Spatial Visualization Skills of Student Teacher Applicants

A Pilot Study in the Finnish CDT Teacher Education Admissions

Rauli Lehtinen, Mikko Huhtala and Eila Lindfors

Problem-solving is a key element in design and engineering processes for finding answers to challenges and open problems. The use of spatial visualization skills is part of problem-solving in terms of transforming ideas into 2D or 3D form and transferring this thinking into practice in a practical hands-on process. Spatial visualization seems to play a key role in the design, engineering and production processes as well as in various professions. Spatial visualization skills can be considered as an important part of teachers' multidimensional professional competence as they teach students and guide and tutor their hands-on projects. While educating teachers, it would be important to know the levels of the student teachers' spatial visualization skills to consider its role in courses and even in admissions. However, there are no existing studies on spatial visualization skills of student teacher applicants. To address this research gap, we pose the following research question: What is the level of spatial visualization skills of student teacher applicants in craft, design and technology teacher education admissions? The data, analyzed with document analysis, includes student teacher applicants' performance in a spatial visualization test (N=89, three tasks) as part of Finnish craft, design and technology teacher education admissions. According to the results, four of the five applicants performed on a good level whilst only four per cent of applicants performed weakly. Since spatial visualization skills can be trained, it is important to recognize student teachers' weak performance so that it can be enhanced in various courses. This study is part of a larger problem-solving skills evaluation project in CDT teacher education admissions.

Keywords: spatial visualization, problem-solving, teacher education, admission test, craft design and technology education, engineering, technical drawing

Introduction

Spatial visualization skills as part of problem-solving in engineering and technology

Spatial visualization skills play a key role in the design, engineering and production processes in many professions (Sorby, 2009; Sorby et al., 2013). These skills are highly important in other traditional hands-on professions besides engineering. For example, a carpenter must be able to switch between two-dimensional (2D) technical drawings and three-dimensional (3D) representations of objects (Cuendet, et al., 2014) as well as their parts, details and layers in their daily work. According to McGee (1979) and Salthouse et al. (1990), spatial visualization is a mental manipulation of an entire spatial configuration, which imagines the rotation and position changes of objects in space. It also displays changes and the relationship between the elements. Ramey and Uttal (2017) use the concept of spatial thinking and link it to internal cognitive processes such as the mental rotation of 2D or 3D figures. They also discuss the concept of thinking involving external objects or spatial representations, such as models and diagrams that are needed in engineering and hands-on technology projects. In this way, the object can be manipulated and represented in different points of view (Strong & Smith, 2002). Spatial visualization skills in the form of spatial thinking are necessary to understand objects in 2D and 3D space and to transfer this thinking into practice during a practical hands-on processes.

In general, problem-solving is transforming a given state into a goal state when no obvious method of solution is available (Mayer, 2003). According to Sugrue (1995), problem-solving may take place in different educationally relevant domains, and a large body of research has been conducted in domain-specific areas such as mathematical, scientific or technical problem-solving. In some cases, problems are logical and have only one or few right answers or solutions; in creative problem-solving, however, there are numerous ways to accomplish different solutions that are not necessarily right or wrong. Thus, problem-solving is a key element in design and engineering processes for finding answers to challenges and open problems. The use of spatial visualization skills is an important part of problem-solving by transforming ideas into 2D or 3D form (Ramey & Uttal, 2017; Sorby, 2009; Sorby et al., 2013). The acquisition of knowledge and skills are closely connected, and to a certain degree, a good representation is a necessary condition for establishing specific goals and for deducing interventions to solve a problem (Novick & Bassok, 2005).

Numerous studies have indicated that spatial visualization skills are related to drawing and mechanical design. Spatial visualization is an important link between the conceptualization stage of mechanical design and converting design concepts into sketches (Hegarty & Sims, 1994; Bertoline et al., 1995) in logical and creative problem-solving processes. Therefore, individuals who lack the ability or experience in the use of spatial visualization might have problems learning mechanical engineering drawing (Magin & Churches, 1996; Potter & van der Merwe, 2001; Yasemin, 2013).

Spatial visualization skills, teaching and teacher education

Additionally, craft, design, engineering and technology education teachers across various education levels must be able to understand technical drawings and visualize representations of objects, their parts, details and layers as they teach and tutor students in their technology projects. These spatial visualization skills are considered as an important part of technology and engineering education teachers' multidimensional professional knowledge.

Craft, design and technology (CDT) education is taught in the Finnish educational system from early childhood and continues through comprehensive education to higher education as a subject defined by national core curricula. The aim of the subject is to enhance student-based innovative design and creative problem-solving skills that are carried out with various learning assignments in technologically rich learning environments. Moreover, it intends to presuppose students' sense of commitment and responsibility to master a holistic process with various technologies, either individually or in collaboration with others (Jaatinen & Lindfors, 2019; Lindfors & Hilmola, 2016; Porko-Hudd et al., 2018). The process includes ideating, problem definition and design of solutions that also include drawing and technical design. Visualizations and technical drawings are further used in a practical hands-on process with various technologies.

In craft, design, engineering and technology education, where problem-solving skills are taught from early to higher education, teachers should also have the spatial visualization skills to be used in teaching the design and engineering processes to their students. In teacher training, student teachers should acquire and develop their problem-solving skills during their bachelor's and master's studies. Studies have shown that spatial abilities affect students' performance in design-related courses and those spatial abilities can be improved through appropriate educational training (Tuckey et al., 1991; Alias et al., 2002; Amir, 2002; Wanzel et al., 2002; Burton & Dowling, 2009).

There are a few experiments (Kok & Bayaga, 2019) that indicate that student teachers' spatial visualization skills can be enhanced by training them in the form of sketching and 3D computer modelling, even with eye-tracking (Li et al., 2020). However, to the best of our knowledge, there are no existing studies that analyze student teacher applicants' spatial visualization skills. In this paper, we fill this research gap by presenting a study that assesses student teacher applicants' (N=87) spatial visualization skills on the basis of three visual tasks. The tasks were part of logical problem-solving tests and measured spatial visualization skills in the form of three different picture tasks (Pictures 1-3). We seek to answer the study question: What is the level of spatial visualization skills of student teacher applicants in CDT teacher education admissions? The sub-questions are: 1) In what way the applicants performed in the spatial visualization test and 2) What kind of mistakes do the applicants make in the spatial visualization tasks?

Research design

The data was gathered in CDT teacher education admissions (combined bachelor's and master's program) in higher education in a Finnish university in 2018. Altogether, 87 applicants took a problem-solving test as part of the applicability test. Each participant gave permission for the researchers to use their test results as research data. The applicants had already completed and passed the first phase test that assessed their academic skills. The problem-solving test included ten tasks: two creative and eight logical problem-solving tasks. Three of the logical problem-solving tasks tested spatial visualization skills (see Sorby, 2009), which are reported in this study. This data includes 87 answers for each task, constituting a total of 261 answers altogether. All of the data was anonymized before it was handed over to the authors; the applicants cannot be recognized in the results.

The documentation analysis (Bowen, 2009) was executed by one of the authors and each spatial visualization task was reviewed and monitored. A starting point was to figure out how the CDT student teacher applicants performed in the three spatial visualization tasks. First, the right and wrong answers to each task were sorted out (Figure 1). Next, the wrong answers were analyzed and divided into categories on the basis of a type of the wrong answer (Figure 2). Finally, the level of the applicants' spatial perception skills was determined. Each of the authors considered and discussed the implementation of the analysis and evaluated the results.

Results

First, we present a result in what way the student teacher applicants (N=87) performed in the spatial visualization tasks. Next, we introduce what kinds of mistakes the applicants made in the spatial visualization tasks. Thirdly, we conclude by evaluating the level of spatial visualization skills of the applicants.

All answers were divided into right and wrong ones. There were 261 answers across the three tasks: 92% were right and 8% were wrong.

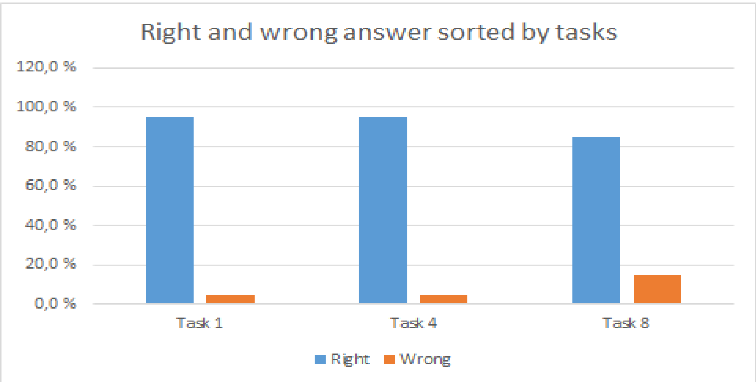

Figure 1. The right and wrong answers in the three spatial visualization tasks.

Next, we studied how the right and wrong answers were divided within the three tasks (Figure 1). In the first task (Figure 3), there were 95% right answers and 5% wrong answers. In task two (Figure 5), there were also 95% right answers and 5% wrong answers. In task three (Figure 7), there were 85% right answers and 15% wrong answers.

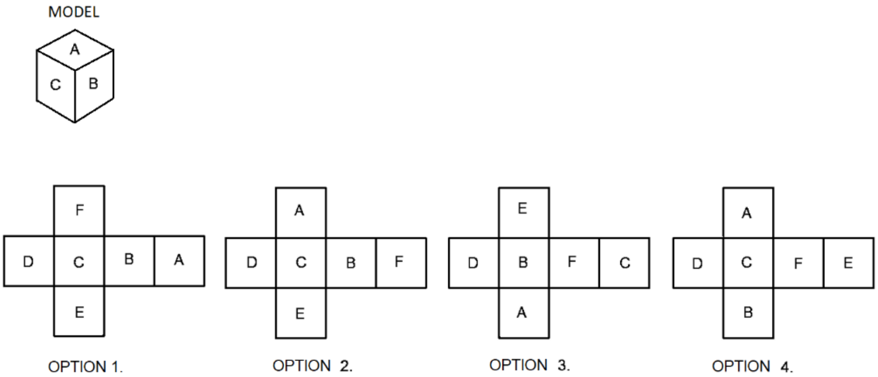

Figure 2. The authentic spatial visualization task one: the cube and its flat pattern.

Task one (Figure 2) required the applicant to use their imagination to open the cube shown in the upper level of the task model. The applicant had to choose which of the four options made the same pattern when folded into a cube. The correct answer is option two. Option two received 95% of the answers, option one had 2.3% of the answers, and options three and four both had 1.2% of the answers. The wrong answers were divided almost equally across the wrong options.

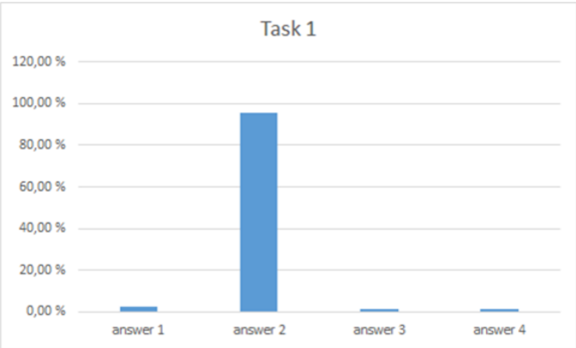

Figure 3. The choices made by the student teacher applicants in task one.

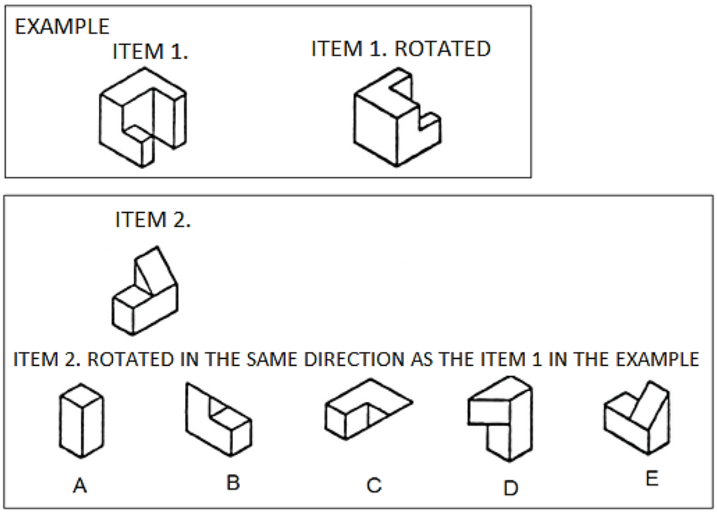

Figure 4. The authentic spatial visualization task two: a 90-degree counterclockwise rotation of an object.

Figure 4 depicts the second task, which required the student teacher applicants to study how an object is rotated. Each applicant had to picture in his/her mind what the object shown in the middle of the task would look like when rotated in exactly the same manner, 90 degrees counterclockwise, as the object in the upper example. They had to choose the correct object from the five options provided at the bottom of the task. The object had to be rotated into the correct position. The correct option (B) was chosen by 95% of the student teacher applicants. Each of the wrong answers (5%) were for option E (Figure 5). These applicants figured the 90-degree rotation clockwise, instead of counterclockwise, as specified in the instructions.

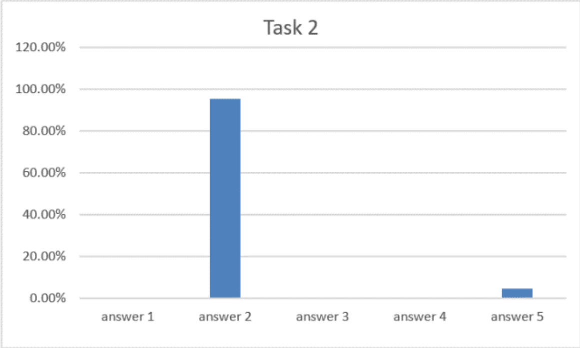

Figure 5. The answer options chosen by the student teacher applicants in task two.

Task three is shown in Figure 6. This task was to study the depicted fully enclosed object, tiny stairs. The applicants had to imagine how it would look as an opened flat pattern and choose the correct answer.

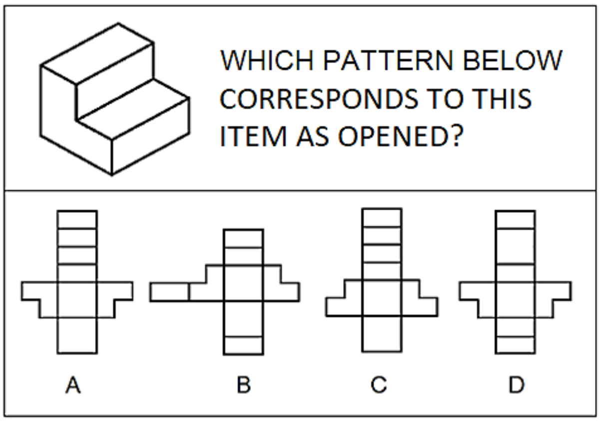

Figure 6. The authentic spatial visualization task number 3: An object and its flat pattern.

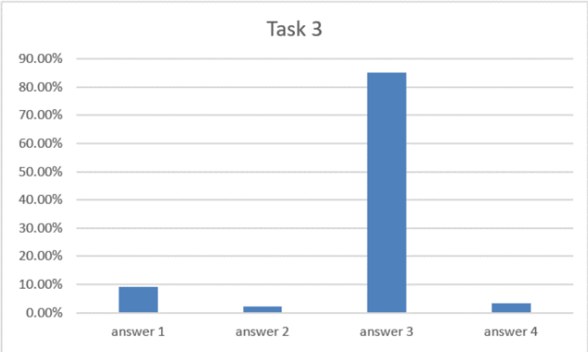

Figure 7. The answer options chosen by the student teacher applicants in task three.

Task three had four answer options. Option C was the correct one, receiving 85% of all answers (Figure 7). Option A got 9%, option B got 2% and option D got 4% of all answers.

Next, the student teacher applicants' performance in separate tasks were evaluated according to the total performance of spatial visualization skills (Figure 8). The researchers defined and agreed on the performance levels of spatial visualization skills. Applicants that reached a good level (79%) had the right answers to all three tasks. The applicants that had the right answers to two tasks (17%) were deemed to have moderate spatial visualization skills. Finally, the applicants that had incorrectly answered each of the tasks or had only one right answer (4%) were classified as having weak spatial visualization skills.

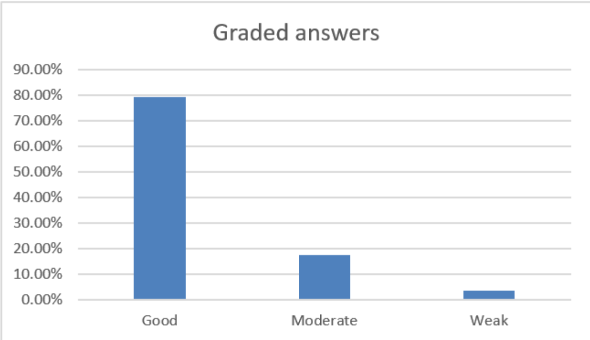

Figure 8. The student teacher applicants' performance in the spatial visualization test. Good = all answers right, moderate = two right answers, weak = one right answer or all wrong.

Discussion and conclusions

This study analyzed the spatial visualization skills of student teacher applicants in CDT teacher admissions. This is a pilot study, as the data only includes one year of admission problem-solving spatial visualization tests in one university. The answer to the first sub-question is that depending on the spatial visualization task (Figures 3, 5 and 7), the student teacher applicants could choose the correct answer within the range of 85-95% (Figure 1). In terms of the second sub-question, it can be concluded that in task one, which depicted the cube and its flat pattern, the wrong answers were equally distributed between the options (Figure 3). In task two, which required applicants to visualize the object rotation 90 degrees counterclockwise, each of the applicants who chose incorrectly selected the same wrong answer; instead, they chose the option that depicted the 90 degree clockwise rotation (Figure 4). In the visualization of the tiny stairs and their flat pattern in task three (Picture 3), most of the wrong answers focused on option A (Figure 6). This means that these applicants could not figure the form of the 3D object to its flat pattern. To answer the main study question, it can be argued that four of the five applicants who performed the spatial visualization test demonstrated a good level (Figure 8) whilst only four per cent of the applicants performed weakly. According to these results, it can be stated that most of the applicants have enough spatial visualization skills to be selected as CDT student teachers. However, the small proportion of the applicants who demonstrated weak spatial visualization skills is not a good precondition to begin studies to become a CDT education teacher (Magin & Churches, 1996; Potter & van der Merwe, 2001; Yasemin, 2013).

Since spatial visualization skills are seen to play a key role in design and engineering (Sorby, 2009; Sorby et al., 2013) as well as in traditional hands-on professions like a carpenter (see Cuendet et al., 2014), it is important that teachers of craft, design, engineering and technology can use these skills themselves and also teach and train their students to advance their skills. In conclusion, the spatial visualization skills in the educational context of design and engineering are seen as a construction of mental manipulation of an entire spatial configuration (McGee, 1979; Ramey & Uttal, 2017; Salthouse, et al.,1990; Sorby, 2009; Strong & Smith 2002). This includes the rotation and position changes of objects in a space, changes and relationships between the elements, layers and details and the whole construction of objects in 2D and 3D form to be able to transfer this thinking into practice during a practical construction, fabrication or manufacturing process. In CDT education there is a constant need for teachers to teach sketching and technical drawing and switch between 2D technical drawings and 3D representations of objects to guide and tutor students' innovative problem-solving processes in technologically rich learning environments (Jaatinen & Lindfors, 2019; Lindfors & Hilmola, 2016).

It is notable that the performance of the student teacher applicants in the spatial visualization test was better than we had expected. Thus, the reason for the high levels of spatial visualization might be that the tasks were too easy or that to the admissions join the student teacher applicants whose level of spatial visualization skills is good. It is unlikely that the applicants could have succeeded in the test by simply guessing in the three tasks. Based on the data used in this study, it is evident that the student teacher applicants have strong spatial visualization skills. However, the tasks used in our test are commonly available and there are plenty of training possibilities; certain tasks are commonly used in different admission tests, in higher education and in military forces. Thus, it seems that there is no need for developing extra courses for learning spatial visualization. However, it is important to develop the teaching of spatial visualization skills as part of CDT teacher education in the future.

The next study should focus on exploring which applicants of this data got was accepted in the CDT teacher education program and how they perform and develop their spatial visualization skills as part of logical and creative problem-solving. According to earlier research spatial abilities, the effect on students' performance in design-related courses and these can be improved through appropriate educational training (Alias et al., 2002; Amir, 2002; Wanzel et al., 2002; Burton & Dowling, 2009; Tuckey et al., 1991). To be able to train spatial visualization skills (e.g., Kok & Bayaga, 2019; Li et al., 2020), it is necessary to know the level of applicants. Ultimately, this pilot study advances the understanding of spatial visualization skills of student teacher applicants and the results can be used for planning future studies or tests for student teachers.

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