated or not. Our main tenant in implementing the Early Learning STEM Australia (ELSA) pilot program was to focus on *practices* that enhanced STEM ideas and engagement rather than developing integrated content-based learning experiences derived from the respective disciplines. As Sanders (2009) argued, *practices* are more likely to alter the status quo of traditional content-based learning that has monopolized education for more than a century. Moreover, the focus on practices supports the notion that learning and understanding is best supported in contexts where values described in curricula and policy, the methods employed by educators to support learning, and the ideas developed in children's play are aligned. Such alignment is akin to Kemmis' (2008) conceptualisation of practice architectures.

## The Notion of Practices in Early Years STEM (and Beyond)

We have defined a practice as an application or use of an idea, value or method. The focus on practices helped ensure that understandings are related to the real-world contexts that are enacted through participation and engagement (Kemmis, 2008). An analysis of the Early Years Learning Framework (EYLF; DEEWR, 2009) and the Foundation year of the Australian Curriculum for both mathematics and science (Australian Curriculum, Assessment and Reporting Authority, 2016) helped us to select a number of powerful ideas related to STEM learning that could be framed into STEM practices. These practices included: (a) spatial reasoning, (b) location and arrangement, (c) patterns and relationships, (d) problem solving and inquiry, (e) design and making, and (f) understanding change. These practices were classified in terms of core ideas and methods used to enact these ideas (see Table 1). Given the strong association between spatial reasoning performance and participation in STEM-based occupations (Uttal et al., 2013), it was essential that we identified spatial reasoning as a core STEM practice. The development of learning activities associated with (1) locations and arrangement and (2) patterns and relationships provide opportunities for spatial understandings to be enhanced through intentional

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teaching and play. The second core STEM practice, identified as fundamental in STEM literacy, was problem solving and inquiry. Problem solving for young children involves identifying the problem and thinking clearly about it, determining and applying strategies, checking if they were successful and, if not initially successful, persisting in the process until a successful solution is discovered. Problem solving can be either an individual or group activity. Both types require persistence, focused attention, and creativity. After establishing our second core practice, we then identified learning activities associated with (1) design and making and (2) understanding change, which would provide authentic opportunities for young learners to inquire and problem solve.

Table 1
*STEM Practices within the ELSA Framework*

| **Spatial Reasoning** | |
|---|---|
| Location and Arrangement | Patterns and Relationships |
| **Problem Solving and Inquiry** | |
| Design and Making | Understanding Change |

Given page-length restrictions, for the remainder of this paper, and across the third paper in the symposium, we focus on the core practice of spatial reasoning.

## Spatial Reasoning as a Core STEM Practice

Spatial reasoning is considered critical for everyday tasks and helps us to understand, appreciate and interpret our geometric world (National Council of Teachers of Mathematics [NCTM], 2000). Spatial reasoning is identified as a core component in the Numeracy general capability within the Australian Curriculum and thus is to be incorporated into all subjects across the curriculum. In particular, spatial reasoning is a major focus of mathematics, science understanding, and digital technologies knowledge and understanding. Spatial reasoning can be defined as the process of recognising and manipulating spatial properties of objects and the spatial relations among those objects (Mulligan, 2015). The National Research Council (2006) reported that thinking spatially is an essential aspect of learning and distinguished ways in which we think: *in* space (navigating through buildings, playing sports or organising shelving); *about* space (investigating the structure, function and motion of things in the world, designing a tool, a building or a dam); and *with* space (decoding and encoding diagrams and maps). The capacity to locate, orientate, and visualise objects; navigate paths; decode information graphics; and use and draw diagrams are identified as critical to success in STEM problem solving. Spatial thinking can be improved in primary school-aged children through exposure to explicit spatial reasoning activities and intentional teaching (Lowrie, Logan, & Ramful, 2017). Providing such spatial activities to young children in play-based environments will similarly develop their spatial reasoning.

## Spatial Reasoning as a Practice in the Early Years

Our decision to endorse spatial reasoning as one of our essential STEM practices was not based on the rich literature base alone. Play-based investigations were at the core of our learning design, and such contexts are well suited to the development of spatial reasoning.

Spatial concepts tend to develop through engagement in our inherently spatial world or through activities that promote particular spatial skills or understandings. The interactions with our environment are associated with thinking *about* space, thinking *in* space, and thinking *with* space (NRC, 2005). Research has indicated that infants as young as 16 months of age are able to hierarchically code location by combining distance information with information associated with a category (Huttenlocher, Newcombe & Sandberg, 1994). Although spatial understandings develop through experiences outside-of-school contexts, there is an increasing body of evidence that demonstrates that spatial reasoning also improves as a consequence of intentional teaching (Newcombe, 2013), and this development change can be rapid (Huttenlocher et al., 1994).

Newcombe and Frick (2010) argued that two simultaneous approaches should be taken to promote spatial reasoning in the early years. The first approach is to bring spatial thinking into the learning centre, by providing opportunities for children to engage with spatial ideas through everyday experiences and embodied knowledge. Of note for ELSA, they maintained that digital media could enhance these experiences. The second approach is to engage with spatial skills at home and in play. Both these approaches align well with the principles of the EYLF (Sumsion & Wong, 2011), since they capture the authors' idea of cartography within the EYLF's motif of "belonging, being and becoming". They argue that "belonging", in particular, should consider the conceptual mapping of landscapes through approaches that provide opportunities for rich and culturally diverse ways of participating in learning. That is, belonging includes an understanding of who and where you are, and what surrounds you. Moreover, our conception of the ELSA apps extends beyond the device to encourage active play that supports STEM practices. The twin pillars underpinning spatial reasoning in the ELSA apps are: (1) Location and Arrangement and (2) Patterns and Relationships

### *Location and Arrangement*

Practices associated with location and arrangement have strong links to the EYLF since children explore the world around them through physical play; moving and orientating themselves in space such as dance and shared play; learning through and with different text types including diagrams and drawings; thinking and learning about symbols and patterns as spatial representations; and learning and communicating about numeracy understandings. Location and arrangement is clearly related to spatial reasoning across a range of STEM disciplines. Location and arrangement activities include investigations regarding position, movement and direction and then communicating this information to others using spatial language. For example, children engage in play using actions and language associated with: space (e.g., behind, on, in front of, below); movement (e.g., over, through, between, along); direction (e.g., sideways, forwards, backwards, turn, up); sequencing movement along pathways; and visualising plans for movement around locations. These practices underpin design and construction (engineering); wayfinding and navigation (mathematics); and describing the properties and behaviours of familiar objects (science).

### *Patterns and Relationships*

This STEM idea incorporates understandings about sequences, patterns, and relationships that children encounter in their everyday lives. As was the case with location and arrangement, the practices associated with patterns and relationships are also closely linked to the EYLF. As part of a play-based learning approach, children: explore their environment; manipulate objects and experiment with cause and effect, trial and error, and motion; make predictions and generalisations about their daily activities; and contribute constructively to discussions and argument using mathematical language. These practices are developed explicitly in our apps, and in activities that springboard from the apps, as children use actions and language when: sorting, classifying and matching objects and materials; making patterns using themselves, objects and materials; recognising predictable sequences that are part of an event; and beginning to understand notions of time in relation to their own lives. Play-based investigations utilising experiences in patterns and relationships provide core opportunities for children to *mathematise* concepts, that is, notice the mathematical ideas presented in the play. They also provide opportunities for scientific thinking as they engage in discussions about observations and ideas.

## Conclusion

We acknowledge the importance of discipline knowledge in each of the four STEM areas; however, our argument is that it is developmentally inappropriate for knowledge to be the organising principle for young learners. Instead we focus on STEM practices, applicable to all STEM disciplines, but more philosophically attuned to the core principles of the EYLF. Whilst a range of practices were identified, spatial reasoning and problem solving are critical to later success in STEM.

## References


Australian Curriculum, Assessment and Reporting Authority. (2016). *The Australian Curriculum.* Retrieved from http://www.australiancurriculum.edu.au/

Australian Government Department of Education, Employment and Workplace Relations. (2009). *Belonging, being and becoming: The early years framework for Australia.* Canberra: Commonwealth of Australia.

Breiner, J. M., Harkness, S. S., Johnson, C. C., & Koehler, C. M. (2012). What is STEM? A discussion about conceptions of STEM in education and partnerships. *School Science and Mathematics*, *112*(1), 3-11.

Huttenlocher, J., Newcombe, N., & Sandberg, E. H. (1994). The coding of spatial location in young children. *Cognitive Psychology*, *27*(2), 115-147.

Kemmis, S. (2008). Praxis and practice architectures in mathematics education. In M. Goos, R. Brown, & K. Makar (Eds.), *Navigating currents and charting directions: Proceedings of the 31st Annual Conference of the Mathematics Education Research Group of Australasia.* Brisbane: MERGA.

Lowrie, T., Logan, T., & Ramful, A. (2017). Visuospatial training improves elementary students' mathematics performance. *British Journal of Educational Psychology*. doi:10.1111/bjep.12142

Mulligan, J. (2015). Looking within and beyond the geometry curriculum: connecting spatial reasoning to mathematics learning. *ZDM Mathematics Education 47*: 511. doi:10.1007/s11858-015-0696-1

National Research Council. (2005). *Learning to think spatially: GIS as a support system in the K-12 curriculum*. National Academies Press.

Newcombe, N. S. (2013). Seeing relationships: Using spatial thinking to teach science, mathematics, and social studies. *American Educator*, *37*(1), 26.

Newcombe, N. S., & Frick, A. (2010). Early education for spatial intelligence: Why, what, and how. *Mind, Brain, and Education*, *4*(3), 102-111.

Sanders, M. (2009). STEM, STEM education, STEM mania. *Technology Teacher*, *68*(4), 20-26.

Sumsion, J., & Wong, S. (2011). Interrogating 'belonging 'in Belonging, Being and Becoming: The early years learning framework for Australia. *Contemporary Issues in Early Childhood*, *12*(1), 28-45.

Uttal, D. H., Meadow, N. G., Tipton, E., Hand, L. L., Alden, A. R., Warren, C., & Newcombe, N. S. (2013). The malleability of spatial skills: A meta-analysis of training studies. *Psychological Bulletin, 139*(2), 352-402. doi:10.1037/a0028446

# ELPSA and Spatial Reasoning: A Design-Based Approach to Develop a "Mapping" App

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Early Learning STEM Australia (ELSA) is a play-based digital learning program for children in preschool to explore the practices that underpin Science, Technology, Engineering and Mathematics (STEM). ELSA apps will go beyond the screen to encourage active play that supports STEM practices, such as exploring location, patterns and problem solving. Here, we outline current research into spatial reasoning apps for mathematics, suggest a pedagogical framework to underpin mathematics learning using mapping as an exemplar, and then explain how we will use a design based approach to create apps that support learning in Mathematics.

## Introduction

Early Learning STEM Australia (ELSA) is a play-based digital learning program for children in preschool to explore the practices that underpin Science, Technology, Engineering, and Mathematics (STEM). ELSA apps will go beyond the screen to encourage active play that supports STEM practices, such as exploring location, patterns and problem solving. These apps will support learning through play, and act as a springboard for children to explore the natural world. In this symposium paper, we outline current research into spatial reasoning apps for mathematics, suggest a pedagogical framework to underpin mathematics learning using mapping as an exemplar, and then explain how we will use a design based approach to create apps that support learning in mathematics.

## Spatial Reasoning, Apps, and Early Years Learners

Research suggests that student knowledge and understanding of spatial reasoning is vital as it enables students to understand and interpret their environment. Importantly, it relates to, and predicts, future performance in mathematics (Lowrie, Logan, & Ramful 2017) and in related STEM disciplines (Jirout & Newcombe, 2015; Uttal et al., 2013). Consequently, spatial reasoning is now viewed as a core component in promoting higher-level thinking skills in mathematics and beyond. It is generally accepted that quality digital experiences support mathematical learning (see Larkin, 2016), particularly in spatial reasoning (Lowrie, 2015). Despite the widespread use of apps in primary schools, their use in early years settings is relatively unexplored.

Focussing on developing practices rather than skills, it is necessary to locate the use of the apps in the broader ecology of early childhood. We see ecology as the interplay between the physical, social and cultural elements of the environment (see Arnott, 2016) and that when children use apps we must consider how these contribute "to their social interactions and experiences during digital play" (p. 277). This notion sits comfortably within the philosophical underpinnings of the Early Years Learning Framework (EYLF) where intentional teaching within play-based contexts is promoted. Thus, we see the role of apps as two-fold. First, they contribute towards children's "epistemic" learning – in other words, what does the app do? Second, and perhaps more importantly, apps must

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contribute towards young children's "ludic" learning i.e. what can I do with the app? (Bird & Edwards, 2014). Based on research by the lead author, we suggest that this is where many apps fail, as there is either no scope, or very limited scope, for children to extend their interactions with the app. So, they learn what the app does, often teaching just a skill, but cannot then use the app in any meaningful way in their own context. For example, in many geometry apps the children can only interact with pre-loaded shapes; whereas in one of the better apps (Area of Figures), the children have the additional capability of creating and measuring shapes they have created.

## Using ELPSA as a Pedagogical Frame for the Apps

In designing the apps, we are guided by the ELPSA pedagogical Framework (Lowrie & Patahuddin, 2015), which recognises that learning is constructivist and social in nature. This framework thus recognises that young children develop understanding, and ways of knowing, both individually (intra-personal) and in social interactions with others (inter-personal) (Vygotsky, 1978). ELPSA is an acronym for Experience, Language, Pictorial Representations, Symbolic Representations, and Applications. The following examples of the five stages are adapted from Lowrie and Patahuddin (2015). Experience considers how students have used mathematics and which particular concepts they know both inside and outside of classrooms. Language is used to promote understanding and can be generic (i.e., associated with literacy) or specific (i.e., associated specifically with mathematical terms). Pictorial representations are used to represent mathematical concepts and are a critical aspect of mathematics. Symbols are then used to represent mathematical ideas and are the most common aspect of many mathematics classrooms. The final component in the learning design illustrates how pictorial and symbolic understandings can be applied in novel situations. Although the process appears linear in nature, learning is complex and unpredictable and does not occur in a linear sequence, and thus the elements of the model should be thought of as interrelated and overlapping. It is a tool that early childhood educators can use to make planned and informed interventions in the largely play-based experiences of children.

## ELPSA in Action: Building a "Mapping" App

As a brief exemplar, we have outlined below the process of early ideation for the location and arrangement "mapping" app. In essence, children's progression in spatial understanding commences with their own experience and then progressively become more complex. We suggest that initially children understand themselves in space (Where am I now?) and then understand their movement in space (Where am I going?). Next, they understand that there are others in space with them (Where are you in space?) and finally they begin naïve understandings of space that they cannot see (What is around the corner? What can my teddy see?). Early childhood educators can scaffold play-based experiences to support spatial development using the ELPSA framework. The following are our initial conceptualisations of how the various elements might be supported by an app.

- **Experience**: What can we see in our childcare centre? What can we see when we are at home?
- **Language**: Using directional and positional language to describe – What does it look like from here? What would it look like from over there? Language might include Left, right, forward, backward. Kindergarten terms include next term, near and far, above and below, in front and behind.

- **Pictorial**: Represent what my teddy might see while held in my arms looking forward or what she might see sitting on the swings outside. This involves seeing from a different perspective. Movement can be represented, for example by ant trails.
- **Symbolic:** Creating a map of what I see "inside space". Creating a map of what others might see "outside space in the app". Using symbols that represent things – real or imagined.
- **Application:** Noticing new locations at home and different environments. Noticing on the route. Noticing where I am in relation to others, in relation to me, and in relation to things I can't see. Creating a map of how I find my way to a significant place in my environment – home, shopping centre etc.

## Our Design-Based Process

Based on the work of Katz (2010), we suggest that young children should frequently have the following experiences: be intellectually challenged, engaged and absorbed; use language to communicate their experiences and assist others; participate in sustained investigations of their world; take initiative and develop self-confidence; and apply their developing basic literacy and numeracy skills in purposeful ways. In order to offer young children these experiences, we utilise a four-stage design approach: Discovery, Alpha, Beta, and Live (Figure 1). This approach outlines a clear process to develop the apps; from initially understanding the needs of the young children, their educators and their families, through to the delivery of the finished apps. We envisage the process of app design in the following way:

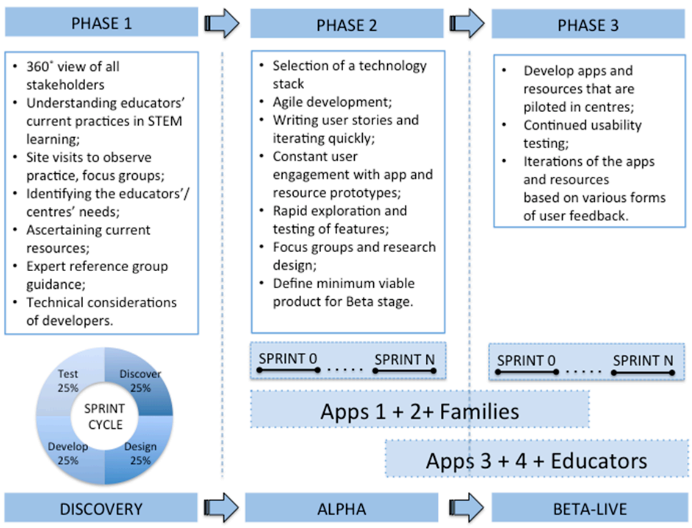


*Figure 1*. An overview of the app design process.

Due to their attention span, their motivation to please adults and their ability to adjust to new people and experiences, user testing with young children requires careful planning (Hanna, Risden, & Alexander 1997). Children three to five years of age will be encouraged to explore the apps according to their own interests and pacing as opposed to undertaking a series of directed tasks. They are often happy to show you what they know and what they can do independently within the app. As children at this age can find expressing their likes and dislikes in words a challenge, we will utilise observations of children's behaviours (e.g., smiling, sighing, looking confused or frustrated) as key indicators of their level of engagement with the apps during the pilot programme (Hanna et al., 1997). Two key parts of the design process are user stories and prototype testing.

*User stories.* The requirements of young children will be expressed via user stories, which will be developed as features that we want to test during prototyping (e.g., a preschool child indicates their favourite activities in the block corner). In essence, each user story will describe the child's primary objective in interaction with an element in the app.

*Prototype testing.* We envisage our apps as toys and thus they will not contain overt teacher instruction. We will initially develop "paper prototypes" (use of paper with a combination of other real-life objects) to represent what will appear in the apps. This design approach, based on Engineering principles, requires minimal investment and often provides a better indicator of engagement because the user is less likely to be distracted by technology and multitasking during play testing. Early learning mathematics concepts (e.g., mapping) can therefore be thoroughly investigated to develop our understanding of how children will engage with the app.

## Conclusion

In this paper, we argued that spatial reasoning is a critical component in developing concepts that underpin later understanding in mathematics and more broadly across STEM disciplines. We suggest that thoughtfully-designed apps become a part of the ecology of young children and help them to explore their world. Finally, via the example of the design of a "mapping" app, we noted that the ELPSA framework, which supports educator intervention in play-based learning, is an important tool for supporting early learners.

## References

Arnott, L. (2016). An ecological exploration of young children's digital play: Framing children's social experiences with technologies in early childhood. *Early Years*, *36*(3), 271-288. doi:10.1080/09575146.2016.1181049

Bird, J., & Edwards, S. (2104). Children learning to use technologies through play: A digital play framework. *British Journal of Educational Technology*, *46*(6), 1149-1160. doi:10.1111/bjet.12191

Hanna, L., Risden, K., & Alexander, K. (1997). Guidelines for usability testing with children. *Interactions*, *4*(5), 9-14.

Jirout, J. J., & Newcombe, N. S. (2015). Building blocks for developing spatial skills: Evidence from a large, representative U.S. sample. *Psychological Science*, *26*(3), 302-310. doi:10.1177/0956797614563338

Katz, L. (2010). *STEM in the early years.* Retrieved from http://ecrp.uiuc.edu/beyond/seed/katz.html

Larkin, K. (2016). Geometry and iPads in primary schools: Does their usefulness extend beyond tracing an oblong? In P. S. Moyer-Packenham (Ed.), *International perspectives on teaching and learning mathematics with virtual manipulatives: Mathematics education in the digital era*. Dordrecht, The Netherlands: Springer.

Lowrie, T. (2015). Digital games, mathematics and visuospatial reasoning. In T. L. R. Jorgensen (Ed.), *Digital games and mathematics learning: Potential, promises and pitfalls* (pp. 71-92). New York, NY: Springer.

Lowrie, T., Logan, T., & Ramful, A. (2017). Visuospatial training improves elementary students' mathematics performance. *British Journal of Educational Psychology*. doi:10.1111/bjep.12142

Lowrie, T., & Patahuddin, S. M. (2015). ELPSA as a lesson design framework. *Journal on Mathematics Education*, *6*(2), 77-92.

Vygotsky, L. S. (1978). *Mind in society: The development of the higher psychological processes*. Cambridge, MA: Harvard University Press.