Situating spatial ability development in the Craft and Technology curricula of Swedish compulsory education

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ABSTRACT

Spatial ability has been shown to have a causal relationship with students' success in science, technology, engineering, and mathematics (STEM) subjects. While an abundance of research has investigated how spatial ability development is and could be integrated to science, engineering, and mathematics curricula, little attempt has been made to date to situate where spatial ability manifests in technology curricula. This paper uses document analysis to examine the locations of spatial ability related learning outcomes within the craft and technology curricula in Swedish compulsory education. A qualitative inductive approach is employed to analyse the policy document from the Swedish National Agency for Education. We argue that spatial ability development manifests in the Swedish craft and technology subject curricula along two dimensions. First, the curricula are underpinned by visual components, which are graphical, pictorial, and manufactured components. Second, along with the visual components, the curricula are delivered with the aim of constructing students' conceptual and procedural knowledge. Whilst the technology curriculum dominantly cultivates students' conceptual and procedural knowledge by interacting with the graphical and manufactured components such as sketches and objects, the craft curriculum is taught in a more diverse way where students are not only required to deal with graphical and manufactured components but also to involve in various pictorial components that convey cultural and historical meanings by craft products.

Key Words: Technology education, spatial ability, document analysis, Swedish compulsory education

1. INTRODUCTION

Spatial ability refers to the ability to mentally create, store, understand, reason, retrieve, and transform visual images (Kyllonen et al., 1984; Lane & Sorby, 2022; Lohman, 1996). We harness spatial ability in our daily life. From two to three dimensions, we engage with lines and points that form various geometric flat shapes such squares and circles, and we interact with solid objects such as cubes and buildings (Lane & Sorby, 2022).

Spatial ability has garnered substantial attention in science, technology, engineering, and mathematics (STEM) education globally (Buckley et al., 2018; Stieff & Uttal, 2015). While an abundance of research has investigated how spatial ability development could be integrated to science, engineering, and mathematics curricula, little attempt has been made to investigate where spatial ability manifests in specific curricula of technology education.

Many European countries have included technology education into their national compulsory curricula. For example, Finnish technology education is compulsory for pupils aged from 7 to 15, aiming to boost their self-esteem through cultivating their understanding, creativity, and hands-on skills of manufacturing and crafting (FNBE, 2016). In Slovenia, compulsory technology education is delivered through the design and technology (D&T) curricula for pupils aged from 9 to 13, aiming to develop pupils' problem solving and creative thinking skills (OECD, 2022). D&T is also part of the national curriculum in the UK for pupils aged 4 to 11 (Brown, 2022). In addition, Estonia, Iceland, Ireland, and Sweden also offer technology education for pupils in primary and secondary schools (Autio, et al., 2019; Lane & Sorby, 2022). This paper is conducted in the context of Swedish technology education.

Technology education in Sweden is mandatory for pupils of 7 to 16 years old. Currently, Swedish technology education has been divided into two separate curricula—craft and technology. While teaching craft aims to develop pupils' knowledge of various artefacts and skills in merging thinking, sensory, and hands-on experience together, teaching technology prepares pupils for the fast-changing technology world through developing their technical awareness and expertise. This paper is to investigate the locations of spatial ability related learning outcomes within the craft and technology curricula in Swedish compulsory education. The results of this paper will not only contribute to the qualification of where spatial ability is represented, but in how they interact with curricular knowledge, which can provide educational researchers and practitioners with increased insight into designing and implementation of effective pedagogical strategies.

2. LITERATURE REVIEW

2.1. Spatial ability and STEM performance

Spatial ability and its malleability have been empirically shown to correlate with the success of STEM learning (e.g., Posamentier et al., 2021; Stieff & Uttal, 2015), resulting in substantial spatial trainings in the STEM-related fields (e.g., Lane & Sorby, 2022; Lowrie, et al., 2017). Researchers have suggested some in-depth reasons why the correlations take place between spatial ability training and STEM performance.

First, the correlations might take place when the practice of spatial ability shares domain-general and domain-specific cognitive processes with the problem-solving process of a subject. Take mathematic as an example, the shared cognitive processes between the use of spatial ability and mathematical problem solving might be the processes that require mental rotation ability (i.e., domain-general) and that require spatial transformation for geometry and measurement problem solving (i.e., domain-specific) (Hawes, et al., 2022). Hence, the natural connection between spatial ability and mathematical performance could be bound.

Second, spatial strategies are applied by learners when solving STEM problems. For example, in chemistry learning, Stieff et al. (2020) found that novice chemistry students automatically recruit spatial ability strategically to process the embedded information in those chemistry representations, regardless of their insufficient domain knowledge of chemistry. Similar examples could also be found in technology education. Technology subjects often involve hands-on activities such as sketching and modelling (Lin, 2016). Learners would naturally hone their spatial orientation as well as fine motor skills in these hands-on activities, which respectively refer to the ability to measure angles and distances and the skills to transform visual information into fine motor activities (Posamentier et al., 2021).

Therefore, spatial ability development is not only naturally situated, but also potentially to improve pupils' technology subjects learning.

2.2. Spatial ability in technology education curricula

Generally, technology education has inherited the vocational nature, and its required skill sets are used and developed in many of today's technology-related fields (Buckley et al., 2018). The required skill sets often involve spatially-focused skills such as sketching, modelling, drawing and so on (Lin, 2016). Researchers have found that spatial ability is positively related to one's success in the technology-related fields (e.g., Julià & Antolí, 2016). Indeed, compared to verbal descriptions, using graphical representations such as symbols not only makes the ways of conveying messages among technologists more effective, but also allows technologists to keep the records of the design process for reference (Ben & Berry, 2012).

Previous studies have shown that a high portion of spatial tasks are embedded in some national curricula of STEM-related subjects (Lowrie, et al., 2017). However, most of the previous investigations are conducted in the subjects of mathematics (e.g., Lowrie, et al., 2017; Ramful, et al., 2017) and science (e.g., Sugai & Suzuki, 2011). For example, according to Lowrie et al. (2017), most national mathematics evaluation programmes tend to shift away from word-based tasks to quantitative as well as graphics content for learners to decode. This paper initiates the first attempt to examine how spatial ability is situated in the technology education curricula in the context of Swedish compulsory education. Particularly, two technology-related subjects are investigated—craft and technology.

3. METHODOLOGY

3.1. The Swedish compulsory curriculum

The curriculum document *Curriculum for the Compulsory School, Preschool Class and School-age Educare* by the Swedish National Agency for Education was examined (Skolverket, 2018).

The document is structured by five sections—*the fundamental values and tasks of the school, overall goals and guidelines, preschool class, school-age educare,* and *syllabuses*. This paper is mainly to address how spatial ability develops within the curricula of craft and technology, targeting pupils who age around 7-16 years old (i.e., Years 1-9). Hence, only the *syllabi*, more specifically, *syllabuses* for craft and technology, will be examined.

The *syllabuses* include *subject aim, core content,* and *knowledge requirements*, which show the intended learning outcomes, the required subject knowledge and skills, and assessment criteria respectively. Pupils' achievements are evaluated by the end of Years 6 and 9. Based on the *knowledge requirements*, pupils' performance is graded by the ranking letters from A (highest performance) to F (fail).

3.2. Coding

A qualitative methodology was adopted to analyse the document by using the analysis software NVivo. First, the authors read the craft and technology syllabi and identified the content that relates to spatial ability development, referred to as "spatial-related content" in this paper. The identification of the spatial-related content was mostly based on the spatial literature and supplemented by the authors' expertise. The authors of this paper have substantial research experience upon the topics of spatial ability development as well as curriculum development.

Second, an in-vivo and descriptive coding method was conducted on the syllabi. Specifically, a code was assigned to a spatial-related content by either extracting a word from the content (i.e., in-vivo coding) or creating a new term (i.e., descriptive coding) (Charmaz, 2006). Table 1 shows the examples of the in-vivo and descriptive coding process. A codes list was generated after the coding process.

Table 1.
Examples of in-vivo and descriptive coding

Content	Subject	Codes	Coding method
Developed forms of **handicraft** techniques, such as moulding, weaving and cutting and turning metal.	Craft	Handicraft	In-vivo
What computers are used for and some of the basic component parts of a computer for entering, retrieving and storing information, such as keyboards, monitors and hard disks.	Technology	Object structure	Descriptive

Third, the authors read the codes and reviewed the coding process together. Disagreements regarding the codes were addressed through constant discussion. 27 codes were generated, with 15 codes from the craft syllabus and 12 from the technology.

Fourth, the 27 codes were then re-coded by an axial coding technique. All authors got familiar with the codes and looked for patterns among them. Two main dimensions with 5 sub-dimensions were identified. The first main dimension represents visual components that pupils engage in craft and technology learning. These visual components include three sub-categories, which are *graphical, pictorial,* and *manufactured* components. Codes are mapped to these sub-categories in the following ways:

- Graphical components: codes that expose schematic features such as "symbol" and "model". They are in a two-dimensional form with the essential attributes that show the details of the structure, framework, and construction of an entity.
- Pictorial components: codes that show contextual features such as "picture" and "materials". They are in a two-dimensional form with not only schematic features but also more aesthetic details such as colours and texture.
- Manufactured components: codes that refer to a three-dimensional entity which combines both graphic and pictorial components such as "handicraft" and "artefacts".

After all codes were mapped to the visual components, they were categorised into the sub-dimensions of the second main dimension. The second main dimension represents the type of knowledge that pupils acquire, which indicates how pupils' knowledge is learned. Two sub-dimensions—conceptual and procedural knowledge—are contained in the second main dimension.

- Conceptual knowledge: knowledge that pupils acquire about the concepts, principles, as well as cultural and historical facts of an entity.
- Procedural knowledge: knowledge that pupils are applying while carrying out hands-on activities to reach a solution of a problem.

The categorization of codes into conceptual and procedural knowledge is based on the context of the spatial-related content. For example, the context of the spatial-related content "*two- and three-dimensional sketches, models, patterns and task descriptions, both with and without digital tools*" (Skolverket, 2018, p. 256) indicates that pupils are required to understand how sketches, model, patterns and task descriptions could be interpreted and related to mathematical calculations, which falls into the sub-dimension of conceptual knowledge. Also, the context of the spatial-related content "*pupils' own constructions applying principles for solid and stable structures, mechanisms and electrical connections, in the form of physical and digital models*" (Skolverket, 2018, p.298) suggests that pupils need to conduct a hands-on construction of model by applying theoretical knowledge, which falls into the sub-dimension of procedural knowledge.

Finally, the spatial-related content of the 27 codes were re-coded by a new pair of codes. To be specific, the new pair of codes consist of one visual component and one knowledge type. Table 2 shows an example of how the spatial-related content in Table 1 was re-coded by a new pair of codes. The spatial-related content could be re-coded by more than one pair of codes if the content falls in more than one sub-dimension.

Table 2.
Examples of axial coding

Content	Subject	Codes	Coding method
Developed forms of handicraft techniques, such as moulding, weaving and cutting and turning metal.	Craft	Manufactured, Procedural	Axial
What computers are used for and some of the basic component parts of a computer for entering, retrieving and storing information, such as keyboards, monitors and hard disks.	Technology	Graphic, Conceptual	Axial

4. RESULTS

The spatial-related content occupies 58.1% of the craft syllabus and 34.4% of the technology syllabus. The percentage is calculated by dividing the number of coded word characters by the total number of word characters of the syllabus (NVivo). While both the craft and technology curriculum expose pupils to spatial ability development, the percentages of the spatial-related content suggest that pupils might have higher chances to develop spatial ability in craft curriculum than technology.

4.1. Spatial ability development in the craft curriculum

Table 3 shows the frequency and percentages of the codes in the spatial-related content of the craft syllabus. The numbers indicate that pupils are required to acquire more conceptual knowledge than procedural knowledge in the craft curriculum. Pupils need to acquire factual understandings of a craft process. These factual understandings include conceptual, cultural, and historical knowledge of the graphic (e.g., symbols and structures), pictorial (e.g., inspirational materials), and manufactured (e.g., handicraft and artefacts) components. Pupils need this knowledge so that they can interpret and assess the aesthetic and cultural meanings behind the product and apply the knowledge to create their own craft product. To deliver procedural knowledge, pupils are required to make simple two- and three dimensional sketches for craft design (graphic, procedural), document their work process with pictures (pictorial, procedural), to explore design opportunities by the given materials (pictorial, procedural), and to create their own craft product by using some tools and instruments (manufactured, procedural).

Table 3.
Codes frequency and percentages of the craft syllabus

Codes	Codes frequency	Occupation of codes among the spatial-related (percentage)
Graphic, conceptual	9	14.1%
Graphic, procedural	2	3.1%
Pictorial, conceptual	11	17.2%
Pictorial, procedural	14	21.9%
Manufactured, conceptual	17	26.6%
Manufactured, procedural	11	17.2%
In total	64	100%

4.2. Spatial ability development in the technology curriculum

Table 4 shows the frequency and percentages of the codes in the spatial-related content of the technology syllabus. The spatial-related content predominantly clusters at graphic and manufactured components along with both conceptual and procedural knowledge. Pupils should have the knowledge of the structure of a technical or mechanical system of some everyday objects such as computers, data networks, electricity, or a bridge. Specifically, pupils need to understand the part-and-whole relationship between the components of a system and a system as a whole (graphic, conceptual). Also, they need to know how an individual technical or mechanical system works to produce expected effect for daily life such as how the technology works in order to produce sound, light or movement (manufactured, conceptual). Similar to craft curriculum, spatial-related content in technology curriculum also requires pupils to document their work process. However, while craft curriculum requires pupils to document by using pictures, technology curriculum needs students to use simple sketches, symbols, and drawing to document their process (graphic, procedural). Also, pupils are required to carry out some technology solutions through controlling an object by programming and applying mechanisms in their own construction of technology (manufactured, procedural). Compared to craft curriculum, pupils seem to engage less with the pictorial components in their technology learning. Only two pictorial components in the technology curriculum were identified along with conceptual and procedural knowledge. First, picture is used in documentation of work process by pupils at the Year 1-3 (pictorial, procedural). Second, pupils should have the knowledge of the properties of some everyday materials such as wood and concrete.

Table 4.
Codes frequency and percentages of the technology syllabus

Codes	Codes frequency	Occupation of codes among the spatial-related content (percentage)
Graphic, conceptual	14	29,17%
Graphic, procedural	10	20,83%
Pictorial, conceptual	4	8,33%
Pictorial, procedural	3	6,25%
Manufactured, conceptual	7	14,58%
Manufactured, procedural	10	20,83%
In total	48	100,00%

5. DISCUSSION AND CONCLUSION

This paper examined the locations of spatial-related content within the craft and technology curricula in Swedish compulsory education. The results show that spatial ability development is embedded in both curricula to a different extent. Specifically, in craft curriculum, spatial ability is developed through requiring pupils to work on all visual components (i.e., graphic, pictorial, and manufactured) while inclining to construct their conceptual knowledge rather than procedural knowledge. Technology curriculum, despite its smaller portion of spatial-related content than craft curriculum, is also embedded with spatial ability development mainly by exposing pupils to graphic and manufactured components, and it requires similar portions of conceptual and procedural knowledge of pupils.

The results could be explained and supported by previous spatial literature. The manifestation of spatial ability development in Swedish national craft and technology curricula is supported by the conceptualization of spatial ability by researchers. Two of the most cited conceptualizations are from Lohman (1996) and Schneider and McGrew (2012). According to Lohman (1996), spatial ability is the ability to "*generate, retain, retrieve, and transform well-structured visual images*" (p. 98). Contemporarily, Schneider and McGrew (2012) considered spatial ability as "*the ability to make use of simulated mental imagery to solve problems—perceiving, discriminating, manipulating, and recalling nonlinguistic images in the 'mind's eye'*" (p.125). Both conceptualizations indicate a mental process of manipulation and transformation of visual images, which might be represented by pupils' conceptual and procedural knowledge in this paper.

For example, in craft curriculum, pupils are asked to interpret a craft artefact by reasoning its symbols and form (Skolverket, 2018). Pupils need to manipulate the symbols and form in mind, starting from perceiving the symbols and form, then retrieving the visual knowledge that they store in mind previously, and finally reasoning the symbols and form with the previously-stored knowledge. In addition, one of the hands-on tasks in technology curriculum is to transform raw materials into a finished product by pupils (Skolverket, 2018). Other than manipulating the objects (i.e., raw materials) in mind such as perceiving the structure and sizes of the objects, pupils also need to mentally transform the nature of the objects and visualise the finished product, which demonstrate one of the core capabilities of spatial ability—spatial visualisation (Kyllonen et al., 1984).

The results fill in the literature void of compulsory curriculum in conjunction with spatial ability development. Particularly, the results uncover how spatial ability development integrates into the technology education curricula and how it interacts with the technology-related subject knowledge (i.e., craft and technology). In addition, this paper examines the compulsory curricula at a national level, which guides the rationale, aims and objectives, as well as content of the curricula at micro levels (Akker, 2003).

Educational researchers and practitioners who work at school and classroom levels could gain insight from the results of this paper. As teachers possess the freedom to interpret the curriculum and design their pedagogies in the classroom (Bernstein, 2018), with knowing how spatial ability development integrates into the curricula, they could design and implement pedagogical strategies that are effective to develop pupils' spatial ability. For example, teachers could be more aware of the visual components that show up in the craft and technology curricula, engaging pupils to perceive and chunk visual components into more visual information (Stieff, et al., 2020), such that pupils' visuospatial capacity could be increased and further lead to a better performance in craft and technology curricula.

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