A Study of Spatial Reasoning Skills in Carpenters' Training

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***Abstract*—One difficulty with the Swiss dual system is the gap between the practical work in the company and the theoretical teaching at school. In this article, we examine the case of carpenters. We observe that the school-workplace gap exists and materializes through the importance given to drawing classes at school, while carpenters almost never draw at their workplace. The existence of the drawing classes are justified by their contribution to the development of spatial skills, which are essential to carpenters. To gain a clearer view on spatial skills for carpenters, we performed a large-scale (n=512) field study on spatial skills, in which carpenters were compared with logistics apprentices and high school students. We report the results of this study and show that carpenters' spatial skills are higher than the two other populations' but that they do not improve between the end of the first year and the end of their apprenticeship. Those results give us indications on how to build a future learning environment to improve the training of carpenters.**

***Index Terms*—spatial skills, spatial ability, learning, learning environment, carpenter**

I. Introduction

One difficulty with the Swiss dual system is the gap between the practical work in the company and the theoretical teaching at school. Indeed, while apprentices have to learn all facets of their profession, it is often the case that the theoretical courses they attend at school seem to be of little relevance to the tasks they accomplish in the company. For example, the syllabus for the carpenters' apprenticeship weekly dedicates 3 hours – i.e. 60% of the profession-specific teaching – to drawing. However, in practice, apprentices almost never draw anything, since most of the plans are either done with a computer aided design (CAD) software or by a more experienced worker. Our research focuses on helping to bridge the gap that exists between school and the workplace by using new technological devices. This article reports the first stages of this process in the case of carpenters.

A. Identifying the problem

In order to find out in what domain a learning environment is most needed, we visited 5 companies currently training carpenters as well as the apprentices' school.

During this process we experienced the challenges of the dual training. The directors of the companies insisted on the necessity to reduce the part dedicated to drawing at school, arguing that plans were not hand drawn nowadays anymore. Insisting on the metamorphosis of the profession, they explained that most of the work of a modern carpenter was to perform other tasks than pure carpentry, such as roof covering or applying insulation to the roof. In their opinion, the most pressing matter to address was therefore the one of *physics building*.

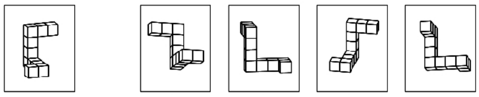
The teachers, on the other hand, had a completely different take on the subject: they insisted on the fact that drawing was the basis of the profession and that it should definitely not be abandoned. They acknowledged that drawing was not per se used in the professional environment anymore, but emphasized that it was key to learn the concepts of the profession, helped apprentices learn to read plans, and most importantly developed their spatial skills. The latter turned out to be the only point on which company directors and teachers would agree: being a carpenter requires excellent spatial skills.

However, the claims that spatial skills were (1) trainable and (2) that the drawing done by carpenter apprentices indeed trained their spatial skills were yet to be verified. The next two sections examine the veracity of those two claims.

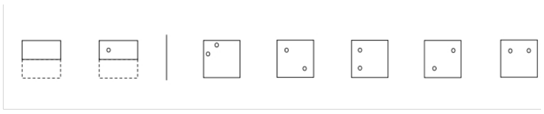
B. Background on spatial skills

As asserted by Sorby in [1], "spatial skills have been a significant area of research in educational technology since the 1920s or 30s". For the purpose of this article, three main findings made in the field of spatial skills research are of interest. First, in the course of time, and throughout many studies, researchers have discovered that activities requiring eye-to-hand coordination lead to a development of spatial skills. Typical such activities include playing with construction toys at a young age, attending classes of drafting or mechanics, or playing 3-dimensional computer games. This answers our two questions on spatial skills: not only are spatial skills trainable, but moreover we know what kind of activities can train them, and drawing is one of them.

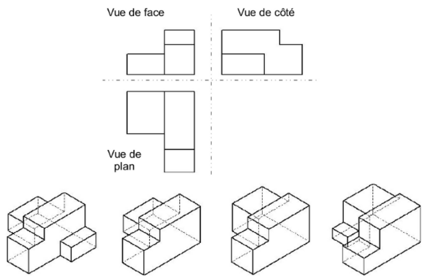
Second, spatial skills depend on the gender, men consistently outperforming women [2]. Third, highly developed spatial skills lead to a higher success in some school subjects such as organic chemistry. In the professional world, spatial visualization skills and mental rotation abilities are especially important for technical professions [3].



(a) Mental rotation



(b) Paper folding



(c) Orthographic projections

Fig. 1. Example questions for the three tests used to assess spatial skills. For the mental rotations test (a), two of the four figures on the right are a vertical rotation of the left image. For the paper folding (b), the piece of paper is folded and then punched as shown on the left. The subject has to find which one of the five figures on the right matches with the piece of paper once unfolded. For the orthographic projections (c), subjects must tell which one of the four 3D models matches the three orthographic projections. A variant of this question, also used in the test, is to show one 3D model and an angle from which it is observed. The subjects must then determine out of four possibilities which 2D drawing matches the 3D model when seen from the given view.

II. Spatial skills and carpenters

The importance of spatial skills reported by both the carpentry teachers and the directors of carpentry companies matches with the scientific finding that technical professions require some well-developed spatial skills [3]. According to [1], sketching contributes to the development of spatial skills, as was postulated by the teachers. However, to assess the truth of those claims in the special context of carpenters, we conducted a study with the goal of finding out (1) whether carpenters indeed have more developed spatial skills than other populations of the same age, and (2) whether their spatial skills improve throughout their training.

We created a test composed of the three different kinds of questions:

- mental rotation
- paper folding
- orthographic projection

Mental rotations (MR) and paper folding (PF) are two widely used tests to measure respectively mental rotation abilities and spatial visualization [4], [5]. The orthographic projection part (OP) was designed specifically for this test. There were a total of 50 questions, distributed as follows: 24 questions of MR, 20 questions of PF, and 6 questions of OP. Example questions of each of three tests are shown in Figure 1.

A. Test settings

A total of 512 subjects were tested. The subjects were either carpenter apprentices, logistician apprentices, or high school students. The target populations were chosen as to represent various parts of the population, i.e. apprentices of another profession (logisticians), but also more "academic" subjects (high school students). Tables I and II summarize the data by year and by gender with the type of curriculum. Note that all three curricula are done in three years, but that because of practical reasons, data for the third year is only available for carpenters. The tests were taken at the very end of the academic year, meaning that first year students already had an entire year of training behind them. The test took about 35 minutes and was taken in the classroom by all students of the class at the same time. A timed powerpoint presentation displayed the instructions for the test to ensure equality of treatments among the subjects.

	Year		
Curriculum	1	2	3
Carpenter	150	148	65
Highschool	38	48	0
Logistician	33	30	0

TABLE I
NUMBER OF SUBJECTS BY YEAR AND BY CURRICULUM.

	Gender	
Curriculum	Female	Male
Carpenter	1	362
Highschool	46	40
Logistician	7	56

TABLE II
NUMBER OF SUBJECTS BY GENDER AND BY CURRICULUM.

B. Test results

The overall score to the test was computed as the mean of the Z-scores of each part of the test. When comparing across the three populations, the data needs to be adjusted in two ways. First, to account for the different distribution of men and women[1] among the three types of population and since carpenters were almost exclusively men, females were excluded from the data. Second, only carpenters had data for the third year. To avoid a potential year effect, we also removed the third year carpenters from the data for the analysis reported here.

Figure 2 shows that there is no significant difference between the carpenters and the high school students. The only significant difference is between the logisticians and the rest of the subjects ($F(2,390) = 40.5, p < 0.001$). The fact that the carpenters are as good as the high school students may suggest that *carpenters have specially developed spatial skills*, since it is generally admitted that high school students perform

[1]In accord with the literature, we found a significant gender difference in our data. However, since this is neither a new result nor the main focus of this article, those results are not mentioned explicitely here.

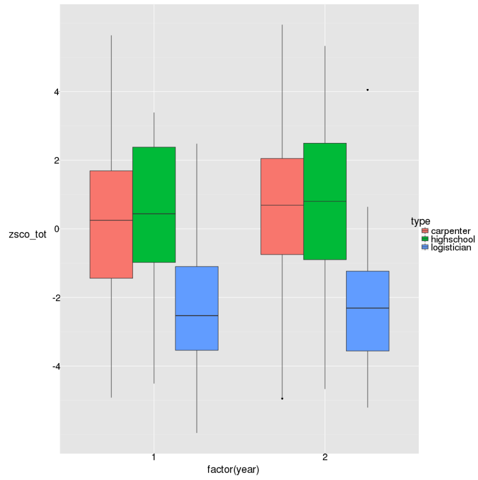


Fig. 2. Boxplot representation of the scores for each curriculum for the first and second year. Significant differences exist between logisiticians and the two others curricula, but not between carpenters and high school students.

better at intelligence tests. The significantly lower score of logisticians is a second point towards this interpretation.

Figure 3 shows that there is no year effect on the score of carpenters. This means that carpenters' spatial skills *do not improve significantly* between the end of their first year and the end of their third year. The stagnation of spatial skills along the apprenticeship can be interpreted as either a null effect or as a ceiling effect on the development of spatial skills of the drawing activity. Giving the test to apprentices before they get any training should allow to determine whether carpenters enter the apprenticeship with extraordinary spatial skills or whether they simply develop them during their first year of apprenticeship.

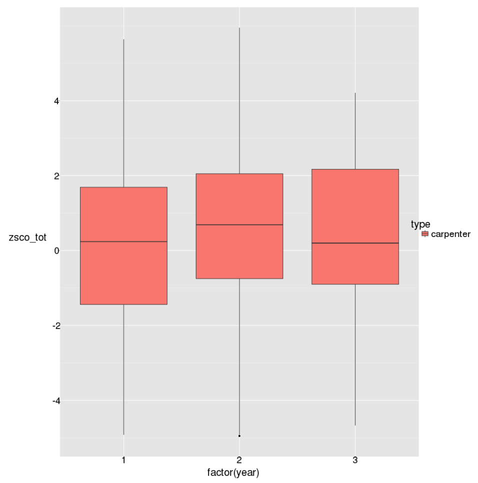


Fig. 3. Boxplot representation of the score of carpenters for the three years. None of the differences are significant.

III. Conclusions and Future Work

We have discovered that spatial skills are central to the activities of professional carpenters. The literature on spatial skills reports that they are trainable, and that sketching 3D objects and manipulating 3D blocks in a multimedia software are efficient ways to train spatial skills [1]. A field study has revealed that carpenters indeed have well developed spatial skills. However, despite lengthy drawing classes, their spatial skills do not improve beyond the first year of their apprenticeship. Since the existence of the drawing classes are justified mostly by their contribution to the development of the spatial skills, one can ask the following question: could a tangible environment supplant or complement the drawing classes to accomplish the development of the carpenters' spatial skills? In the future, we will develop such an environment to answer this question.

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References

[1] S. Sorby, "Educational research in developing 3-d spatial skills for engineering students," *International Journal of Science Education*, vol. 31, no. 3, pp. 459–480, 2009.

[2] M. C. Linn and A. C. Petersen, "Emergence and characterization of sex differences in spatial ability: A meta-analysis," *Child Development*, vol. 56, no. 6, pp. 1479–1498, 1985. [Online]. Available: http://www.jstor.org/stable/1130467

[3] P. H. Maier, *Rumliches Vorstellungsvermgen*. Peter Lang Frankfurt, 1994.

[4] M. Peters, B. Laeng, K. Latham, M. Jackson, R. Zaiyouna, and C. Richardson, "A redrawn vandenberg and kuse mental rotations test: different versions and factors that affect performance." *Brain and cognition*, vol. 28, no. 1, pp. 39–58, June 1995. [Online]. Available: http://dx.doi.org/10.1006/brcg.1995.1032

[5] [Online]. Available: http://create.alt.ed.nyu.edu/assessment/vz2/start.html