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Developing spatial literacy through design of built environments: Art and crafts teachers' strategies

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Abstract

Designing built environments demands the ability to make translations between your visions, visual representations of these, and the full-scale environment that is to be built. Pupils working on architectural tasks face these challenges of translation. How can the teacher come to their aid? Research on teaching strategies for the architectural studio has sought to articulate the entire design process, something that leads to overarching strategies but less hands-on, detailed descriptions. This article offers greater in-depth insight into the strategies teachers use to enhance pupils' spatial literacy. In semi-structured interviews, six lower secondary school *Art and crafts* teachers described their teaching practice related to architectural tasks. From the teachers' detailed moves, we have identified five teaching strategies and placed them in a visual model that demonstrates what role they may play in aiding pupils in the process of designing built environments. By articulating these strategies, we hope to contribute to the development of the vocabulary used in and about teaching design and architecture.

Keywords

Art and craft education, Architecture education, Spatial literacy, Design process

Introduction

Our built environments surround us and affect our everyday lives. Designing and planning built environments in compulsory education is therefore relevant for more than aspiring architects. In designing built environments, children and youths can develop general life skills that are useful in planning, redecorating or choosing private housing. In addition, it enables children and youths to become engaged, critical, and knowledgeable citizens who can participate in democratic processes (Nielsen & Digranes, 2007) regarding our built environments.

The new Norwegian national curriculum for primary and lower secondary education was implemented in August 2020. The subject *Art and Crafts* is compulsory across Years 1 to 10 and is the fifth most comprehensive subject in primary and lower secondary education. After Year 10, pupils are expected to be able to sketch and model new solutions for their local built environment (The Norwegian Directorate for Education and Training, 2020a). This is a tall order for youths aged 15–16, as it has been found to be challenging for adults too. Observing the interaction between an architect and two clients while planning a residential building, Nielsen (2000) found that the clients understood the architectural drawings only to a certain extent and had difficulties imagining the spatial properties of the finished building. Another example of the challenge of interpreting drawings is found in the building of a centrally located hotel in Oslo, the Thon Hotel Opera, in 2000. The hotel was criticised as being too tall, creating a wall in front of the Opera building (Neubert, 2007). The politicians behind the decision had not fully comprehended the drawings and stated that they would not have consented to the plans if they had understood their implications (Lundgaard, 2000; Nielsen, 2004). The ability to read visual representations and imagine them as finished buildings, as well as shifting between different scales while designing, are components of spatial literacy. The above-mentioned aims in the curricula are intended to develop pupils' spatial literacy through the subject *Art and Crafts*. However, because the skills involved are difficult to demonstrate or explain, it is important to examine how they can be taught. This article aims to describe strategies used by lower secondary school teachers to enhance their pupils' spatial literacy and to further develop the vocabulary used in teaching design and architecture. As there is little research on how this topic is taught in lower secondary school *Art and crafts*, we present how learning is facilitated in higher education.

Facilitating learning in the architectural studio

Teachers in architectural studios have been criticised for not articulating the design process to their students (van Dooren et al., 2019; Taneri & Dogan, 2021). They comment on the students' products but do not give a sufficient explanation of how the process should be conducted. Taneri and Dogan (2021) link this to a learning-by-doing approach that emphasizes implicit learning acquired while working on design tasks, while van Dooren and colleagues (2019) explain that this reflects a traditional lack of a shared vocabulary and that the teachers are expert architects – not trained teachers. Yorgancioğlu and Tunali's (2020) research on the pedagogic identities of tutors and students in the design studio corroborates the image of students learning through practical work, while the tutors critique the products in one-to-one dialogues with the students. They suggest that tutors shift their roles as "a source of 'expertise' or 'authority'" (Yorgancioğlu & Tunali, 2020, p. 29) to being facilitators of peer critique among students to engage the students more in the learning process. However, peer critique does not help students untangle the difficult design process, as the products are the focal points for these too, nor does it address teaching strategies.

Research aiming to develop strategies for teaching design has been mostly developed within the context of higher education (McLaughlan & Chatterjee, 2020; Shanthi Priya et al., 2020; Van Dooren et al., 2019). Of these, only McLaughlan and Chatterjee (2020) explored existing teaching practices, while the other two explored the implementation of teaching methods constructed theoretically. Regarding classroom practices as unique resources for developing educational research, while identifying a research gap here, we have chosen an approach empirically based on descriptions of teaching practices. Pupils in lower secondary schools demand more explicit, step-by-step guidance through the design process, as opposed to architecture and design students. In addition, lower secondary school teachers often have a solid pedagogical foundation. This creates both the need and the conditions for developing suitable approaches to enhance pupils' spatial literacy through designing built environments. An exploration of these teaching strategies could contribute to developing education in both the subject of *Art and crafts* and the architectural studio.

Spatial literacy: Moving from cognitive processes to complex practical tasks

Spatial skills are useful in everyday activities, such as manoeuvring a car or rearranging furniture (Sutton & Williams, 2011), orienting yourself in an environment (Ishikawa, 2021), or choosing the shortest route home (Nielsen, Oberle & Sugumaran, 2011). In architecture, engineering, design and technology, spatial skills are especially important (Buckley et al., 2022;

Ilić & Đukić, 2017; Lane et al., 2019; Lehtinen et al. 2021; Liao, 2017; Ramey & Uttal, 2017; Sutton & Williams, 2011). For example, the ability to understand the relationship between two-dimensional representations and three-dimensional objects, which is an implicit part of spatial skills (Lohman, 1979; Macnab & Johnstone, 1990; Sutton et al., 2005), is essential in interpreting architectural drawings.

There are no clear definitions of spatial skills, and the terms spatial skills and spatial abilities are often used interchangeably (Berkan et al., 2020; Heil, 2019; Ilić & Đukić, 2017; Sorby, 1999). Two seminal definitions of spatial skills commonly used are the ability to mentally manipulate, rotate, twist, or invert objects (McGee, 1979) and "the ability to generate, retain, retrieve, and transform well-structured visual images" (Lohman, 1996, p. 98). Meanwhile, empirically proven theories on cognitive abilities describe spatial abilities as a constellation of factors. The most updated framework, the Cattell-Horn-Carroll (CHC) theory, is not an absolute model; additional factors have been suggested (Buckley et al., 2018). Examples of factors relevant to designing built environments are *Visualisation*, "the ability to perceive complex patterns and mentally simulate how they might look when transformed (e.g. rotated, changed in size, partially obscured)," *Length estimation,* and *Imagery*, the "ability to produce very vivid images" (Schneider & McGrew, 2012, cited in Buckley et al., 2018, p. 953). While these theories seek to define spatial skills as internal cognitive processes, *spatial literacy* also concerns the use of spatial skills in complex, practical tasks (Lane et al., 2019). Moore-Russo and colleagues (2012, p. 98) describe a spatially literate person as able to "(a) visualize spatial objects; (b) reason about properties of and relationships between spatial objects; and (c) send (and receive) communication about spatial objects and relationships." This demands well-developed spatial skills but also the ability to convey them in complex tasks involving others. In a study conducted by Ramey and Uttal (2017), participants in a middle school summer engineering camp were found to use both internal cognitive processes and thinking with external objects and spatial representations, such as gestures, while collaborating in hands-on engineering activities. While it is relevant to understand the internal cognitive processes linked to spatial skills, the term *spatial literacy* is most suitable in this investigation into the design of built environments due to the practical, hands-on work in materials associated with the *Art and crafts* subject.

Designing built environments entails a translation from the abstract into the concrete. One goes through a process of visuospatial abstraction, imagining what is to be built, design conceptualisations through two-dimensional drawings, and digital and analogue three-dimensional models, all of which are related to a concrete product in full scale (Bhatt & Schultz, 2017). To illustrate this process, we developed the model shown in Figure 1, to be used as a framework for further discussion.

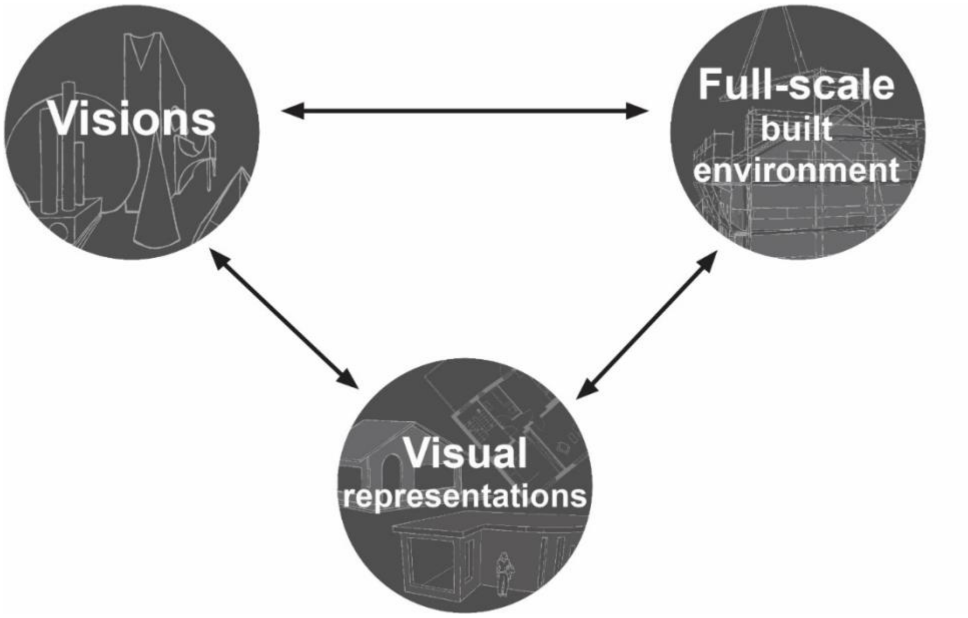

Figure 1. A visualisation of the relationship between different levels of abstraction and scale involved in the process of designing built environments.

Visions are abstract ideas and plans, *visual representations* include drawings and models, and the *full-scale built environment* represents the finished room, building, or other architectural product. The bidirectional arrows indicate the shifting between these three properties throughout the process. This translation between visions, visual representations, and full scale in educational activities is our main interest in this article.

Spatial skills are malleable and can be developed through relevant educational activities (Uttal et al., 2013). Berkan and colleagues (2020) noted significant progress in architecture students' spatial skills after completing a first-term introductory course on the architectural design process. Julià and Antoli (2016) conducted an educational robotics course aimed at improving 12-year-olds' spatial skills through practical hands-on learning. After 10 one-hour sessions, the children's spatial skills improved. Spatial development also occurs as children mature, according to Piaget. Pupils in lower secondary school, ages 13–16, are at the stage of mastering the ability to switch between two and three dimensions, understand area, volume, distance, translation, rotation, and reflection, and combine measurement concepts with projective skills (Piaget & Inhelder, 1956). Unfamiliar or moving objects can be difficult for these youths or even older people to visualise (Sorby, 1999). This makes it especially valuable to investigate how lower secondary school teachers work to enhance their pupils' spatial literacy.

Research questions and aims

In this article, we seek to answer the following research question:

> *Which strategies are used by Art and crafts-teachers to enhance their pupils' capacity to translate between visions, visual representations, and full-scale in designing built environments?*

In this article, strategies are directly linked with actions: “a broad brush depiction of plans – of what should be done to achieve certain objectives” (Goodyear, 2005, p. 87). Strategies are understood as descriptors of what teachers do to facilitate learning. The term refers to both planned procedures and moment-by-moment activities engaged in by teachers and students (OECD, 2010) during supervision. The aim is not to recommend one strategy. As Marzano (2007) points out, research will never be able to identify strategies that work with every student in every class. The individual teacher must determine which strategy to employ depending on the singular situation, and our contribution is to showcase and discuss a broad range of available strategies.

Methods

A qualitative method of semi-structured interviews was used to construct the main data for this article. While describing the teachers’ strategies, corresponding episodes from fieldwork in lower secondary education are added. These episodes were captured using participant observation and semi-structured group interviews.

Semi-structured interviews with teachers

Six participants were purposively sampled (Bryman, 2016, p. 410) for the interviews. The sampling was guided by the following criteria: *Art and crafts* teachers in lower secondary school with relevant education, as well as experience with and a special interest in using architectural tasks in their teaching. Potential participants were identified in two ways: (1) as authors of *Art and crafts*-related texts found in searches in a non-academic journal and an open national base of educational resources, and (2) through inquiries within our professional network. This led to the identification of 10 teachers who received a request to participate in a research interview, followed by one reminder. Six responded positively and participated in interviews conducted by the first author.

The participants’ teaching experience ranged from 3 to 20 years. All taught at the lower secondary level, with pupils aged 13–16, in public schools at the time of the interview. Teaching competencies in *Art and crafts* can be achieved in several ways, such as through specialised teacher education or art education combined with pedagogy. For anonymisation considerations, the individual teachers’ education will not be described, but all six had at least 60 ECTS, the equivalent of a full year of study, of specialisation in the subject.

The interviews were semi-structured (Brinkmann & Kvale, 2015, pp. 31–32), lasted between 50 and 70 minutes and were conducted via video conference in December 2020–January 2021. In the interviews, the teachers were asked to describe one or more architectural assignments they regarded as successful (presented in Table 1), and to elaborate on the active moves they employed to enhance their pupils’ spatial literacy. The interview guide used for the interviews is included in Appendix A. The interviews provided the teachers’ own narrative of what they considered important rather than their exact teaching practice. Although this could be considered a weakness (Jerolmack & Khan, 2014), in this study we view it as a strength, as our interest lies in the moves and actions regarded as most successful rather than the most common. Another potential weakness is that participants may adapt their statements to please the researchers (Brinkmann & Kvale, 2015, p. 38). Asking them to describe their actual practices, rather than an ideal approach or discussing more value-laden questions, is thought to help mitigate this weakness. One final note on the method’s limitations regards the concept of data saturation (Cohen et al., 2018, pp. 222–224). As all interviews were scheduled in advance, we did not attempt to reach saturation, which means that new participants might have provided new perspectives. However, a noticeable overlap across all interviews suggests that the results are trustworthy.

Table 1. Overview of architectural assignments, as described in teacher interviews (names are pseudonyms)

	Assignment	Phases	Level	Time frame
Alexander	Design a holiday home of 100 m^2. Focus on exterior, with the option of decorating the interior.	1. Open exploration with different digital and analogue techniques 2. 3D-modelling in Ludenso, ending with an AR experience viewing the models in life-size 3. Cardboard model in 1:50 scale	Year 10	About 15 weeks
Birgitta	Design a small cabin of 30 m^2 with an innovative exterior and functional interior.	1. Form experiments in SketchUp, composing three blocks of differing character 2. Individual modelling of the cabin in SketchUp 3. Working in groups to make a floor plan and cardboard model based on one group member's ideas	Year 9	About 3 months
	Plan a remodelling of the school.	1. Needs analysis of the school 2. Sketching over existing floor plans and making drawings 3. 3D-modelling in SketchUp	Year 9	12–15 weeks
Christine	Design a house suitable for a figure 1- or 2-cm tall; work only on the exterior.	1. Practice cutting and gluing a pre-drawn house to learn how to make three-dimensional shapes 2. Cardboard model 3. Urban planning, placing the models together, thinking about location according to function	Year 8	Starting with one full day, adding as much time as needed
Danielle	Design the interior of a studio for a chosen artist, area based on the artists' needs.	1. Drawing the studio in one-point perspective 2. Floor plan 3. Cardboard model in 1:40 scale	Year 8	About 10 weeks
Elise	Design a small cabin of 18 m^2. Focus on an experimental shape of the building.	1. Open exploration with different digital and analogue techniques. Pupils were assigned a random geometric shape as a starting point and further challenged to move, remove, or double the shapes.	Year 10	About 8 weeks

		2. Three-dimensional "paper sketches" or prototypes in thin paper 3. Cardboard model in 1:25 scale 4. Poster where the model is edited into the assigned plot of land		
Frida	Design a "writing cabin" of 8 m^2. In the modelling, the focus was on the exterior. Project in the elective subject *Technology in practice.*	1. Idea phase with sketching and modelling in SketchUp 2. Floor plan 3. Model in scale, made of wood with electrical components	Year 8–10 mixed	About 19 weeks

Data analysis

Recorded interviews with teachers were transcribed by the first author, which may be viewed as the analysis's first step (Langdridge, 2006, p. 261). This was followed by a collective qualitative analysis in four steps (Eggebø, 2020). Although Eggebø (2020) inspired its collective form, our analysis also drew on the thematic interview analysis described by Langdridge (2006, pp. 262–267) and King & Horrocks (2010, pp. 152–158).

1. *Collective review of the data material*, in which we discussed each interview. In preparation for this step, we read the transcripts separately, and the first author wrote a summary of each interview. The aim of this step was to become familiar with the informants and the narratives in their interviews.
2. *Collective coding:* In this step, we used a web-based interface emulating a board with Post-it notes. Working separately but on the same board, we wrote descriptive codes that labelled the teachers' mentions of actions and moves in the transcripts, such as "make a cardboard model" or "start with 3D paper sketches." The summaries were checked towards the end to ensure that no important points were lost, as the aim was to include all approaches mentioned by the teachers.
3. *Grouping of themes* entailed moving the Post-it notes around to group the related codes and identify patterns across the interviews. Overlapping codes were removed and similar codes were combined. After identifying the initial groups, a descriptive headline for each group was created, leading the coding process into interpretive coding. This step was conducted in three rounds in which we thoroughly discussed what each code entailed, which codes should be grouped and the rationale behind the grouping. This step led to 10 initial groups that were further combined and restructured into five strategies. The above examples of codes were grouped under "Physical experiments", which is a part of the strategy "Encouraging three-dimensional visualisations".
4. *Outline of the text and plan for further work*: As the strategies began to evolve, we created an outline of the text and planned the writing process. The first author was responsible for writing, with comments and edits from the second author. Some sections were written collaboratively.

Corresponding episodes from fieldwork in Year 10 *Art and crafts*

Concurrent with carrying out and analysing the interviews, we conducted fieldwork at a Norwegian public school where pupils worked on an architectural assignment in Year 10 *Art and crafts*. While these pupils had no relation to the interviewed teachers, we recognised several of the approaches described by the teachers when observing how the pupils handled the challenges in the assignment. To deepen our understanding of the strategies and showcase their relevance in learning, we included corresponding episodes from this fieldwork. The episodes are not used to validate or revise the identified strategies but to show how the perspectives of teachers and pupils align. This strengthens the strategies' credibility and relevance.

The fieldwork was carried out in August 2020–May 2021. The pupils worked on an architectural assignment developed by the second author, who was a teacher at the school. During nine two-hour lessons, they designed a 50–120 m^2 building with a function of their own choice. After deciding on a concept and drawing a floor plan, the pupils made models of their buildings using either Lego, cardboard, Minecraft or SketchUp. The study methods used were participant observation (Cohen et al., 2018, pp. 551–555) and semi-structured group interviews (King & Horrocks, 2010, pp. 61–72). The first author was primarily a partially participating observer (Bryman, 2016, p. 436), but was also the responsible teacher in some lessons. After each lesson, the first author wrote field notes from interesting interactions narrated as episodes (Emerson et al., 2011, pp. 77–79). Included in these are notes from informal unstructured interviews (Bryman, 2016, p. 467) with some of the pupils. In addition, 24 of the 90 pupils chose to participate in semi-structured interviews of 10–30 minutes conducted in groups of 2–4.

After identifying the five strategies described by the teachers, we searched the field notes and interview transcripts for similar approaches used by the pupils participating in our fieldwork. The corresponding episodes are presented at the end of the description of each strategy.

The teachers' strategies

The teachers' projects exhibited a wide variety in terms of procedure, focus and duration, as described in Table 1. Some teachers, such as Christine and Elise, focused on creativity and experimenting with architectural styles and shapes, while others, such as Birgitta and Danielle, focused more on functionality and realistic measurements. The pupils of Alexander, Birgitta and Frida worked for quite a long time on a project consisting of several parts, while the project of Christine was shorter and focused on a cardboard model. Nevertheless, there are many parallels in their approaches to enhance their pupils' capacity to translate between visions, visual representations and full scale while designing built environments. Five strategies (Fig. 2) were identified through the analytical process of assigning descriptive codes to the teachers' detailed moves and actions and grouping them according to theme. The teachers' actions and moves are presented as part of the description of the strategies.

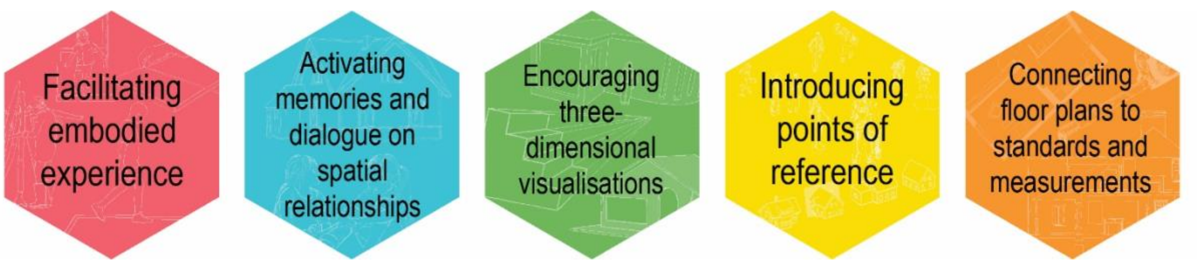

Figure 2. The interviewed teachers employed these five strategies: Facilitating embodied experience, Activating memories and dialogue on spatial relationships, Encouraging three-dimensional visualizations, Introducing points of reference, and Connecting floor plans to standards and measurements.

All these strategies were used by at least five or all six of the teachers, albeit to varying degrees, and are presented in depth below. Descriptions of the strategies are followed by corresponding episodes that illustrate how the pupils observed in our fieldwork used a similar approach.

Facilitating embodied experience

This strategy entails gaining an understanding of spatial properties through bodily interactions with full-scale environments. This strategy was used by all teachers except Christine.

In an exercise conducted by Birgitta, Elise and Frida, the class measured a given area and marked it with tape on the floor (Fig. 3), alternatively with pupils standing to mark each corner. They were encouraged to move around and experience this area to get an initial feel for the area in which they would work. Elise asked her pupils to plan their buildings from a plot of land they could visit. This was something that Alexander had not done, but stated that it would be ideal to provide such a concrete experience.

Figure 3. Marking the outline of a building with tape. Pupils are standing within the marked area and standing or lying in place of furniture. Photo by the second author.

Another approach to embodied experience mentioned by Alexander and Danielle was to measure the classroom and compare its size to the area of the assignment. Several teachers mentioned that pupils became curious about floor-to-ceiling height, the height of doors, and other dimensions in the classroom. Alexander stated that he always keeps a measuring tape in his desk for this purpose. Birgitta and Elise said that they told pupils to measure it themselves when asked about the size of an item.

Understanding spatial properties in relation to one's own body is significant, in Elise's opinion. She used the example of designing a bench or stairs and described instructing pupils to determine suitable measurements by measuring the chair they were sitting on or their own legs. Frida instructed pupils to look around and take measurements in relation to their own height, such as standing in the doorway and measuring it. During her interview, Birgitta expressed the importance of this strategy: "In working with spatial properties, there must be physical examples one can relate to. One can have an embodied experience with them. I believe that's important."

Corresponding episodes related to the strategy

Many of the observed pupils used measurements in the classroom to orient themselves. One, planning to add a pool, discussed with his fellow pupils whether a four-meter pool would be too long. Upon hearing this, the teacher pointed out that one of the walls of the room was four meters long, enabling the pupil to make a design decision. Another pupil related in the interview that after the teacher said the door was one meter wide, she began to imagine all the measurements in different numbers of doors. Yet another said that the teacher helped him measure the classroom at the beginning of the project "to put things into perspective," as he said. While planning his project, he was able to relate it to the area of the classroom when considering how large an area he needed. A fourth pupil was observed estimating distances in the classroom with paces. He stated that this was helpful while drawing furniture into the floor plan, as judging from how the classroom was furnished within a similar area helped him imagine how much would fit and how large it all was.

Activating memories and dialogue on spatial relationships

This strategy relies on pupils' reflections and mental visualisations. The teachers conducted whole-class dialogues or individual dialogues regarding spatial properties. These gave teachers the opportunity to activate the pupils' memories of familiar houses and rooms. Some pupils became curious about the size of their own rooms, measured them at home and used this knowledge in their design process. Birgitta explained that while working with the floor plan of their school, her pupils understood the scale of the floor plan when they recognised the gymnasium. Imagining the size of a familiar room put the scale of the whole floor plan in context. "So, the fact that they can relate to, that they have been to the places they are talking about or that they have experienced it physically, these exact sizes, I think that is of great importance," Birgitta said. Elise and Frida had also asked their pupils to design their buildings for specific and familiar plots of land in the school's vicinity.

Most teachers also presented examples that their pupils were unfamiliar with and showed pictures and drawings for inspiration. Both Alexander and Danielle told their classes the size of their own apartments to exemplify how much you can fit into a certain area.

Corresponding episode related to the strategy

One of the observed pupils struggled to find a suitable area for his building and started over a few times. It all fell into place when he decided to combine rooms of 20 m^2, which was the area of his living room at home. Connecting the project to a familiar room helped him understand the area in which he was working. "Then I knew that all the rooms would be large enough," he said in the interview.

Encouraging 3D-visualisations

Three-dimensional visualisations of ideas can be done through drawing in perspective, doing physical experiments, digital 3D-modelling, or a combination of these. Examples of three-dimensional models are shown in Figure 4. All the interviewed teachers encouraged their pupils to make some form of 3D-visualisation.

Figure 4. Three-dimensional visualisations made by pupils participating in the authors' fieldwork, using SketchUp (top), Minecraft (bottom left), and Lego (bottom right).

Alexander allowed his pupils to choose their own methods in the idea phase; some pupils worked with wooden blocks. He mentioned that he valued working with materials in the idea phase, which was also mentioned by Elise. She instructed her class to make three-dimensional sketches by taping together paper, which she found to be the most comprehensible method for form experiments. As a part of the project's introduction, Christine did an exercise in which the pupils cut out a pre-drawn shape from paper and taped it together into a three-dimensional house. Three-dimensional models, usually in cardboard but also in wood, plastic, or other materials, were a part of all the teachers' projects, although Alexander and Birgitta also included digital 3D-modelling. A physical three-dimensional model was considered useful for understanding how the planned building would turn out. Christine said that she sometimes asked pupils to imagine their cardboard model enlarged to life-size and picture how it would be to walk into it.

Digital 3D-modelling, in Ludenso and SketchUp, was used by Alexander and Birgitta. Here, the pupils used full-scale measurements instead of converting them to scale. Elise and Frida had previously used SketchUp, but the schools' implementation of iPads hindered further use. In the interview, Elise talked enthusiastically about her plans to include Ludenso in her next project. Some of Alexander's and Elise's pupils also used Minecraft in the idea phase. Being able to quickly model a structure in three dimensions, study it from different angles and easily edit it were mentioned as important attributes of digital 3D-modelling, although Alexander pointed out that its rapidity may not afford time for reflection. Alexander and Elise also highlighted the option of viewing models in augmented reality (AR), offered by Ludenso, as a new and promising feature. Through AR, pupils can view their models on site in full scale, and thus get a preview of the finished buildings.

The third way to visualise in three dimensions is by drawing in perspective, a topic discussed in all six interviews. However, its usefulness was a bit debatable – a couple of teachers described it as elusive. Alexander, who let his pupils work freely during the idea phase, said that those who had drawn their houses in perspective seemed to have less general sense of size and scale. Danielle, on the other hand, viewed perspective drawing as an important part of the preparation phase. Her pupils drew in one-point perspective before moving on to the floor plan and model at scale. Drawing in perspective was used to create a feeling for the space and as a basis for discussion on whether the room should be made smaller or larger. Birgitta and Christine expressed a desire to continue teaching perspective, even though the new curriculum does not carry this part of the subject forward. “I think it is a very important part of understanding the transition of illustrating 3D to 2D,” Birgitta said.

Corresponding episodes related to the strategy

The observed pupils worked in groups on an introductory task. They were asked to design a small house by drawing a floor plan, which most groups started right away. One group did, however, fetch an iPad and make drafts in Minecraft. They said that they struggled to envision the building on a two-dimensional floor plan and that Minecraft helped spark ideas. The 3D-model especially helped them imagine the placement of windows, they noted.

A pupil who worked in SketchUp said in the interview that he struggled to visualise the finished building while drawing the initial floor plan and only drew a rectangle. Digital 3D-modelling helped him see how the building would turn out and design a more complex structure.

Introducing points of reference

This strategy entails the use of an object to orient oneself and understand or judge the measurements and scale of the model. Five of the six teachers introduced some points of reference to their pupils, the most common point of reference, was figures at scale, mentioned by all but Danielle and Frida. Christine used figures at scale most actively. She used them as the starting point, asking her pupils to design a house to fit a figure of 1 or 2 cm. The heights of the model were calculated to fit the figure, while other measurements were proportionate to the heights. Throughout Christine’s projects, the figures were used frequently to gauge whether the pupils were on the right track with the scale of their models. Elise gave her pupils the task of making a metal wire model of themselves at a scale of 1:25, the same scale as the model. These figures were used while working with the models. When asked whether the scale of the model seemed correct, she would reply, “Just bring yourself out – can you get through this door?”. In a similar fashion, Alexander brought a scaled figure around when his pupils were working on their physical models to check whether they had gotten the scale correct. Both Alexander and Birgitta mentioned that the software they had used, Ludenso and SketchUp, had figures in the modelling area for scaling purposes, as shown in Figure 5. They were both unsure whether their pupils had actually used them, but as Alexander said, “… he is standing there, so if it is a complete disaster, at least you understand that you’ve started all wrong.”

Other points of reference might be asking pupils to compare the size of their models with each other’s or with models from previous classes. Given that the whole class worked with the same area and scale, if one was significantly smaller or larger than the others, the scale was incorrect. Elise told her pupils that the floor of their model should be around the size of a sheet of A5 paper.

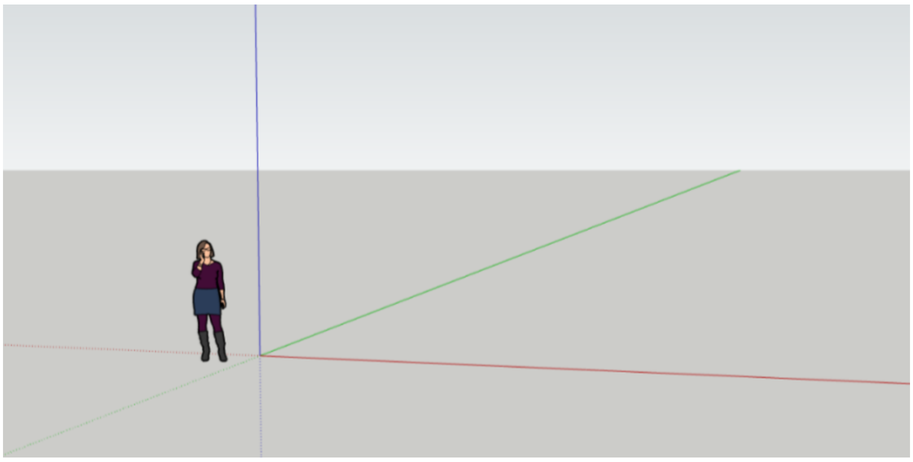

Figure 5. Screenshot of the modelling interface of SketchUp showing how the figure at scale appears at the start of the project.

Corresponding episodes related to the strategy

A couple of the interviewed pupils mentioned spontaneously that they had used "the SketchUp woman" as a point of reference. One used the software's tape measure to find her height, and then measured other items in relation to her. Another pupil said that she had moved the figure around the model to confirm that the size of the rooms was appropriate, especially in nooks and crannies.

Connecting floor plans to standards and measurements

The abstract language of symbols and numbers is connected to full-scale built environments in this strategy. It was applied in one way or another by almost all teachers, except Christine, who took a stance against the use of calculations in a practical subject such as *Art and crafts*.

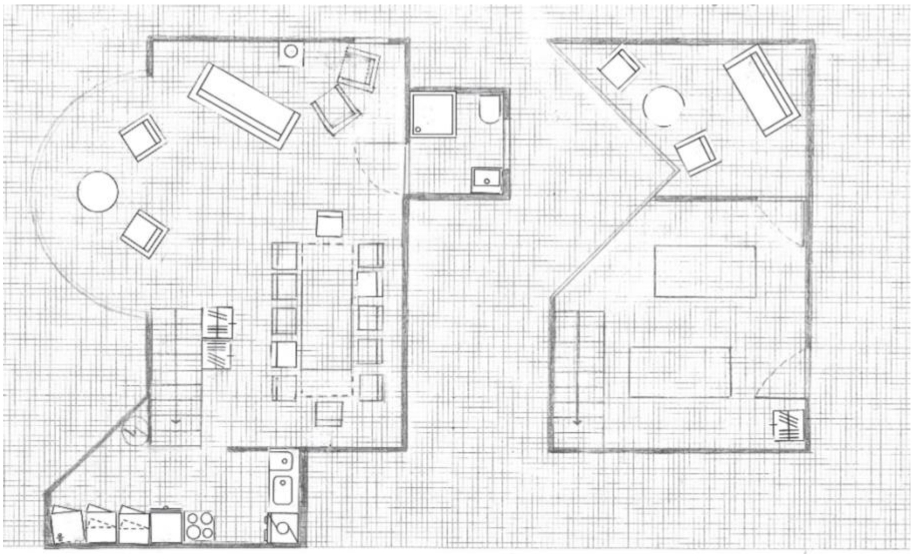

Figure 6. A detailed floor plan, drawn by a pupil participating in the authors' fieldwork, that combines cut-outs from a sheet of floor plan symbols with hand-drawn symbols.

All teachers mentioned floor plans in their interviews. Elise, who skipped traditional sketching and started instead with three-dimensional experiments, did not include floor plans in the described project, but had previously done so. For Christine, floor plans were quick sketches in the idea phase, while the other four teachers worked more thoroughly with scaled floor plans, as exemplified in Figure 6. Drawing floor plans was done in most cases as a part of the idea and planning phase, while Birgitta favoured having her pupils work on floor plans and the digital model simultaneously, so that each could inform the other. Floor plans were mentioned as a way to get an overview of the project and to use them as a blueprint for the physical model. Alexander highlighted that those pupils who drew floor plans in the idea phase tended to have better insight on the spatial properties of their buildings. Birgitta observed that adding furniture to the floor plans often helped her pupils make sense of the spatial properties, as they had a better understanding of the size of a standard bed, for example, than of square meters. A couple of teachers also mentioned that they asked the pupils to look for errors in their own or other pupils' floor plans, as a part of understanding scale.

Alexander, Birgitta, Danielle, and Frida raised their pupils' awareness of real measurements by measuring doors, windows and other items in the classroom and discussing the standard measurements of doors and floor-to-ceiling heights. These teachers expected their pupils to use realistic, scaled measurements in floor plans and physical models, and full-scale measurements in their digital 3D-models. Through experience with the measurements of specific items, it was believed that the pupils would build an understanding of how the abstract language of numbers relates to spatial properties.

While most teachers gave their pupils a set area to work with, Danielle asked them to select the area based on users' needs. This forced them to focus on functionality, determining how many square meters they actually needed rather than distributing square meters into a nice shape. Measuring furniture and equipment in their workshop, such as wood carving benches and sewing tables, prepared the pupils to decide how large an area their artists would need.

Corresponding episodes related to the strategy

The interviewed pupils were asked about their approaches to understanding how large an area they worked with. One mentioned adding furniture to the 3D-model and evaluating the area in relation to these items. "I think that's easy to see, comparing to things I know the size of," she said.

Their floor plans were drawn on grid paper with bold lines forming squares representing 1 m^2. To begin, a few pupils drew a rectangle of the entire area they were to plan and subsequently designed the shape by moving square meters from one side to the other until they were satisfied with the look. One pupil drew 100 m^2 and said that she struggled to imagine such a large area but visualising it on paper helped.

A broad range of strategies in the teachers' toolbox

When teachers assign their pupils the task of designing built environments, the pupils go through a process of visuospatial abstraction and design conceptualisations related to products in full scale (Bhatt & Schultz, 2017), as illustrated in Figure 1. The identified strategies play different roles in helping pupils make this translation between visions, visual representations, and full scale. The strategy of *facilitating embodied experience*, allows pupils to connect their visions with the full scale of their planned buildings. The experience offers a reality check for pupils of what can fit within a set area and tests how their ideas will work in practice.

Conversely, the embodied experience with full scale provides an arena for pupils to spark ideas and move from a vague notion of possibilities to feasible solutions. The strategy of *activating memories and dialogue on spatial relationships* encompasses the development of pupils' visions. When teachers initiate a dialogue, former experiences with rooms and buildings or a mental picture of new examples are used by the pupils to form and refine their visions of the built environment they are planning. This strategy can be compared to the sensemaking practice Ramey and Uttal (2017, p. 299) call "spatial analogy", in which the American pupils use their knowledge of Chicago houses to imagine a house in the Arctic. Teachers have this strategy ready at hand, but the pupils' understanding relies on their ability to form mental pictures, which in turn depends on their innate aptitudes (Buckley et al., 2018, p. 953) and prior experiences (Berkan et al., 2020). Making the connection between the pupils' ideas and the physical world occurs when teachers are *encouraging 3D-visualizations,* by drawing in perspective, making physical or digital models or a combination of these. This strategy forces abstract ideas into concrete shapes and reveals shortcomings in the pupils' visions, such as forgetting to add a staircase or the relationship between the floor plan and the site. However, the spatial properties of visual representations are elusive, since interpretation of size is dependent on the level of detail, scale, and point of view. This strategy does not require pupils to make translations to full scale – they can remain in the internal logic of the visualisation. However, Ramey and Uttal (2017, pp. 309-310) found that the use of visualisation through, for example, gestures, object manipulation, and working from sketches and diagrams was important when the learners make sense of spatial problems. The strategy of *introducing points of reference* falls within the realm of visual representations and offers tools to ensure that the scale and size of the design conceptualisations are correct. This strategy is mostly concerned with the task of creating a correct representation of the built environment and challenging the internal logic of the model. Although this strategy does not develop pupils' understanding of spatial properties, such as area and distance, it is an important part of understanding the concept of scale. Creating a correct visual representation is also crucial in the process of visuospatial abstraction, both to test one's visions and to convey to others how the full-scale built environment should turn out. The last strategy, *connecting floor plans to standards and measurements*, entails a shift between full-scale and scaled visual representations. The teachers asked their pupils to use full-scale measurements in their digital models or to calculate their measurements to the scale of their floor plans and models. This mathematical approach, with a focus on real measurements, helps remind pupils that they are planning a functional, full-scale built environment. Figure 7 illustrates how the strategies facilitate the various modes of translation.

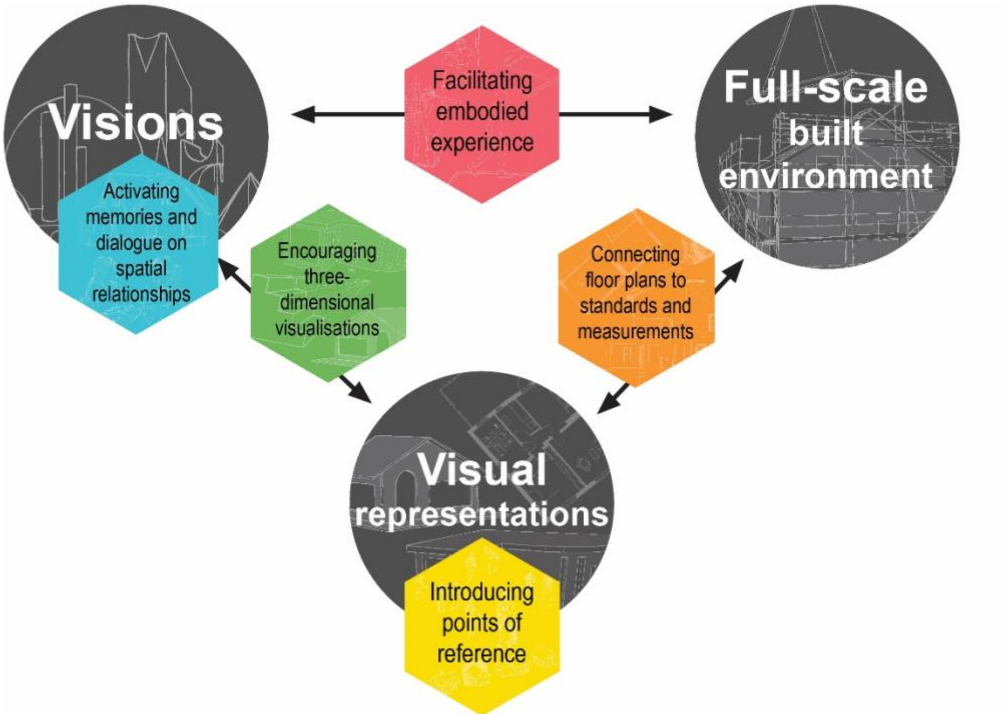

Figure 7. The strategies placed within the model of the process to visualise their roles in the process

The projects described in this article are most common in secondary school *Art and crafts*, with pupils 13–16 years old when, according to Piagetian theory, they are in the process of mastering spatial skills (Piaget & Inhelder, 1956; Sorby, 1999). Meanwhile, spatial skills are malleable and can be improved through general experience and targeted educational activities (Berkan et al., 2020; Julià & Antoli, 2016; Uttal et al., 2013). In Norway, lower secondary school is the last of the compulsory levels before choosing between programmes for general studies and programmes for vocational education and training (VET) (The Norwegian Directorate for Education and Training, 2020b). Spatial literacy is useful in both career paths as well as in everyday living. It is therefore important to facilitate the development of spatial literacy in education for the general public through, for instance, complex tasks such as designing built environments.

In working with architectural assignments and designing built environments, pupils encounter a number of challenges. Their innate aptitudes and experience with spatial tasks vary, so while some master these assignments, others find them challenging. With limited experience in handling abstract numbers relating to areas or measurements, visualising a house of 100 m^2 or a cabin of 30 m^2 might be a challenge, which in turn may lead to struggles getting started. In visual representations, pupils often encounter difficulties with scale, perhaps making the interior disproportionate to the rest of the building. Likewise, a correct representation created without reflection on functionality or the feel of the space could produce a plan that does not work as a full-scale built environment. Successful architectural processes comprise shifting between visions of what is to be built and visual representations of these, firmly related to the full-scale environment, as illustrated in Figure 1.

To accommodate pupils' different needs and challenges, teachers must have a broad range of strategies in their toolbox. In the interviews, a few of the teachers commented that they were unsure what they could contribute to this topic, as they also found it challenging. As the interviews offered an opportunity to reflect upon their own practice, it became evident that they all used a varied set of approaches. Our role as researchers has been to systematise and articulate this knowledge from the practice field. Van Dooren and colleagues (2019) and Taneri and Dogan (2021) pointed out that teachers in the architectural studio do not articulate the design process. Although the strategies presented here emerged from lower secondary school teaching, this vocabulary can also be utilised in design and architecture education to make this part of the design process explicit. In our analysis, the teachers' detailed moves were categorised and reframed into overarching strategies that elevate the individual teacher's practice into an articulated common language. This vocabulary can be developed further within the community of design researchers. Moreover, we hope to contribute to the practice field. As coined by Michael Bassey (2007, p. 141), "Educational research aims critically to inform educational judgements and decisions in order to improve educational action". We have showcased and discussed a broad range of available strategies and posited a language for discussing professional practice. We leave it to individual teachers to determine which strategies to employ depending on their singular situations. An increased awareness of possible teaching strategies may aid them both in lesson planning and in solving moment-to-moment challenges. The strategies have different properties, ranging from the abstract to the concrete, from discussions and calculations to practical work in materials, and they play different roles in the process. Figure 7 places the strategies on the translations between visions, visual representations, and full scale. Awareness of these properties and roles may aid teachers seeking to position their professional practice, decide which aspect of the project they wish to emphasize, and how to approach it in practice.

Concluding remarks

This article investigated how lower secondary school *Art and crafts* teachers enhance their pupils' spatial literacy while working on architectural assignments. Our aim was to map their current teaching practices in this topic to develop a vocabulary for the field of *Art and crafts* and Architecture education. Based on the interviews, five teaching strategies were identified and placed in a visual model to demonstrate the role they may play in aiding pupils in the process of designing built environments.

Teachers can prioritize different aspects of an architectural assignment, such as form exploration, the use of accurate measurements, or designing for functionality. Some may view this as an isolated project with its own justifications. Others wish for the learning outcome to be transferable, such as the ability to draw sketches of other products or to understand the relationship between two-dimensional representations and three-dimensional objects. Although such variation in learning objectives was found among the interviewed teachers, the five identified strategies were applied by at least five or all six of the participating teachers. This verifies that these strategies are relevant across different learning situations. In an architectural assignment, the pupils face challenges for which they have different capabilities to handle. By exploring the teachers' approaches to these challenges, we attempted to unpack some tools that can aid pupils in this endeavour. The corresponding episodes illustrate how small moves can dissolve uncertainties and difficulties, and help pupils advance through the process.

In further research, the usefulness of the identified strategies could be tested in *Art and crafts* or in architecture and design education. Relevant questions to examine are whether this articulation of the strategies and the roles they play in the design process could help teachers prepare lessons, identify students' struggles, and target their moves towards alleviating these. Alternatively, the strategies' usefulness can be evaluated from a student perspective by investigating how the students react to them and whether they use other approaches. Because we did not aim to reach data saturation, as mentioned in the methods section, a broader study including more participants could validate the results or discover additional strategies. Such a study could concentrate, as this one, on teachers with a special interest in architecture or investigate the practices of all teachers in the subject of *Art and crafts,* regardless of their background. One final suggestion for further research is an in-depth exploration of the process of visuospatial abstraction, building upon our model shown in Figure 1, to investigate, for example, the role of visual representations in the process. Although this includes visualisations in two and three dimensions, only three-dimensional visualisations came up as a strategy supporting the process. This correlates with Ramey and Uttal's (2017) study, in which only one of 31 learners was observed sketching (p. 302). As sketching and drawing are considered integral parts of *Art and crafts* (Skjelbred & Borgen, 2019), it is relevant to investigate whether, when, and how two-dimensional drawings can be used in designing built environments.

As challenging as architectural assignments may be, they are an important part of the subject of *Art and crafts*. Architecture surrounds us in everyday life, and it is impossible to be neutral about it. Most pupils will not become architects or designers, but skills developed through such assignments are useful in choosing or building private housing. Many may become involved in democratic processes regarding our built environments, either as politicians, stakeholders, or laypersons. Gaining a solid foundation for expressing visions, interpreting visual representations, and translating between visual representations and full scale through general education could contribute to facilitating real democratic processes and ensuring the quality of our built environment.

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Appendix A:

Interview guide for the semi-structured interviews with teachers

1. What is your education?
2. How many years of teaching experience do you have?
3. Is your school a lower secondary school or Year 1-10 school? At which level do you teach Art and crafts?

4. You have been chosen to participate in this interview because we have heard about an architectural assignment where you …… Can you tell me more about how you worked on this project?
    - Which finished product did the pupils work towards?
    - What was the duration of the project?
    - Which part does the pupils usually start with?
    - Did the pupils make a floor plan or a model at scale?
    - Did the pupils work digitally, analogue or a combination of the two?
    - Why have you been teaching in this way?
    - In your experience, how have the pupils' responded to this way of teaching? Have you seen any changes to their products or their learning outcomes?
5. What is the most important learning outcome the pupils can have, in your opinion?
6. Is there something you have noticed that pupils often struggle with or find difficult?
    - Which actions or moves have you made to make this easier for them? And which effect have this had on the pupils?
7. In your experience, how does pupils master the task of imagining the finished product? In example, how large will it be, how much can they fit into a certain area, what the spatial properties and feel of the room or area would be?
8. Which actions and moves do you make to help the pupils to get an understanding of the size of a room, e.g. on a floor plan, how tall a building is, e.g. on a scaled model, how big an area a square meter really has?
9. How do you prioritize teaching architecture in the subject Art and crafts?
10. Why do you regard this as an important/not important topic for the pupils to learn about?
11. Is there something else you wish to discuss in relation to teaching the topic of architecture?