Plane and space in pattern design

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In garment design, flat pattern design is central to form giving. In designing, the three-dimensional form is developed in two dimensions. Interaction between the two-dimensional presentation and three-dimensional reality is characteristic of the process. Despite its essential role in the teaching and learning of pattern design, the process has received only a limited interest in didactic studies. Internationally, most of the studies are American, and they have concentrated on the effects of spatial ability. The present article enquires how students in the textile teacher program of a Finnish university experienced the flat pattern design process and its difficulties, and what kind of processes were actually used. The results of the conducted survey indicate that studies in clothing design and construction had only a minor effect on how the students evaluated the difficulty of various pattern design tasks on the advanced level as compared with the introductory level. The possibility that this is due to crafts in the curriculum of the Finnish comprehensive school is discussed. As to the processes of pattern design, the survey found that on the advanced level, when the students were free to choose among various alternatives, more than half of the processes were different from each other. Half of the processes included a mix of 2D and 3D methods, and two thirds of the total were iterative in nature. Improvement of design and ease allowances were the main reasons for iteration. After the basics, a flexible approach to the pattern design process appears to be advantageous for students' development in the subject.

Key words: garment design, pattern design, spatial ability, iteration

Introduction

Pattern design process

A flat pattern is designed in reciprocal relation to the design of a garment. The iterative connections among the design sketch, pattern, and trial garment (Figure 1) are used until the outcome is satisfactory. (Salo-Mattila, 2009, pp. 15–16)

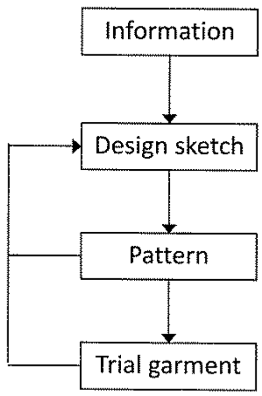

Figure 1: Pattern design process (Salo-Mattila, 2009, p. 15)

Iteration in general means executing activities again. In design research, several types of iteration have been differentiated: for example, iteration to correct errors, to improve the design, to repeat the same design activity or, in an organization, to execute different design processes in parallel. (Verstegen, Barnard & Pilot, 2006, pp. 482–483) Product development processes are commonly considered inherently iterative. Studies have shown that early iterations are generally beneficial and late iterations detrimental to the efficiency of the process. (Martínez León, Farris & Letens, 2013, p. 552) On the other hand, there appears to be no relationship between the number of iterations and the quality of results (Verstegen, Barnard & Pilot, 2006, pp. 505–506). A study of weaving design showed that the process was iterative in nature and that experts tried out fewer design ideas and proceeded to the basic shape of the textile much more directly than advanced students did (Seitamaa-Hakkarainen, 2000, pp. 171–173).

The pattern design process may include both two and three-dimensional phases, both of which can be performed in different scales, like full, half, or quarter size. The trial garment is used to estimate the realization of the sketched idea as to the style and fit produced. Appraisal of fit emphasizes the realization of lines, forms, and ease allowances in accordance with the design, the functionality of ease allowances, and the fulfilment of the user's personal preferences of style and ease. (For the discussion of fit, see DeLong, Ashdown, Butterfield, & Turnbladh, 1993; Ashdown & O'Connel, 2006)

Design sketch and spatial ability

A designer uses spatial ability in sketching a style. The garment's three-dimensional construction is taken into account by articulating the drawing in proportion to the spatial divisions of the human body and by adding spatial details like darts and seam lines. The sketch may be supplemented with construction notes like information on proportions and forms. Overall, spatial ability is considered essential in garment design. (Workman, Caldwell & Kallal, 1999, p. 129)

Spatial ability in pattern design

The factor structure of spatial ability has been studied since the 1940's (Yilmaz, 2009, p. 84). According to Workman, Caldwell and Kallal (1999, p.130), the pattern design process requires abilities in spatial relations, orientation, and visualization. (Figure 2)

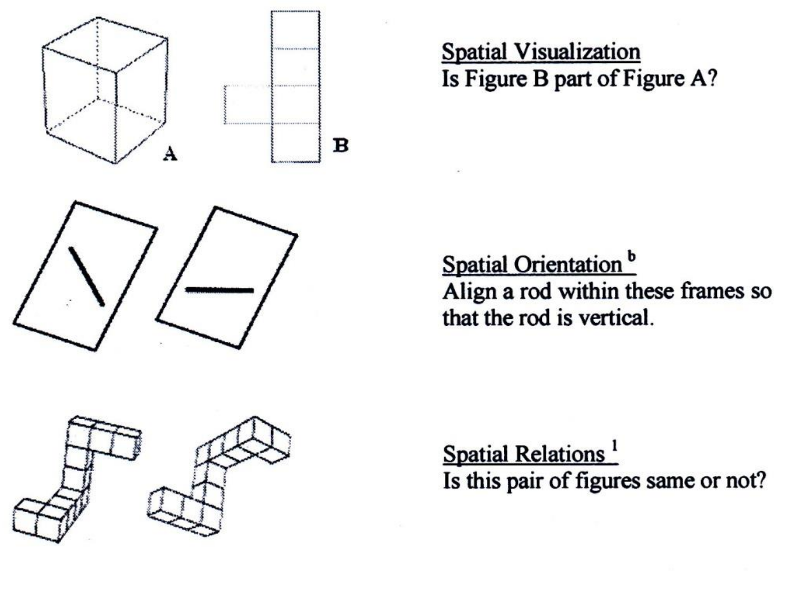

Figure 2: Factors of spatial ability illustrated by tests (Yilmaz, 2009, p. 87)

Spatial relations ability means the ability to imagine the result of a mental rotation. For example, a designer has to perceive how the rotation of a dart would affect the shape of the pattern. *Spatial orientation* ability is the ability to grasp distances, directions, and depth relations. For example, when a designer views a trial garment on herself or on another person in the mirror at different angles, she has to be able to adjust herself to the changes in the orientation of her own body. *Spatial visualization* ability is the ability to manipulate mentally the elements of a spatial configuration. A designer needs this ability, for example, to perceive how a sketched design would look from behind or from the side by looking at the front view. She should also be able to imagine how addition, subtraction or movement of various elements like yoke, seam lines, pleats, gathers, or pockets would affect the outcome. (Workman, Caldwell & Kallal, 1999, p. 130; for different factor structures of spatial ability in literature, see e.g. Yilmaz, 2009)

Measurement of spatial ability

Spatial ability can be measured with different paper-and-pencil tests. For example, Differential Aptitude Test – Spatial Relations (DATSR) measures the ability to visualize a three-dimensional object from a two-dimensional pattern. The test comprises 35 patterns that can be folded into one of four figures shown next to each pattern. Different tests give different results. For example, the DATSR shows only a low correlation with the following tests: Cube Comparison (spatial orientation, .39), Card Rotation (spatial orientation, .44), Paper Form Board (spatial visualization, .12). (Workman, Caldwell & Kallal, 1999, pp. 130–132)

Workman, Caldwell and Kallal (1999) developed a special test to measure spatial ability in garment design. (Figure 3) They showed that their Apparel Spatial Visualization Test (ASVT) revealed the effect of training in clothing construction and pattern making better than DATSR. (pp. 130–132)

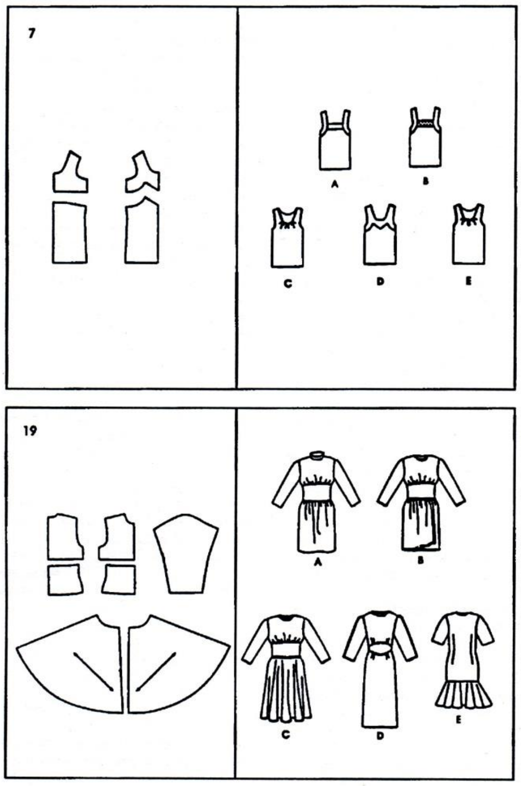

Figure 3: Example of items in Apparel Spatial Visualization Test, ASVT, (Workman, Caldwell & Kallal, 1999, p. 131)

The ASVT comprises 20 two-dimensional pattern groups that can be used to construct a garment. In the test, one has to choose the right garment from five alternatives. (Workman, Caldwell & Kallal, 1999, p. 130)

Effects of training in clothing construction and pattern making on spatial ability

The Apparel Spatial Visualization Test (ASVT) has contributed to several studies on the effects that various factors have on the test results. Workman and Lee (2004) examined the effects of culture and training on the results of ASVT and Paper Folding Test, which measured the ability to visualize transformations from three-dimensional to two-dimensional. Both tests showed that training significantly improved spatial ability regardless of cultural background. (pp. 23, 26, 28)

Gitimu, Workman and Anderson (2005) studied how training and styles of spatial information processing affected the test results of apparel design students. The tests were ASVT and Strategical Information Processing Test, which identified a student's preferred processing style by using 15 imagined situations, each with five possible processing strategies. The style categories were visuo-spatial, analytical, social, and categorical. The tests showed that training significantly improved spatial ability regardless of spatial information processing style. (pp. 154–157, 163–165),

Workman and Caldwell (2007) studied how different courses in apparel design affected the students' spatial ability. The courses were Beginning Clothing Construction, Computer Aided Design and Flat Pattern. The applied tests were ASVT and Paper Folding Test. The test scores were highest before and after a course for the Flat Pattern. The Beginning Clothing Construction was clearly the most effective in improving the results of the ASVT, which used 2D/3D-assembly tasks. Similarly, the Computer Aided Design, also an introductory course, showed the largest change in the results of the Paper Folding Test, which used 3D/2D transformations. (pp. 50–54)

Khoza and Workman (2009) examined how cultural background and training affected information gathering styles and spatial ability in apparel design. The tests were ASVT and Perceptual Modality Preference Survey, which used statements to find out perceptual preferences. The tests showed that cultural background affected those preferences but not the improvement of spatial ability. (pp. 69–76)

Development of spatial ability

The problem of how to improve spatial ability of students has been specifically addressed in the field of engineering. Sorby (2007) reported on the development of spatial skills at Michigan Technological University. The project started with a pilot study in 1989. The study showed that the rotation test that was part of a Purdue test set for spatial visualization (Figure 4) best anticipated a student's progress in the course of technical drawing. Weak spatial skills and difficulties in that course were seen as increasing the drop-out risk, especially for female students. In 1993, a special course was introduced for the development spatial skills. All first-year students took the rotation test and those who failed the test (scored lower than 60%) were advised to take the course, which included lectures and computer aided exercises. After the course, they were tested again. From 1993 to 1998, the drop-out rate was significantly reduced in comparison with the control group, especially in the case of female students. (pp. 4–7) Dong and El-Sayed (2011) reported similar results from Kettering University.

Cantero, Company, Saorin and Naya (2006) developed software for engineering students to improve their spatial skills by producing three-dimensional forms. Testing showed that the exercises that proceeded from freehand drawing to 3D modeling significantly improved spatial skills. The improvement was most pronounced for female students.

Although the literature seems to indicate that improved spatial skills lead to improved results in engineering and science studies, the measurement of such improvement in specific cases may produce unexpected results. Tseng and Young (2011) studied the relationship between spatial skills and coursework in engineering design at Massachusetts Institute of Technology. In the particular course, the purpose was to design and build remote-controlled robots that were tested in a competition at the end of the course. The hypothesis was that students with higher spatial abilities would produce designs that are more complex. However, the outcome was that spatial skills were negatively correlated with design complexity, possibly because simplicity rather than complexity appeared to be desirable for competition performance.

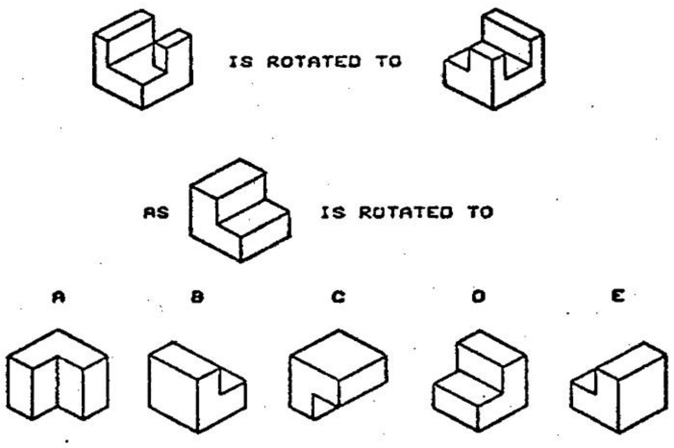

Figure 4: Sample problem from the Purdue rotation test (Sorby, 2007, p. 4)

Research questions

The literature review indicates that training in clothing design and construction improves spatial ability regardless of cultural background or style of spatial information processing. It is also evident that the results of different tests do not correlate well (cf. Workman, Caldwell & Kallal, 1999, p. 132; Workman & Lee, 2004, p. 28; Workman & Caldwell 2007, pp. 52–53). It can also be concluded that it is possible to use specifically designed spatial exercises to improve the ability and, at least in engineering drawing, performance of students. On the other hand, difficulties in pattern design have not been discussed.

In the present study, the aim was to find out how students coped with the pattern design process that required different 2D/3D and 3D/2D transformations. *The first question* was how students experienced the difficulties in flat pattern design on the introductory and advanced levels. *The second question* was how they proceeded in their advanced-level pattern design process when, instead of a given process, they were free to combine different two and three-dimensional subprocesses.

Survey design

Evaluation of tasks in the flat pattern design process

In the fall of 2012, advanced-level students (n=19) in the textile teacher program (five years, M. Ed.) at a Finnish university were asked to estimate the relative difficulty of different tasks in the pattern design process, as experienced in the basic and advanced courses. The students were taking an advanced comprehensive course in clothing design and construction, and they had completed the basic and intermediate courses in the subject during the first and second years of study, correspondingly. In the basic course, they proceeded from body measurements to a quarter-size basic pattern and on to a full-size basic pattern that was tested with a muslin trial garment and styled with a flat pattern method in quarter size to conform to the design sketch. Next, a full-size style pattern was drafted and tested with a muslin trial garment. In the intermediate course, the quarter-size patterns were not used. In the advanced course, the students could freely combine different flat pattern and draping steps.

The basic course work included design and construction of a blouse and a skirt, while on the advanced level, an overcoat and a dress or pants or skirt as an ensemble were designed and constructed. The intermediate course work, which was not enquired about in the present study, had included a sweatshirt and pants. A questionnaire was presented to the students at the end of the advanced course. All 19 students returned a completed form, but there were five who did not respond to the basic course part of the questionnaire as the course had been credited to them due to previous vocational studies in the subject.

The questionnaire included the following tasks of flat pattern design: (1) take the measurements and draw the basic pattern; (2) analyze the elements of the design sketch in relation to the basic pattern and design the overall ease of the garment; (3) mark darts, seam lines, position of gatherings and pleats, and the neckline, and design the necessary ease allowance for gatherings, pleats, and flare; (4) if part of dart is transferred to a seam line, gathering or pleat, extend the corresponding marking to the point of the dart in the basic pattern; (5) cut the basic pattern as required; (6) attach the cut pattern onto a backing and, at the same time, close the darts or part of them as indicated by the design sketch, and leave space for the designed ease allowances and elements of form; (7) true the contour lines to make them fluent, mark the symbols for gatherings, pleats and grain lines, mark the facings, and add the necessary alignment notches. For each pattern design task, a five-level Likert-like scale from 1, "easy," to 5, "difficult," was presented, separately for the basic course and the advanced course. For comparison, the average, standard deviation, mean, and frequencies of ratings were calculated for each task.

Survey of pattern design processes

At the end of the advanced course, the 19 students were also asked about the pattern design process they had used for coat bodice, coat collar or hood, and dress. The questionnaire was handed out at the same time as the one for the evaluation of tasks in flat pattern design. The time period available for designing the style and a tested pattern was seven weeks. The first four weeks were used to study pattern design for coat, coat collar or hood, coat sleeve, and dress. At the same time, a design sketch was produced in a parallel course, and it was to reflect the life style and identity of the student.

The students reported their progress from the design sketch to the end of their process step by step. The questionnaire showed eight subprocesses or design steps that were available in the course: (0) starting with a design sketch or modifying it; (1) designing a flat pattern 1:4; (2) designing a flat pattern 1:2 and testing it on a model with muslin; (3) designing a flat pattern 1:1 and testing it on a model with muslin; (4) draping muslin on a model 1:2; (5) draping muslin on a model 1:1; (6) designing a flat pattern 1:1; and (7) constructing a trial garment of muslin and fitting it. The subprocesses (3) and (5) were added to the original questionnaire by the students. For each student, two other students performed the fitting, and the teacher commented on it. For fitting evaluation, there were also the design sketch and the full-size flat pattern attached to a partition. Photos were taken from the fitting, where several mirror partitions were used, to assist in the final adjustments. The questionnaire also enquired if iteration in the design process was caused by unsatisfactory ease allowances or by an unsatisfactory match with the design idea or by another reason.

As to spatial ability, design sketch and its modification involved mental 2D/3D transformations as did flat pattern design at various scales. In the same way, flat pattern design steps that included testing on model represented 2D/3D/2D transformations. Draping steps included a 3D/2D transformation to draft a flat pattern used to make a trial garment, while trial garment fitting involved 3D/2D transformations to make corrections to the flat pattern.

All 19 students responded to the questionnaire. All 19 had made a coat bodice pattern, 17 of them had also completed a coat collar or hood pattern by the time of questioning, and nine had made a dress pattern. One student was in the middle of designing a dress pattern and did not include the dress in her response. Five students had made either a skirt or pants pattern, which were not included in the questionnaire, as such patterns, although not as demanding as those in the advanced course, had been studied in the basic and intermediate courses, respectively. The remaining four students had designed patterns for a coat, only, as they had opted for less credit points in the course. The recorded processes were analyzed by using matrices that showed the order of steps taken and the subprocess used in each step for every student, separately for coat bodice, coat collar or hood, and dress.

Results

Evaluation of tasks in the flat pattern design process

The results from the evaluation of tasks (Table 1) show that the differences between the basic and advanced course were minor as to difficulties experienced in the various tasks of the pattern design process. The tasks (2–4) that are generally viewed as demanding with regard to spatial ability (cf. Workman, Caldwell & Kallal, 1999) were considered slightly more difficult than other tasks in both basic and advanced studies. Spatially, all of them were 2D/3D transformations.

Table 1: Relative difficulty of flat pattern design tasks

Scale 1 to 5 (1= easy, 5= difficult)

	(1) Taking measure-ments and drafting basic pattern	(2) Design-ing overall ease	(3) Adding form ele-ments and ease allow-ances to basic pattern	(4) Control-ling dart divisions and transfers	(5) Cutting basic pattern	(6) Pasting cut pattern onto back-ing with designed adjust-ments	(7) Truing lines, marking symbols, facings, and align-ment notches
Basic course n=14							
Median	3	2.5	3	3	2	3	3
Average	3.0	2.6	3.4	2.8	2.4	2.6	2.3
STD	1.0	0.9	1.0	0.5	1.0	0.8	0.9
Advanced course, basic course taken n=14							
Median	2	3	3	3	2	2	2
Average	2.1	3.0	3.2	2.7	2.0	2.4	2.3
STD	1.1	0.9	1.0	0.9	0.9	1.0	0.9
Advanced course, all n=19							
Median	2	3	3	3	2	2	2
Average	1.9	2.8	3.1	2.7	2.0	2.3	2.3
STD	1.0	1.0	1.0	1.0	0.9	1.0	1.0

Overall, the most difficult task was no. 3, which involved designing various form elements and related allowances and adding them to the basic pattern. In the terms of spatial ability, it required a complicated 2D/3D transformation. Even in this case, the differences between the basic and advanced course were not meaningful (95% Confidence Interval for Average= ±0.5 when STD=1, n=14). The comparison of rating frequencies for the three most difficult tasks requiring 2D/3D transformations (Table 2) shows that the students considered flat pattern design tasks only slightly easier due to previous studies in clothing design and construction.

Table 2: Comparison of the most difficult flat pattern design tasks requiring 2D/3D transformations – frequencies of ratings

Task evaluation	Basic course, n=14	Advanced course, basic course taken, n=14	Advanced course, all, n=19
Designing overall ease			
1 Easy	2	1	2
2 Fairly easy	5	3	6
3 Average	4	5	5
4 Fairly difficult	3	5	6
5 Difficult	0	0	0
Adding form elements and ease allowances to basic pattern			
1 Easy	0	0	1
2 Fairly easy	3	5	5
3 Average	5	3	6
4 Fairly difficult	3	4	5
5 Difficult	3	2	2
Controlling dart divisions and transfers			
1 Easy	0	2	3
2 Fairly easy	3	2	3
3 Average	9	7	9
4 Fairly difficult	1	2	2
5 Difficult	0	0	1

Note: One student did not answer to the question of controlling dart divisions and transfers.

Survey of pattern design processes

The results of the process survey show that as a whole, most of the processes were iterative in nature. For coat bodice, only five of 19 students had applied a process that was linear in nature. For coat collar or hood, nine of 17 students had used a linear process, while the corresponding ratio for dress was only one of nine. (Table 3) Figures 5, 6, and 7 show the recorded processes separately for coat bodice, coat collar or hood, and dress.

Table 3: Breakdown of processes

Exercise	All applied processes			Iterative processes		
	total count	different	individual	total count	different	individual
Coat bodice pattern	19	79%	58%	14	79%	57%
Coat collar or hood pattern	17	88%	82%	8	100%	100%
Dress pattern	9	78%	67%	8	75%	63%
Combined	45	56%	36%	30	63%	43%

Note: The percentages for processes that are different or individual are lower for the 45 observed processes than for any of the separate exercises. A process that, for example, differs from other processes in one exercise may have a duplicate in another exercise.

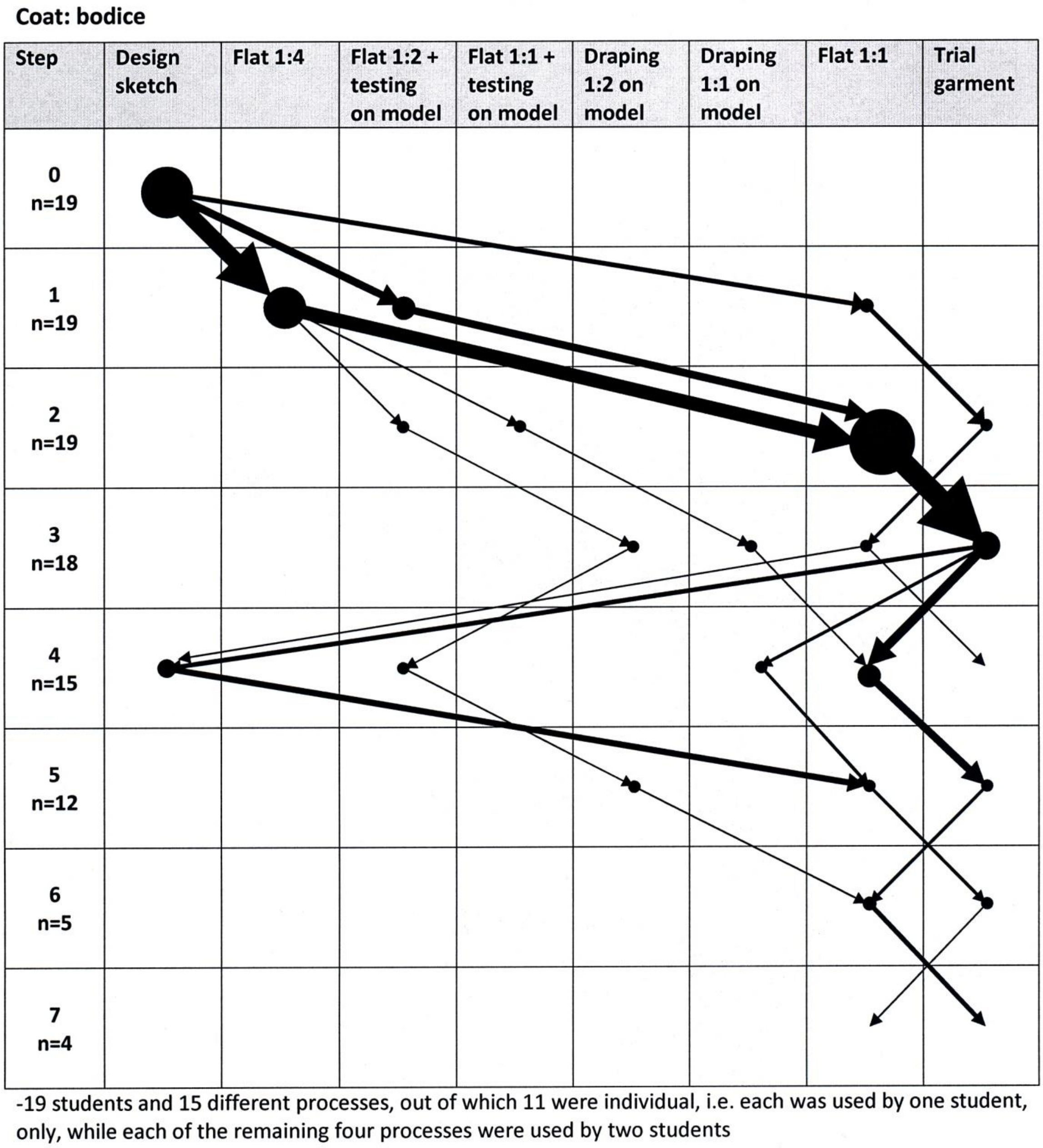

Figure 5: Processes used by students to design a coat bodice pattern

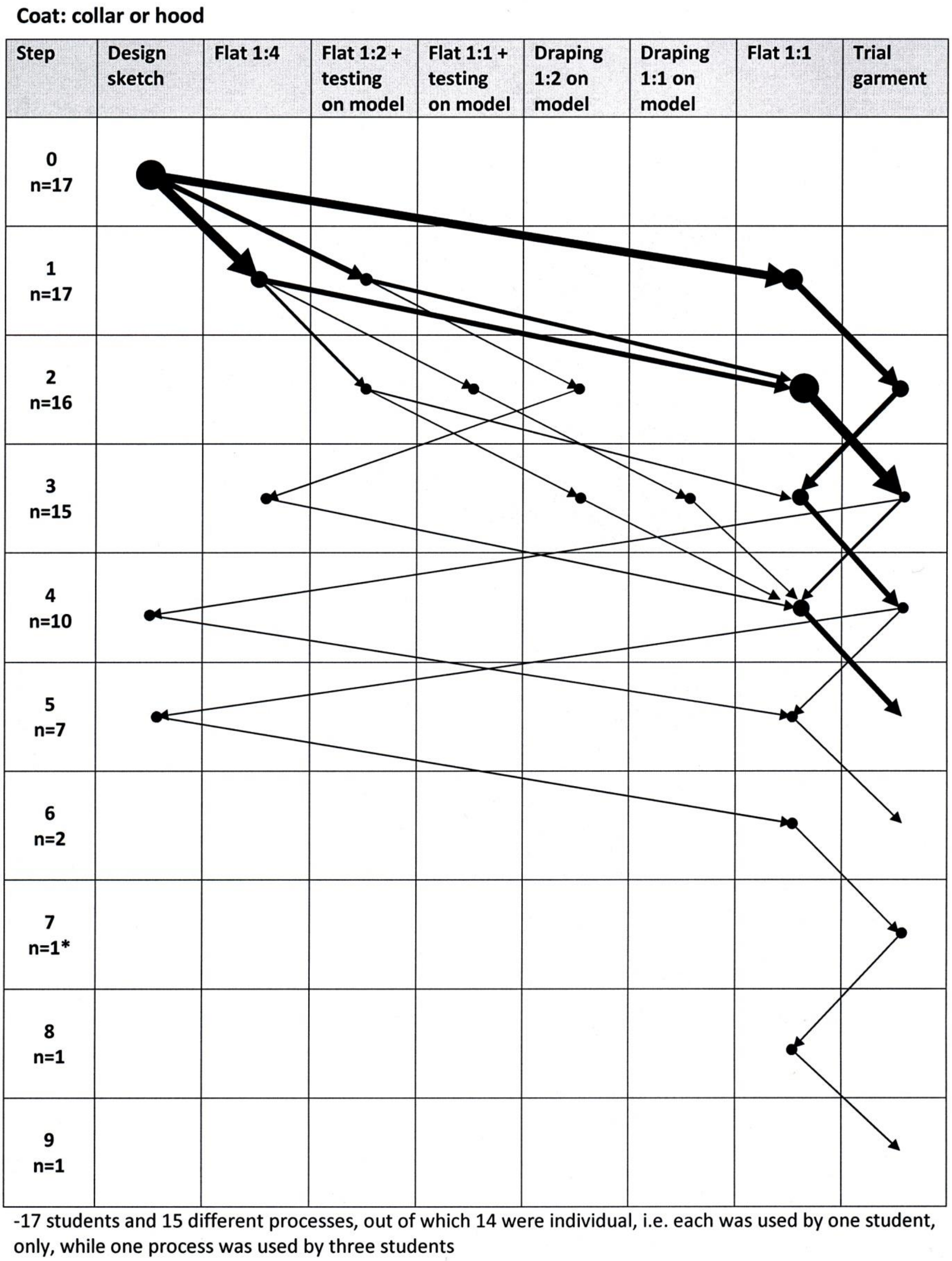

Figure 6: Processes used by students to design a coat collar or hood pattern

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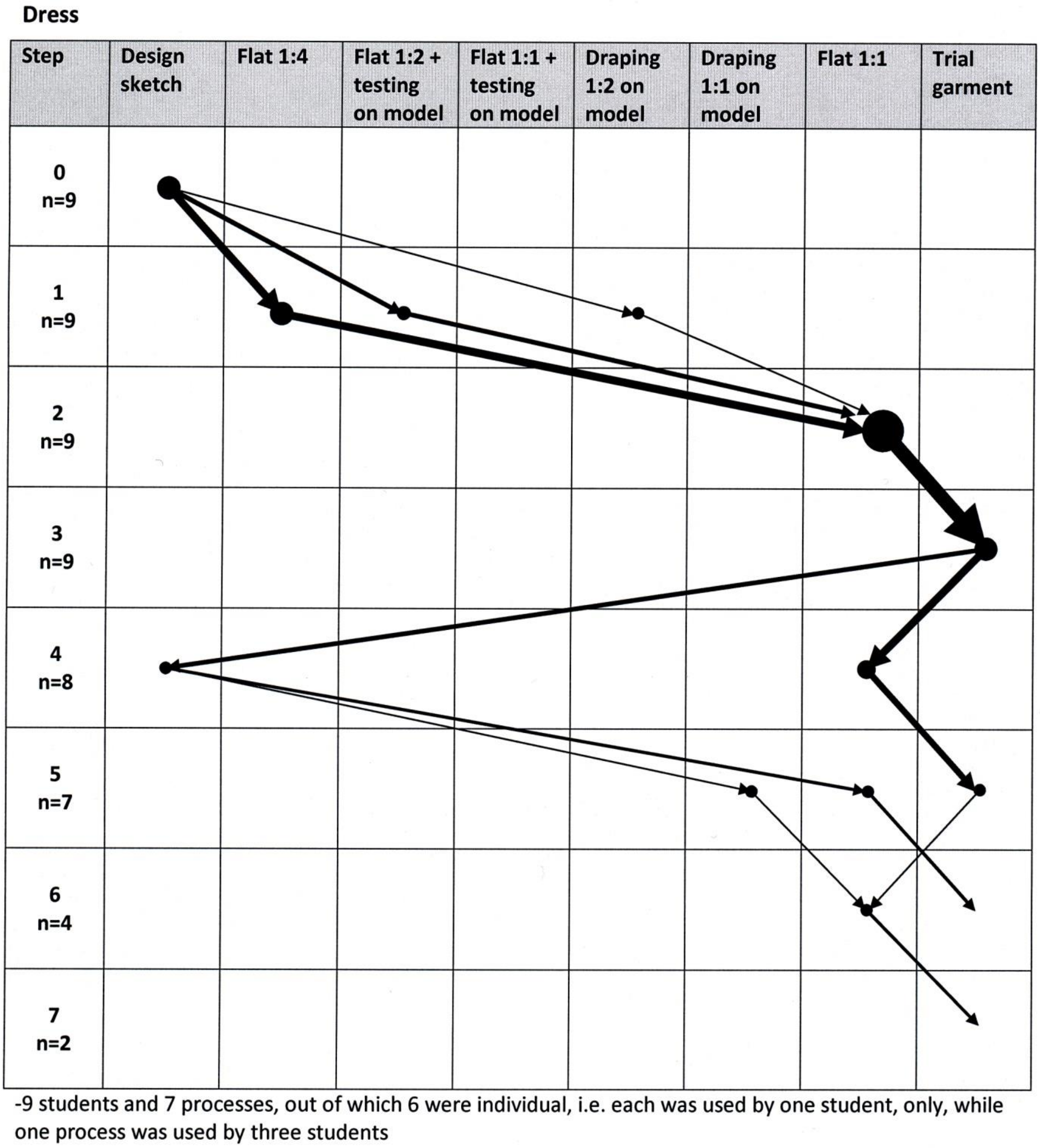

Figure 7: Processes used by students to design a dress pattern

The relatively high number of linear processes in the case of coat collar or hood pattern probably reflected an easier exercise in comparison with the other two. It should be noted that although processes for coat bodice and coat collar or hood were analyzed separately, they came together at several points, in several cases from the very beginning and at the latest in the trial garment phase.

Overall, only three of 19 students had applied a linear process in all three exercises. Previous experience gained through vocational studies did not appear to influence the complexity of the process used. As to the reasons of iterations, unsatisfactory match with the design idea caused 60%, unsatisfactory ease allowances 35%, and other reasons like error correction 5% of 40 reported iterations. (Table 4)

Table 4: Iterations and breakdown of their reasons by exercise

Exercise	Iterations	Reasons for iterations		
		ease allowances unsatisfactory	match with design idea unsatisfactory	other reasons
Coat bodice pattern	19	37%	58%	5%
Coat collar or hood pattern	11	27%	73%	0%
Dress pattern	10	40%	50%	10%
Combined	40	35%	60%	5%

For coat bodice, nine students of 19 proceeded to trial garment in the same way as in the basic course, using the flat pattern method in quarter and full size, but only two of them were satisfied with the result. (Figure 5) In the example (Figure 8–10), the trial garment revealed a problem with the location and form of pleats in the hem area. The student went to full-size draping and made the necessary adjustments to the full-size flat pattern.

Three students used the flat pattern method directly in full size as in the intermediate course, but only one was satisfied with trial garment. (Figure 5) In the example (Figure 11–13), the trial garment revealed problems with raglan sleeve ease and with the number and form of the gatherings in the lower bodice. The student first backtracked to full-size flat pattern, on to design sketch, and returned to full-size flat pattern.

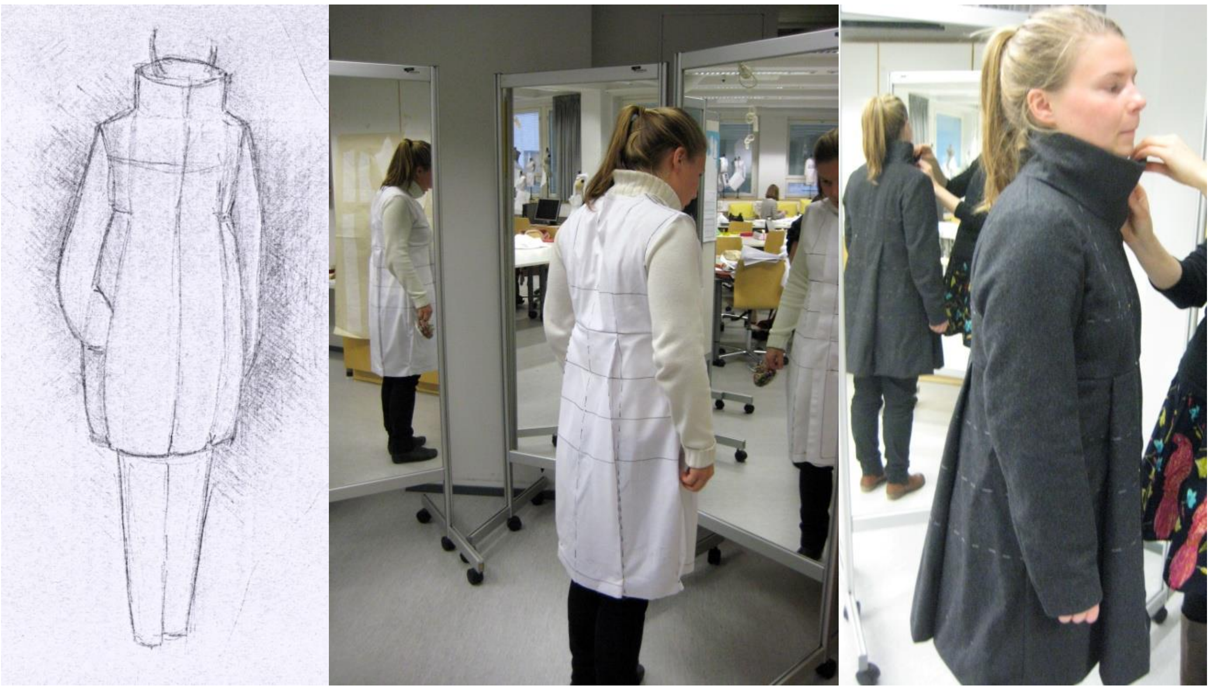

Figure 8–10: On the left, design sketch; in the middle, trial garment in muslin; on the right, fitting of the garment in wool. In the middle, the left-hand mirror shows the full-size flat pattern in the background. The overall process steps were design sketch, flat 1:4, flat 1:1, trial garment, draping 1:1, and flat 1:1.

Figure 11–13: On the left, the design sketch for the back; in the middle, the trial garment of muslin; on the right, fitting of the garment with detachable felt lining. The overall process steps were design sketch, flat 1:1, trial garment, flat 1:1, design sketch, flat 1:1.

Figure 14–15: On the left, testing of half-size flat pattern on model with muslin. On the right, the finished garment with detachable felt lining. The overall process steps for coat bodice were design sketch, flat 1:2 + testing on model, flat 1:1, and trial garment. The steps for hood were the same.

Figure 16–20: On the upper left, the design sketch for the front; on the upper right, fitting of the trial garment, parts of the unfinished flat pattern attached to a partition. Below, the finished garment in wool. The frontal view in the middle shows a zipper in the upper seam of the collar. The hood of thin leather is inside the collar. The overall process steps for the coat bodice were design sketch, flat 1:4, flat 1:1, trial garment, draping 1:1, flat 1:1, trial garment. The steps for the collar and hood were design sketch, flat 1:2 + test, draping 1:2, flat 1:4, flat 1:1, trial garment.

The remaining seven students used a route that involved 3D testing of flat pattern. Five of them started with half-size flat pattern plus 3D testing with muslin, and one used the same method after quarter-size flat pattern, while another one proceeded from quarter-size to full-size flat pattern and 3D testing with muslin. Six of the seven students who used 3D testing proceeded to trial garment without iterations, but only two were satisfied with the result. Overall, only five students of 19 were satisfied with the result of a linear process. (Figure 5)

In the example (Figure 14–15), the design had demanding curved seam lines and raglan sleeve. Testing of the half-size flat pattern revealed that the ease allowance in the upper arm area was too small. The student took the test result into account in full-size flat pattern and went on to trial garment. She was satisfied with the result. The process was very effective considering the demanding design.

A complex process for coat bodice, collar, and hood is demonstrated by another example (Figure 16–20). For bodice, trial garment that was based on flat pattern drafting revealed a need to further develop the assymmetrical design with kimono sleeves. The student used full-size draping for the purpose. For the parallel collar and hood design, she developed the form by using flat pattern drafting, 3D testing and draping, all in half size, and proceeded to trial garment by using flat pattern steps.

For coat collar or hood, only four students of 17 proceeded to trial garment in the same way as in the basic course, using the flat pattern method in quarter and full size, and three of them were satisfied with the result. Five students used the flat pattern method directly in full size as in the intermediate course, but only one was satisfied with the trial garment. Of the remaining eight students, one reported only part of the process and seven used 3D testing of flat pattern in some form. Four of them started with half-size flat pattern plus 3D testing with muslin, and two used the same method after quarter-size flat pattern, while one proceeded from quarter-size to full-size flat pattern and 3D testing with muslin. Six of the seven students who used 3D testing proceeded to trial garment without iterations; four of them were satisfied with the result. Overall, eight students of 17 were satisfied with the result of a linear process. (Figure 6)

For dress, five students of nine proceeded to trial garment in the same way as in the basic course, using the flat pattern method in quarter and full size, but they were not satisfied with the result. (Figure 7) In the example (Figure 21–25), the first trial garment showed problems with sleeve construction. The student redesigned the sleeve and yoke combination and raised the starting point for foldings. She used draping in full size with wool crepe to finalize the sleeve pattern with foldings on shoulder tip and elbow.

No student used the flat pattern method directly in full size as in the intermediate course. Three started with half-size flat pattern plus 3D testing with muslin, and one with draping in half size. Only one was satisfied with the result of a linear process. In the first example (Figure 26–28), the direction of folds was changed to start from the right shoulder, and fitting with the final material showed the need to raise the waistline. In the second example (Figure 29–31), the design was changed based on the results of draping: the folds in the skirt were changed to gatherings, and the sleeves were left out.

For designing a coat bodice pattern, the median number of steps taken was five. The corresponding number for a coat collar or hood pattern was four, and for a dress pattern, six. There were a remarkably high number of different processes applied. For a coat pattern, 19 students used 15 different processes; for a coat collar or hood pattern, 17 students also used 15 different processes, while for a dress pattern, nine students used seven different processes.

Overall, there were 25 different processes used in the three exercises, and 16 of them were individual, i.e. used by one student, only. There were 19 different iterative processes, and 13 of them were individual.(Table 5)

Figure 21–25: On the upper left, design sketch; on the upper right, trial garment; on the lower left, design revision; in the lower middle, a new sleeve and yoke being fitted, using wool crepe; on the lower right, the finished garment in wool crepe. The overall process steps were design sketch, flat 1:4, flat 1:1, trial garment, design sketch, draping 1:1 for sleeve, and flat 1:1.

Figure 26–28: On the left, design sketch; in the middle, half-size flat pattern tested on model with muslin; on the right, fitting with wool crepe. The overall process steps were design sketch, flat 1:2 plus testing on model, flat 1:1, trial garment, and flat 1:1.

Figure 29–31: On the left, design sketch; in the middle, draping in half-size with muslin; on the right, the finished garment in linen-viscose blend. The overall process steps were design sketch, draping 1:2, flat 1:1, trial garment, design sketch, flat 1:1, and trial garment.

Discussion and conclusions

Evaluation of tasks in the flat pattern design process

The first question of the present study was how students experienced the difficulties in flat pattern design on the introductory and advanced levels. The students who were on the advanced level of the five-year master's program did not consider tasks that require spatial ability in flat pattern design especially difficult in the basic or advanced course on the subject. The most difficult task was to design form elements and related allowances and add them to basic pattern. Even for that task, there was no meaningful difference between the two courses.

In comparison with the quoted American studies (Workman, Caldwell & Kallal, 1999; Workman & Lee, 2004; Gitimu, Workman & Anderson, 2005; Workman & Caldwell, 2007; Khoza & Workman, 2009), which showed substantial improvement in spatial ability due to studies in clothing design and construction, the results might suggest a higher starting level of spatial ability. This could reflect differences in the educational systems, for example.

In the Finnish comprehensive school, all students learn crafts in grades 1 thru 9. In addition, a few have crafts as an elective in high school, in grades 10 thru 12. In grades 5 thru 7, the program offers a choice of emphasis between technical and textile work, while in grades 8 and 9, it concentrates on one or the other. Most girls choose textile work, which includes the design and construction of several pieces of clothing in grades 5 thru 9. (For the curriculum and subject contents, see Finnish National Board of Education, 2009) In the United States, clothing design and construction as a teaching subject has been largely absent from state school curriculums since the 1980's.

On the other hand, it is unclear how various subjects in the school curriculum affect the development of spatial ability, and how much difference any specific studies make. A three-year study in Canada examined the effects of piano lessons. An experimental and control group were followed up in grades four, five, and six. Piano lessons improved children's cognitive development, especially as to spatial ability. Quantitative and verbal abilities did not change. The experimental group scored significantly higher in spatial ability in the first two years, but in the third year, although the scores continued to improve, there was no difference in comparison with the control group where improvement was larger. (Costa-Giomi, 1999)

Thus, although the answer to the first study question is clear, the implications of the results are ambiguous. A longitudinal study from the introductory level to the advanced level, combined with the measurement of spatial ability, would possibly offer a more reliable basis for interpretation than the mere estimates that were partly based on recollection.

Survey of pattern design processes

The second question was how the students proceeded in their pattern design process when, instead of a given process, they were free to combine different two and three-dimensional subprocesses. The advanced-level students, who had used linear flat pattern processes in the basic and intermediate courses, applied a large number of different iterative processes to design patterns for coat bodice, coat collar or hood, and dress. Table 5 shows a breakdown of the summarized results.

In the basic and intermediate courses, the students had concentrated on flat pattern design. Given free choice of processes in the advanced course, half of them opted for a mix of 2D and 3D methods, while the other half, 53% to be exact, used 2D, i.e. flat pattern design, only. The same division applied irrespective of the chosen process being linear or iterative in nature. More than a half of the observed processes were different from each other, and almost two thirds of the different processes were individual, used by one person, only.

Table 5: Summary of results for the survey of pattern design processes

Process	Total count	Different	Individual	With flat-pattern design, only
Linear	15	6	3	8
Iterative	30	19	13	16
Combined	45	25	16	24

Previous experience gained through vocational studies and presumably combined with better spatial skills did not appear to influence the complexity of the process used. In comparison, the quoted study of Seitamaa-Hakkarainen (2000) showed that in weaving design, experts used less complex processes than advanced students did. However, those experts had extensive professional experience in comparison with the students (Seitamaa-Hakkarainen, 2000, pp. 67–68). In the present study, a comparable difference did not exist.

Free choice of design steps appears important on the advanced level because the design ideas are more ambitious and demanding than on the introductory and intermediate levels. As discussed, performing flat pattern design, although basically 2D, involves complicated 2D/3D transformations. Mixing flat pattern design with concrete 3D steps of testing or draping on a model probably helped the students in their spatial thinking. Two thirds of the used processes were iterative. The main reason for iterations, in 60% of the cases, was to improve the match with the design idea, the rest were mostly, in 35% of the cases, made to improve ease allowances.

The present study is the first of its kind in the field of garment pattern design. Measuring spatial ability at the beginning of the advanced course and developing a rating scale for the complexity of the design could improve the basis of analysis and raise new questions.

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