



Jane Malcolm-Davies

Materials and Making

A Pilot Study of Knitting, Napping and Capping in Early Modern Europe

Introduction

The development of knitting was a key technological innovation of the Medieval and Early Modern eras for which there is little published scientific evidence. There are more than 100 knitted caps dated to the 16th century in museum collections worldwide - an astonishing number given the paucity of extant garments from the period. A scoping study of the caps suggested that they have remarkable similarities in their materials and manufacture which illustrate trade in knitted garments as consumer goods in the emerging Early Modern European marketplace (Malcolm-Davies and Davidson 2015). This paper reports the initial findings of a pilot project to develop methodology for a closer examination and understanding of the archaeological material.

Background to the research

Unusually for a craft activity, European knitting has a short history. Knitting appeared late and moved through Europe at speed compared to other textile crafts (such as weaving, netting and knotting, which are centuries older) - a phenomenon almost unnoticed by historians. It appears in geographically diverse places from the 13th to 15th centuries in some cases associated with "magic" garments said to have been worn by the infant Christ, which expanded as he grew (Rutt 1987; Warburg 1984; Wyss 1973). Two-way elasticity was then a property unknown in contemporary textiles. Its lack was fulfilled by twill-woven wool textiles, which nevertheless had to be cut on the bias to achieve the necessary close fit, most notably in legwear. The transition from cloth hose to knitted stockings produced a significant shift in the functionality of clothing, but it did not happen with the advent of knitting and it took more than a century for this revolution to be complete (Anthony 1980).

One reason this important revolution in clothing has gone unreported is that knitting is undervalued, owing in part to its association with the domestic and the feminine (Turney 2009). Very little research has been done on Medieval or Early Modern knitting despite numerous extant items in museum collections and some literary and legislative references in, for example, wills, probate records and trade protection law (Turnau 1991; Rutt 1987; Thirsk 2003; Gilbert 2009; Ringgaard 2010; Sturtewagen, 2016, 80). Most published work on knitting pays little regard to the archaeological record. Headwear in particular has been of scant interest to scholars with a few notable exceptions (Zander-Seidel 1990, 129-130; Ribbert 2003, 23). Only a few Early Modern knitted caps have been studied and reported in any detail (Boticello 2003; Flury-Lemberg 1988; Buckland 2005, 31-35; Zimmerman 1998 & 2007). Other work on knitted caps has been cursory (Levey 1982; Buckland 2008/9) or speculative (Black 2012; Zimmerman 2000). All of it is descriptive rather than analytical, including a study identifying five distinct categories of caps of which the most common is the flat cap, a term which belies its constructional complexity (Malcolm-Davies and Davidson 2015).

The current project (KEME 2015-2017) recognises the 100 caps as a rich source of reliable information worthy of systematic scientific study. It aims to examine, analyse, record and compare them to fulfil a lack in the archaeological record of the craft of knitting. This pilot study draws new conclusions from these objects by applying a scientific archaeological approach (as is used for ancient textiles) within an interdisciplinary framework pioneered at the Danish National Research Foundation's Centre for Textile Research at the University of Copenhagen (Harlow and Nosch 2014). It follows other scientific studies of

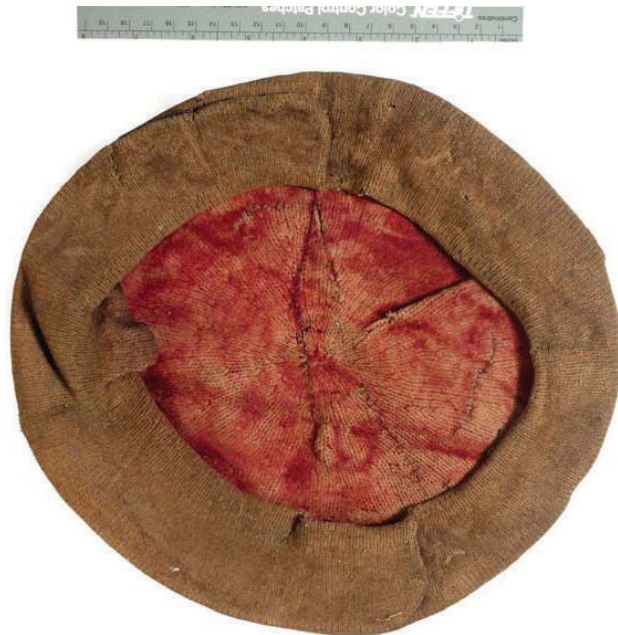


Fig. 1. Knitted cap with neckflap (single-brimmed) with extant red lining at the Museum of London (A6346) purchased from the estate of John Seymour Lucas in 1913 after excavation in Finsbury, London possibly in 1902.

long-overlooked textile evidence (for example, Styles 2010). The primary purpose of the pilot study reported here was to identify the variables to be investigated, gather indicative data and test the methodology to be employed in later stages of the project.

The data

Three main categories of evidence were identified: the archaeological material in museum collections, descriptions and depictions of contemporary trade activities and current comparative craft practices, and insights offered by experimental archaeology.

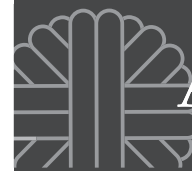
Archaeological evidence from knitted caps

A preliminary study identified more than 100 knitted caps of the kind worn by ordinary people in the 16th century (Malcolm-Davies and Davidson 2015). These are recorded in European collections as having been shipwrecked, deliberately concealed, preserved in peat bogs, or discarded as beyond use (see Fig. 1). Many were unearthed in construction work in cities, during building renovations or discovered on the seabed in far-flung locations – as far north as Norway and as far south as Croatia in Europe, on the east coast of Canada (Kjellberg 1988; Flury-Lemberg 1988), and by 20th century acquisition in north America.

There are five distinct types of caps of which the most common is the flat cap with a variety of brim styles (single, split and half), in addition to brimless examples and head-hugging coifs. Nevertheless, they show remarkable similarities in the materials used and methods of construction employed. Rudimentary measurements and observations identified some key patterns in the data: the caps were knitted in the round in plain knit stitches on at least four needles. The number of stitches (more properly called “wales”) and rows (“courses”) per inch (25 mm) vary considerably but cap crowns are usually finer than brims and linings. Crown diameters and head circumferences suggest the caps were mostly for adult men, maybe some women (Zander-Seidel 2010, 41), and a few for boys, although all show substantial deviation from their original circular form - probably as they shaped themselves to the wearers’ heads even allowing for distortion through burial or other archaeological contexts. Many of the caps have separate knitted linings but there are also linings which survive without their caps. This pilot project was confined to the data provided by examination of the cap linings, of which there were 29 available for study. All except one are in the UK: at the Museum of London (15), Victoria and Albert Museum (10), and one each at the Buckinghamshire County Museum in Wendover, the Mary Rose Trust in Portsmouth, Leicester City Museum, and the Memorial University of Newfoundland in St Johns, Canada.

An important consideration is the state of the cap linings now and how representative it is of their 16th century appearance. In most cases, they are degraded and retain little of their original colour. Their poor condition is a result of their hard use as headwear in the 16th century and long years buried in the earth or under the sea. Most also underwent undocumented conservation treatments in line with conventional understanding of what might preserve textiles in the past. Many have been thoroughly rinsed with water, washed with detergents, and/or impregnated with oils, varnishes or adhesives to improve their appearance or stabilise their form. All of these treatments have distorted the materials now available for study.

A comprehensive review of studies in this area, and soil burial tests in particular, suggests that degradation muddies our view of archaeological textiles and how we interpret them. Experimental specimens experience severe overall colour change, are stiffer, have a lower areal density, and shrink when dried (Peacock 2014). A study of buried fabrics demonstrated the role of dyestuffs in preservation and decomposition of the fibres. There were indications that madder has a preservative effect on wool fibres



and that it easily migrates to surrounding textiles during burial (Ringgaard and Scharff 2010, 223).

There are also studies which report the fibre diameters of the wool used to make four Early Modern knitted caps (Walton 1981; Ryder 1984; Botticello 2003). In isolation, these statistics are of limited value, especially since the process of sorting wool has now been recognised as relevant to fleece identification from fibre diameters (Rast-Eicher and Bender Jørgensen 2012).

Contemporary and comparative evidence for capping

A review of contemporary documents in which knitted garments are mentioned and pictorial sources showing knitwear in manufacture identified details about the land, labour, capital and technology available in the Early Modern era. Many of these sources are identified by Turnau's (1991 and 1983) and Buckland's (1979, 2005 and 2008/2009) descriptive works but others are from archives and art collections where references to knitting are hard won among the details of daily life and death. There is some documentary and pictorial evidence for the tools and techniques used in the capping industry in the Early Modern era which suggests that the key stages in the process are: knitting, fulling, napping and shearing. There are other essential activities such as sorting, scouring and spinning the fleece, and pressing and blocking the caps to finish them, which will be considered in later stages of the project.

Experimental archaeology

Attempts at reconstructing historic garments have provided useful evidence as to how fabrics perform when made into garments (for example, Kruseman and Feis 2014). Most reports on them simply document the choices made (for example, Grömer 2009; Hendzsel et al. 2008). There are very few academic projects which discuss or record in detail the choice of modern materials used to mimic the originals (for example, Demant, 2009; Arnold 2000), although this is a very popular approach to reconstructing garments among reenactors who explain their compromises with evidence and justification (for example, *Alessandra's Closet* 2016). Very few published projects have documented an approach to knitted garments but the reconstruction of the Gunnister man's cap from Shetland is a notable exception (Christiansen and Hammarlund 2013). The pilot study reported here offered an opportunity to develop and document an approach to the selection of materials for experimental reconstruction of a knitted garment from the Early Modern era in detail.

The Centre for Textile Research's (CTR) guidelines

for using experimental archaeology as a scientific method were adopted and adapted (Andersson Strand 2014). These were originally drafted for testing reconstructed textile tools and how they function. For this pilot study, the tools were not the priority because more research is required to reconstruct and test them. The CTR's parameters were applied to the choice of materials (which the guidelines recommend should be selected according to current knowledge of archaeological fibres) and labour (all processes should be performed by more than one skilled craftsperson in order to secure a more objective assessment of the results).

The guidelines also recommend that all processes be documented and some filmed, and that all products must be evaluated by external examiners. There are very few documented methods of evaluation for items produced using experimental archaeology, and only one for reconstructed garments has so far been identified. Toiles of an 1880s gown in the garment and textile study collection at the University of Alberta, Canada were reproduced using three different pattern drafting systems (Marendy 1993). The aim of the project was to investigate which system produced the best reconstruction of the original garment for a British standard size 12 mannequin. Evaluation of the reproductions was carried out by a panel of 12 people drawn from cultural institutions in Alberta who did not know how the reconstructions were made. They undertook their evaluations independently in three parts using a five-point descriptive rating scale, a list of features to be compared with the originals, and ranked the toiles as first, second and third choice in similarity to the original garment (Marendy 1993). This study provided guidance for potential evaluation processes.

Research problem

The most visible item of knitwear in the 16th century (the high point of the hand knitting industry before the era of knitting machines) was the ordinary man's cap. In most cases, these caps were not obviously knitted because they were finished with a mock velvet surface acceptable for wear by those for whom silk was discouraged by convention and sumptuary law from 1533 by Henry VIII, again by Philip and Mary in 1553 and further enforced by Elizabeth I in 1556 and 1559 (Archer and Douglas Price 2011; Williams 1995). A cap in the collection of the Bernisches Historisches Museum in Switzerland was originally catalogued in 1884 as being made of red velvet until conservation work revealed this "reasonable mistake" because of the sophistication with which the woollen yarn had been napped and clipped (Maeder 1980, 227).



The accurate reconstruction of the caps is a challenge which has been tackled in various ways in the past – often without the benefit of close examination of the archaeological evidence (for example, Merrill et al. 1990). However, even more of a mystery – and so named in the medieval period for the secrecy with which it was protected – is the method of producing a silky pile which provided a touch of luxury and much-needed warmth in the little ice age of the 16th century (Fagan 2000, 53, 84 and 94). It has been previously recognised that “an industrial process was at work ... with some 15 to 20 successive stages” but that “much has yet to be learned about the introduction and early history of knitting” (Staniland 1997, 246). The mock velvet texture was not achieved by the knitting but by the finishing processes that followed. It is the surface treatments that produce significant visual and textural differences in woven fabrics with the same weave. Previous studies have noted the challenge of understanding these treatments and the failure of standard identification methods (for example, Walton and Eastwood 1988) to differentiate between them (Hammarlund 1997 and 2005). Knitted fabrics present the same difficulty.

The split-brimmed style of cap has the most complex construction of the five types of extant caps, with overlapping round-ended brims, a facing, and a separate lining (Malcolm-Davies and Davidson 2015). This provides six distinct surfaces on which a plush pile comparable to that of velvet could be created. The potential finishing processes have not been much studied despite being indicative of a highly developed and specialised industry. Some clues to its sophistication are available in the documents of the period, including an English statute of 1571, which lists 14 processes the caps underwent but fails to define them (Archer and Douglas Price 2011).

Research methodology

The project employed an interdisciplinary, triangulated research methodology in an attempt to produce preliminary evidence of the materials and techniques required to produce the mock velvet pile on the knitted caps. Previous work on textile tools has suggested appropriate ways of approaching a scientific analysis including the need to isolate all variables as for an experiment in a science context (Andersson and Rasmussen 2008, appendix D). There are a number of variables which may contribute to the caps’ characteristic finish. An indicative summary appears in Table 1. This pilot study confined itself to exploring the variables presented by sheep breeds and the yarns they produce.

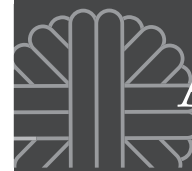
Careful and methodical observation

Each of the extant 16th century cap linings was examined using what has been termed a “slow approach to seeing” (Mida and Kim 2015, 13). This method advocates the use of a checklist for specific measurements and observations, and plenty of time to contemplate what is being observed. The process is divided into three phases: observation, reflection and interpretation (Mida and Kim 2015, 27). These phases refer to capturing the information from the artefact, considering its embodied experience and contextual material, and linking the observations and reflections to theory.

The CIETA methodology offers a more regimented approach to documenting textiles using a *dossier de recensement* (CIETA 2006, 4). It is notably more detailed than other methodologies (for example, Walton and Eastwood 1988). It includes 15 specific observations and aims in particular to capture the set-up of the loom required to weave specific effects in textiles. As a result, it is not immediately applicable to knitting, although an aim of this study was to emulate the rigour of the CIETA recording system.

New criteria proposed to supplement the technical definitions in basic standard woven textile recording systems have been dubbed “a fourth dimension” in textile analysis (Hammarlund 2005, 88). It has been described as a subjective system requiring analysis by an expert craftsman. However, the model is defined with five essential characteristics and two further measurements, which attempt to capture the complexity of a fabric’s appearance (Hammarlund 2005): yarn (length, fineness, fibre diameter, crimp, absorbency, abrasion resistance, twist and direction, orientation, diameter), binding (the system of interlacing threads in the warp and weft), thread count, weaving (the effects of the interplay of the loom, other tools and the weaver), finishing (wetting, stretching, dyeing, fulling or a mix of these techniques), thickness (indicated by yarn diameter) and density (calculated as the cover factor, using the textile industry’s standard formula – see Russell 1965). The first five factors are presented as a pentagon with the last two being the result of interplay between the basic five (Hammarlund 2005, 105-107). One objective of this pilot study was to assess how these seven observations could be adapted for recording knitted fabrics. Emphasis is placed on the importance of recording them when viewing the original object and not relying on photographs, although these are recognised as helpful resources for follow up work (Hammarlund 2005).

Dino-Lite microscopes offering magnification up to x480 facilitated more detailed observations than are available to the naked eye. These observations were



	Type	Tools: materials/size/ form/no	Power: hand/ machine	Processes	Agents	Other	Temperature	Time	
Sheep	Breed	Shears	√	Washing	Water	Health & diet		Shearing season	
Fleece		Combs/Carders		Sorting Combing/carding		Quality: including <i>fibre diameter</i> <i>fibre length</i> <i>pigmentation</i> <i>staple length crimp</i> <i>lustre</i> <i>elasticity</i> <i>texture</i> <i>strength</i>	√		
		Sticks		Washing	Water Soap				
				Scouring	Soapwort (<i>Saponia officinalis</i>)				
Yarn		Distaffs Spindles Wheels Winder	√ √	Sorting Spinning		Twist (direction S/Z) Twist (angle)			
				Plying/doubling		Tension			
Knitting		Needles				Gauge or tension (wales/stitches) Gauge or tension (courses/rows)			
Dyeing		Vessels			Water Dyestuffs Mordants	Fleece/Yarn/Fabric	√	√	
Fulling		Trough Paddles Hammers Mill	√	Fullers earth (Calcium montmorillonite) Soap Urine	Water/steam	Pressure	√	√	
Napping		Teasels Gig	√			Species Technique		√	
Clipping		Shears Form	√					√	
Blocking		Press/iron Form	√	Pressing Drying	Water/steam		√ √	√	

Table 1. Variables in the production of mock velvet pile in knitted cap linings.

taken at a distance from the object and therefore did not require much handling or the removal of any material. Examination of the knitted items carried out with this equipment helps to ensure stitch and row counts are accurate and facilitates close inspection of increases and decreases in the number of stitches, and other construction details. High-resolution images were taken using the microscope which permit further measurements to be taken, such as yarn diameters and spin angle, and second opinions on the material to be gathered after the initial field work (Rast-Eicher and Jørgensen 2012).

Summary of findings

Archaeological survey

The 29 flat, roughly circular cap linings are notably similar in many ways. None are perfectly circular making all measurements approximate. They are on

average 30.5 inches (900 mm) in circumference in a range between 20½ inches and 39¼ inches (525 mm and 1050 mm). The linings are 10 inches (255 mm) in diameter in a range from 8 to 14 inches (210 to 360 mm) based on 27 examples, although six are 12 inches (310 mm). Only 17 are preserved inside their caps but these help to explain notable features in 23 of the linings. Most have a slit (18 examples) or a fold (five examples) from the centre to the circumference allowing an overlap so that the lining matches the cap's crown in size when inside it (see Fig. 2). Three have both a slit and a fold and four have neither. Another five linings are incomplete and it is not possible to tell if they had these features, although there is evidence that a slit or a fold is what caused them to become fragmentary. Most of the linings were probably knitted as flat circles in the round on at least four needles in plain stitches cast on to create the centres and presumably cast



off at the outer circumference edges, none of which remain. Some show evidence of having been cast on at the outer edge and knitted towards the centre (although accurate diagnosis of the knitting direction is a still work in progress). The increases (probably made by knitting twice into one stitch or by the yarn over method) occur at arithmetically random intervals or “haphazardly”, as has been recorded of knitted fragments from the 14th century (Crowfoot et al. 1992, 73). Knitting in the round (as opposed to flat knitting on two needles) produces plain knit stitches (or face loops) on one side of the fabric and purl stitches (or reverse loops) on the other. The reverse loop surface appears to have been regarded as the face of the lining (the right side which was worn next to the wearer’s head) for all those still inside their caps. This is unlikely to be coincidental given their locations at different museums. The exception is the example at St Johns in Canada (EkBc-1:39762H) which now has the face loops on the outside, as does its cap. There is no record of its excavation or conservation in the documentary evidence of its discovery. It is possible that the cap and lining were turned inside out to facilitate the removal

of human remains after excavation or during the conservation process.

The majority of the linings (25 examples) have pile remaining in substantial patches (see figure 2). Most of this is on the purl (reverse loop) sides than on the plain (face loop) sides (which lay next to the undersides of the cap crowns). The pile is usually a dark red colour. In two noteworthy cases, it is a purple red (MoL A6346 and V&A T.188-1958A). In others, the red colour is yellow/red or brown/red. In all cases with extant nap, the yarn is paler in colour than the pile, although it too is discernibly red. The stitches per inch/25 mm (SPI) and the rows per inch/25 mm (RPI) vary greatly: from 5 to 12 SPI, with an average of 7 SPI; and from 8 to 16 RPI, with an average of 11 RPI. Nearly half the linings have equal SPI and RPI counts. For more than half, the SPI must be doubled to equal the RPI. It is not immediately obvious which way the yarn is twisted and, if so, how tightly, because in many cases the pile obscures the knitted stitches or the twist of the yarn into the stitches has distorted the S or Z of the original spinning or plying. It is also a challenge to establish whether the yarn is plied (ie with two or more threads



Fig. 2. Knitted cap lining at the Victoria and Albert Museum (T.191A-1958) with cast-off (or cast-on) edge cut away, substantial extant pile (darker in colour than the yarn from which it is raised), and a slit to allow an overlap for it to fit inside the crown.



twisted together to form the yarn). Occasionally, it is possible to discern two threads in a single knitted stitch (see Fig. 3) but these often lie side by side and are not twisted together (plied) as is the case with modern yarn. All the linings were sufficiently full for the cast-off (or cast-on) edges at the circumferences to have been cut away without the fabric unravelling. Their removal and the fulling process make it possible for the linings to lie flat, although there may be some other purpose for it being cut away. The linings' weights ranged from 18g to 123g with an average of 56g but some were considerable overestimates because the linings are attached to conservation supports of heavy woven fabrics. Others are partial linings for which the weight has been multiplied to be more representative of a complete item.

A smaller sample of the linings was analysed with a Dino-Lite microscope to determine the fibre diameters. A total of ten linings was observed at 435 magnification with ten measures of the fibre diameters recorded for each, from which an average of 31 microns was calculated. The range was 21 to 43 microns, with six examples between 21 and 29 microns, and three between 33 and 39 microns. A summary of the data obtained from the 29 linings is shown in Table 2.

Contemporary and comparative evidence

The most essential tool in the process of capping evades precise definition. That there were knitting needles is corroborated by contemporary records. A Worcester capper's inventory of 1561 listed two pairs (sets) of knitting pins (Dyer 1967, 20). In 1564, a Southampton merchant had knitting needles in his shop valued at 4d (Roberts and Parker 1992, 216-217). In 1593 and 1597, a merchant and a mercer in Northumberland were selling "knytinge nedeles" and "knitting pricks" by weight: a pound and a half cost 2s 6d and 2s 1d respectively (Greenwell 1860, 235 and 281). Edward Hadley, an ironmonger from Oxfordshire was selling "nett needles and pynnes 6d" in 1600 (Gibson 1985, 163) and a Scots bonnet maker in Glasgow owned a dozen "bonnat brodds" in 1605 (National Archives of Scotland CC 9/7/3,15r quoted in Bennett 1981, 133). The Sankeys, mercers of Lancashire in 1613, sold knitting needles which were valued at 6d (anon 1966, 15) and the Howard family recorded the purchase of knitting needles for 3d in September 1621 (Ornsby 1878, 162). The most famous and frequently cited sources for early knitting are paintings of saints, including the Virgin Mary (*Our Lady of Siena*, c1325-1350, studio of Ambrogio Lorenzetti; *Our Lady of Buxtehude*, c1370, Master Bertam of Munich). Despite details which confuse the representation of the actions required, they do provide evidence of needles, their number (at



Fig. 3. The red pile on a knitted cap lining at the Museum of London (A6346) showing the yarn is paler than the pile and two unplied threads forming each stitch.

least four) and their form (long, thin, cylindrical sticks or wires with pointed ends). Archaeological evidence for what must have been ubiquitous tools does not survive in any quantity or, if it does, it is not yet recognised as such. Excavated domestic settings often reveal thousands of pins, as was the case at Acton Court in Gloucestershire (United Kingdom), a modest manor house, where 3,539 were found (Rodwell and Bell 2004). Nevertheless, even excavations of sites which are said to have been capping workshops report no finds that might reasonably be interpreted as knitting needles (for example, Blackfriars in Gloucester, UK). But as knitting was probably done by outworkers, their needles are unlikely to have been found in large numbers at professional establishments and these finds may represent the few from domestic settings that have been recognised as tools of the trade. A review of evidence for early knitting needles has proved similarly inconclusive (Gagneux-Granade 2015, 47-50). The sparse evidence thus far is two double-pointed copper alloy rods (inventory numbers 14697 and 14698) excavated from a 14th century layer in a York (United Kingdom) tenement building at 2 Aldwark identified as knitting needles. A third potential knitting needle found at the Foundry site in the same city is probably post-medieval (inventory number 13304). The two from Aldwick are not likely to be from the same set of needles despite being the same length (7 inches/180mm) because their diameters do not match (2.6mm/UK size 12/US size 2 and 1.9mm/UK size 14/US size 0) (Walton Rogers 2002, 2743-2744). Another medieval knitting needle was reported as having been found at Blackfriars in London (Egan 2001, 5).



Linnings / locations	Inventory numbers	Circumference (inches/mm)	Crown diameter (inches/mm)	Fold (1 yes; 0 no)	Slit (1 yes; 0 no)	Extant pile (1 yes; 0 no)	Yarn paler than pile (1 yes; 0 no)	Stitches per inch/25mm (number)	Rows per inch/25mm (number)	Weight (grams)	Yarn diameter (mm)	Fibre diameter (microns)
Leicester City Museum	C21.1939.2.2.2	30/750	10.25/256	0	1	1	1	8	12	Not available	1.33	
MUN, St Johns, Canada	EKBc-1:39762H	22.5/563	13.5/338	0	1	0	Not relevant	6	7	50	5.68	
Museum of London	22392	33.75/844	10.75/269	0	0	0	Not relevant	6	Not available	58	1.38	
Museum of London	22388	38/950	12/300	0	1	1	Not relevant	7	Not available	78	1.23	
Museum of London	A6342	38.5/963	12/300	0	1	1	1	8	Not available	52	Not available	
Museum of London	5010	24.5/613	8/200	Not relevant	Not relevant	Not available	Not available	7	Not available	82	Not available	
Museum of London	4570*	38.5/963	10/250	1	1	1	1	10	14	67	1.10	
Museum of London	A26567	31/775	12/300	0	1	1	1	7	10	78		
Museum of London	A6060	27/675	10/250	0	1	1	1	9	13	54	1.28	
Museum of London	5004	28.5/713	9/225	1	0	1	1	6.5	10	Not available	1.43	
Museum of London	A6346	21.25/531	10/250	1	1	1	1	9	14	Not available	1.01	
Museum of London	74.42/1	33/825	9.5/238	0	0	1	1	6	10	75	1.90	
Museum of London	22390	31.5/788	10/250	0	1	1	1	8	14	51	1.38	
Museum of London	5005	28/700	10.5/263	0	1	1	1	9	16	53	Not available	
Museum of London	5013	20.5/513	9/225	0	0	0	Not relevant	5	9	Not available	Not available	
Museum of London	22391	39.25/981	12.5/313	0	0	1	1	6	11	65	1.52	
Museum of London	22389	36/900	11.5/288	0	1	1	1	7	16	62	1.23	
The Mary Rose	MR81A6961	Not available	Not available	Not available	Not available	1	1	9	14	18	1.08	
V&A Museum	1574-1901	27.5/688	8.5/213	Not available	Not available	1	1	7	7	51	1.73	
V&A Museum	1563A-1901	35.75/894	12.25/306	1	1	1	1	12	12	62	1.18	
V&A Museum	T.618A-1913	Not available	9.5/238	Not available	Not available	1	1	7	7	18	1.44	
V&A Museum	T.618-1913	Not available	10.5/263	Not available	Not available	1	1	6.5	7	24	1.76	
V&A Museum	T.191A-1958	33/825	10.25/256	0	1	1	1	10	11	48	1.29	
V&A Museum	1575-1901	30.5/763	9.5/238	0	1	1	1	6	8	123	1.08	
V&A Museum	T.619A-1913	22/550	9.5/238	0	1	1	1	5	7	35	1.38	
V&A Museum	T.618B-1913	Not available	10.5/263	Not available	Not available	1	1	8	12	26	1.08	
V&A Museum	1562A-1901	31/775	9.75/244	0	1	1	1	9	14	63	1.45	
Buckinghamshire County Museum	T.188-1958A	27.5/688	8.5/213	0	1	1	1	6	10	40	1.25	
Buckinghamshire County Museum	ABCN: 1948.5HN	34/850	10.5/263	0	1	1	1	7	10	57	1.17	
Average/Total		30.57/63	10/259	5	18	25	25	7	11	56	1.53	31

Table 2. Characteristics of modern yarns in comparison with extant knitted cap linings.



After the caps were knitted, they were fulled, a process which woven textiles also underwent. This must be distinguished from felting, which is the process of creating fabric from wool fibres which are not spun:

“The cloth ... was soaped and beaten in a damp state with heavy wooden hammers, so as to make it warmer, opaque, and more durable. The original process of fulling consisted in trampling the cloth underfoot ... on this account the fuller was sometimes called a walker” (Lipson 1921 139).

Knitted caps were often referred to as being “thicked” as in the *Bill for Thicking of Caps by means Feet and Hands*, which was read in the parliament in London on 13 February 1559 (Simonds d’Ewes 1682, 44-49). Equipment for fulling could be as simple as a wooden trough for kneading or treading the knitted caps such as is preserved at the Ethnographic Museum in Kraków (Turnau 1991, plate 25) or there might be paddles with which to beat them (Lipson 1921, frontispiece). Fulling mills harnessed water to power hammers which not only beat the caps but moved them around so that they rubbed against one another which accelerated the thickening process (Turriano 1595).

Napping was another intense process: “Partly dried woollen knitwear was subjected to roughing with thistle brushes or with combs which were then sheared with large scissors” (Turnau 1991, 116). A regular supply of teasels, the prickly seed heads of *dipsacus fullonum var sativus*, a cultivated variety of the wild thistle, are necessary for the nap to be raised on knitted and fulled fabric. These were imported into London in large quantities – for example a ship from Antwerp named the *George* delivered 22,000 teasels in 1568 (London Record Society 1972). The dried teasels have hooked spikes which are hard, sharp and sufficiently hardwearing that they can be used repeatedly to brush the knitted fabric thereby raising the hairs from the fulled yarn. Teasels were mounted on several spindles to create a gig, which increased the efficiency of the process, as the hooks of multiple heads could be run over the fabric surface.

After napping, the raised pile was shorn. The Worcester capper’s inventory of 1561 listed two pairs of shears (Dyer 1967, 20) and the inventory of John Nasmyth and son, bonnetmakers in Glasgow, included “ane scheir” (National Archives of Scotland, CC 9/7/3,15r quoted in Bennett 1981, 133). Shears are shown on a Polish coffin shield of 1655 which match those included in Diderot’s comprehensive depiction of the tools of the *bonnetier de la foule* (Diderot 1751, plate II fig 9).

It is noteworthy that representations of the tools of the trade later in the Early Modern era do not show the needles since the actual knitting was not done by the cappers themselves. The Polish coffin shield dated to 1655 (Masner 1924 quoted by Turnau, 1991, 212) and a Hungarian guild insignia of 1725 (Iparművészeti Museum, Budapest, inventory number 522907-1) show the teasels and the shears. Even the most comprehensive depiction dating from the 18th century omits needles but includes wooden forms on which the garments were mounted during the napping and shearing processes (Diderot 1751, plate 2), although by 1792, an engraved glass tumbler from Prague (Czech Republic) omits the shears in favour of a ball of wool with four needles stuck through it (Hálová-Jahodová 1955 quoted in Turnau, 1991, 212).

There are craftspeople and workshops still producing garments of cultural and/or touristic value today with a direct link to the way knitted caps were finished in the 16th century. The Tunisian *chechia*, the Turkish and Egyptian *fez*, and the Basque *beret* (all headgear with significant political associations) provide evidence of the likely manufacturing process. The Boinas La Encartada Museoa in Balmaseda, near Bilbao (Spain) demonstrates how machine-knitted Basque berets were fulled, napped and shorn using water-powered machinery based very closely on the hand finishing processes from before the industrial revolution. Wooden fulling troughs with paddles (now reinforced with metal) fulled as many as 70 caps at a time, which were tumbled against the shaped ends. Teasels mounted on metal spindles fixed to spinning drums raised the knitted surface. Wooden and leather forms were inserted into the caps to keep them rigid during napping and shearing respectively.

This brief survey of the tools of the trade confirms the necessary equipment consisted of knitting needles (or pins), fulling troughs, paddles and power, forms for shaping the cap, teasels for raising the nap, and shears for clipping it to a pile. There are also suggestions of the need for other agents to aid the processes required, such as scouring, degreasing and washing the fleece. Another variable is the preparation of the yarn before it is knitted. Spinning may be undertaken using a range of spindles and wheels and in one of two ways. The woollen spin method is used for short staple fibres, which have been carded, while the worsted spin method is suitable for long staple fibres after combing. Carding produces a bundle of fluffy fibres and a relatively soft, woolly yarn, whereas combing arranges the fibres in parallel and produces a relatively firm, smooth yarn (Hiatt 2012 557-559 and 663). However, the other necessary ingredient for successful capping is the wool and the choice of fleece, and the sheep from



which it comes, is a key variable in the process. The study of sheep breeds and their history has a long tradition (for example, Trow-Smith 1957; Ryder 1964). Work on surviving textiles and animal skeletons from the Middle Ages shows the predominant type of sheep was comparable to modern Orkney and Shetland breeds (Ryder 1981). The highly praised “Lemster Ore” or Leominster gold of the Middle Ages and Early Modern era was a very fine wool, and was likely to have been produced by an ancestor of the Hereford sheep, which is now identified with the Ryeland breed, as it conforms to the most common depiction of sheep in the 15th and 16th centuries (Ryder 1983, 464 and 467-468). It produced fine fleeces “unsurpassed by any other breed” with estimated to be 1/750th inch (34 microns) in diameter (Youatt, 1837, 261 quoted by Buckland, 1979, 10). The Welsh Mountain sheep is said to have originated in the 13th century but it had already undergone an improvement in its fleece which distinguished it from that of the Cardy, a primitive breed, by the 16th century (Trow-Smith 1957, 162). The present-day Black Welsh Mountain sheep (officially recognised in 1922) was produced by selective breeding to secure a dominant black gene (The Livestock Conservancy 2016). Nowadays, the wool is sufficiently fine, soft and densely stapled to be regarded as a speciality type and the fleece is used to good effect in combination with other wools. The Wensleydale breed of sheep originated in north Yorkshire early in the 19th century from a cross between a local long wool breed (the Teeswater) and a Dishley Leicester ram named Bluecap, born in 1839 and said to have superb wool, among other qualities. The breed was not named until 1876 (Ryder, 1964, 11; Wensleydale Longwool Sheep Breeders’ Association, 2016). Zwartbles is a sheep breed which originated in the late 19th and early 20th centuries and is thought to be descended from the Schoonebeker, which historically grazed the heaths of north east Netherlands (Zwartbles Sheep Association 2016). Merino originated in the 1340s as a coarse Spanish wool but eventually became the finest of fleeces in the later Middle Ages (Munro 2002). Studies of sheep traded in the 12th century show an important price differential between those producing coarse (6d per animal) and fine wool (10d). Only one in more than 100 manors produced fine wool, demonstrating its rarity (Trow-Smith 1957). A reference to the mingling of Spanish and English wool in Flanders in 1436 suggested that Merino blends were also used in the Early Modern era (Myers 1969, 1033). There is no evidence thus far of the desirable characteristics of wool to be processed into knitted caps in the 16th century but court records provide a tantalising glimpse of it. On 29 August 1548, Robert

Mason robbed Lissott Bannour’s house taking wool which was “clearly cap yarn” valued at 12d (Monmouth Borough Archives, quoted in Buckland, 1979, 3). Something made the wool recognisable as such but the account gives no further details.

Experimental archaeology

Key evidence from the archaeological survey and the contemporary and comparative evidence was used to design the experimental archaeology phase of the pilot study. Although there are choices in all the raw materials, processes and equipment used at each stage of manufacture, these were standardised for the pilot study in order to investigate the yarn as the primary variable. Sheep breeds today have moved a long way from their Early Modern ancestors and it is difficult to know the precise differences in the yarns produced now compared to those of the past (Ryder 1964, 7). Five commercially available yarns were selected for the study but they are very different from those observed in the archaeological record. None had been treated to prevent fulling as is the case, for example, with superwash brands. Four were two-ply and one was three-ply (ie the yarn was composed of more than one strand twisted together). All were aran weight (also known as medium and approximating to US worsted weight), and are marketed as “heritage” sheep: Shetland, Ryeland, Zwartbles/Merino, Wensleydale and Black Welsh Mountain. They had a range of fibre diameters according to published industry standards (British Wool Marketing Board 2016). Three were worsted spun and two were woollen spun. The five yarns were selected in different colours for ease of identification. These details, including specific weights expressed as yarn counts, and other comparative data are in Table 3.

Circular swatches (named “swirbles”) were designed to represent the cap linings, which were on average 10 inches (254 mm) in diameter with approximately 7 SPI or 25mm and 11 RPI or 25mm. The swirbles were knitted half size (5 inches/128 mm diameter) to reduce the time and effort required to produce them for experimental purposes. The swirbles were all knitted by an expert in spinning and knitting who was recruited by recommendation from professional craftspeople. A test set of swirbles was knitted, fulling, napped and sheared (see Fig. 4). The set consisted of one swirble knitted from each yarn. They were all knitted on the same size needles (2.5 mm/UK size 12-13/US size 1-2) and had approximately six SPI or 25mm and seven RPI or 25mm.

The swirbles were soaked in hot water for at least five minutes. Fulling was done by hand by rubbing the knitted fabric vigorously, using soap on a flat, slightly

Fleece (century)	Yarn diameter (mm)	Fibre diameter microns:		Staple length* cm	Yarn count: length/weight (Nm)	Spin		Ply
		Pre-fulling*	Post-fulling			twist	type	
Shetland (c8 th)	5	31	31	9	1.2	S	Worsted	2
Ryeland (c12 th)	3	31	34	7	1.4	S	Woollen	2
Zwartbles/Merino blend (c20 th)	4	33	35	11	1.6	S	Worsted	2
Wensleydale (c19 th)	2	33	31	23	1.6	S	Worsted	2
Black Welsh Mountain (c13 th)	2.5	34	30	8	1.4	Z	Woollen	3
Archaeological yarn	1.53	Not known	21 to 43	Not known	Not known	Not yet known	Not yet known	1, 2 or 3 threads

Table 3. Characteristics of extant knitted cap linings (29 examples). *Industry standard.

ribbed metal surface. Both a soft tallow soap and a green olive soap were used on each. Each swirle was rinsed in hand-hot water, then plunged into cold water. When they were dry, the swirles were napped and the resulting pile sheared. This demonstrated that all five yarns could successfully undergo the primary activities of capping. The same craftsperson knitted six sets of five swirles (one of each yarn). Five of these sets were used by volunteers at five workshops to investigate potential capping techniques. A total of 100 workshop participants with a range of expertise (from sheep rearing through competent knitting to a passing interest in the fibre arts) took turns fulling, napping and shearing in groups of two to three. The sixth set of swirles was kept for reference and in order to facilitate a repeat workshop if there were any difficulties with the processing which rendered the results unusable or invalid. During the workshops, all the swirles were soaked in hot, soapy water for at least five minutes. Most were repeatedly soaked during the 45 minutes they underwent fulling. This was done by hand rubbing the knitted fabric vigorously and beating it with wooden mallets, used singly or in pairs to approximate the action of hammers in a fulling mill. In some cases, the wet surface of the swirles was napped using teasels and a few were sheared in part or in full. The cast-off edge around half of the circumference was cut away to see whether the edge was stable. The workshop participants were all asked to review the test set of swirles knitted, fulling, napped and sheared by the expert craftsperson and assess how silky, velvety and dense they were relative to each other. The participants used a five-point scale from 1 for most to 5 for least for each characteristic.

Results from the experimental archaeology

All the swirles measured 5 inches (130 mm) in diameter when knitted. Fulling caused three yarns to shrink and there were some changes in the gauge – the stitch (wale) and row (course) counts (see Table 4).

The Shetland remained 5 inches (130mm) in diameter and the Ryeland expanded by 15 per cent to 5¾ inches (145mm). The Wensleydale shrank the most (by 15 per cent to 4½ inches/115 mm) whereas both the Zwartbles/Merino and Welsh Black Mountain shrank by 5 per cent to 4⅝ inches (125mm). This suggests that Wensleydale yarn creates the most dense fabric through fulling. However, cutting away 1 inch (25 mm) of the cast-off edge at the circumference of each swirle was unsuccessful for all the yarns. The cut edges began to unravel immediately with only the slightest agitation. Comparisons between the fibre diameters before fulling (based on the industry standard) and after fulling suggested that either the raw yarns differed from the industry standard or they underwent a change – shrinking (two yarns) or thickening (two



Fig. 4. Knitted, fulling, napped and sheared swirles (clockwise from bottom left) – Ryeland (natural), Shetland (red), Zwartbles/Merino (grey), Wensleydale (coral) and Black Welsh Mountain (brown).



Fleece	Swirle diameter (inches/mm)		Percent change	SPI/25mm		RPI/25mm	
	Pre-fuling	Post-fuling		Pre-fuling	Post-fuling	Pre-fuling	Post-fuling
Shetland	5/130	5/130	0	6	6	8	9
Ryeland	5/130	5.75/145	+15	5	6	8	9
Zwartbles/Merino blend	5/130	4.5/115	-5	7	7	9	10
Wensleydale	5/130	4.5/115	-15	7	7	8	10
Black Welsh Mountain	5/130	4.9/125	-5	6	6	8	10
Averages				6	6	8	10

Table 4. Comparative swirle measurement pre- and post-fuling.

yarns). Only the Shetland yarn remained the same in diameter. The Ryeland yarn thickened by 10 per cent and Zwartbles by 13 per cent. Wensleydale thinned by 6 per cent and Black Welsh Mountain (which was the only 3-ply yarn) by 13 per cent.

After fulling, it was extremely difficult to see the stitches (wales) and rows (courses) in the swirles and this made comparable counts impossible to measure accurately. Shining a light through the fabric from underneath and using pins to mark the stitches and rows was the best way to count them by eye.

Some of the experimental swirles were sheared while still wet after fulling to create a vertical pile. The Wensleydale and the Black Welsh Mountain produced more vertical pile than the other three yarns, which produced a fluffier surface. This demonstrated that all five yarns could be fulled, napped and sheared, and that there were clear differences in the surfaces produced. It was noteworthy that the swirles which were fulled for two 45-minute periods (ie by one set of workshop participants and then a second set) very quickly achieved much more impressive surface effects than those fulled for one workshop period only. This suggests that the critical moment at which a noticeable change occurs is after one hour. However, some yarns fulled more swiftly than others.

The workshop participants were asked to examine the swirles made using the five test yarns knitted, fulled, napped and sheared in advance. Their experience of fulling, napping and shearing swirles and prior exposure to early modern depictions of caps helped them approach the evaluation exercise with confidence, although only a small number provided written feedback, representing 15 per cent of the potential total.

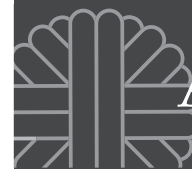
The evaluation criteria under consideration were how dense, silky, and velvet-like the swirles were. The

participants were asked to rate each criteria of the five on a scale (1 for most and 5 for least). An award-winning expert craftsperson (who was not involved in the manufacture or processing of the swirles) was asked to rank the swirles to see how this evaluation compared to the workshop participants' opinions. The participants and the expert ranked Shetland as the most dense. Silky seemed to be interpreted as a measure of how glossy the surface was and how smooth it was to the touch. The participants ranked Ryeland and the expert identified Wensleydale as the most silky. Evaluating a velvet-like surface proved the most challenging. The expert ranked Shetland the most like velvet and the participants ranked Shetland and Wensleydale equally against this criterion. Most participants said they did not think any of the swirles were very much like velvet.

Discussion of findings

A review of sources for the relevant capital, equipment, labour, and raw materials suggests there is more to discover than this short survey offers which will better inform the understanding of how knitted caps were manufactured in the Early Modern era. A critical issue is the need for more precise terminology to describe characteristics of knitted fabric and the actions required to make it.

The pilot project fulfilled its primary purpose by testing the proposed investigative framework and practical methodology. A limitation of this research was the relatively small sample of original yarn fibres (from 29 items). A larger body of evidence will provide a more credible assessment of the range of woollen yarn being used in the 16th century. Further and more detailed examination of the magnified images of the knitted stitches is required for accurate data on the twist (S or Z) and ply of the yarn used in the original linings.



The stitches (wales) per inch and rows (courses) per inch were very difficult to discern providing only approximate guidance on the gauge (tension) of the knitting after fulling. More work on the wale (stitch) to course (row) ratio is also required. New methods of measuring these are under investigation (for example, tomographic scanning). The lack of shrinkage of the fabric during the fulling process suggests the caps and linings were not knitted to a significantly larger size and reduced by processing to a close fit to the head (as is the case with modern machine-knitted berets).

Observation by eye and up to $\times 435$ magnification was not sufficient for the structure of the woollen hairs to be examined but it was adequate for yarn and fibre diameter measurements. These will provide useful data for comparison with other yarn fibre studies. The modern yarns measured between 31 and 34 microns in diameter with an average of 32 microns before fulling. These diameters are larger than the averages stated by the British Wool Marketing Board suggesting either that the raw yarns differed from the standard or they gained size during fulling. Measuring the actual yarn used before knitting and fulling to calibrate the fibre diameter would provide a more reliable indication of change, if any. The closest match in fibre diameters was between the wool in lining T.191A-1958 (29 microns) and Black Welsh Mountain (30 microns) but on average the archaeological yarn fibres were finer (21 to 43, average 31 microns) than the "heritage" yarn fibres (between 31 and 43 microns, average 32 microns) after fulling. However, closer identification of the fleeces used in the extant knitted caps and linings would be helpful. Statistical analysis of fibre measurements such as length, width and crimp will be instructive too. Destructive tests such as micro-CT scanning, isotope and protein analysis may pinpoint sheep breeds and their whereabouts more accurately. The discovery that a majority of the linings had yarn paler than the pile (64 per cent) suggests that the linings were dyed after they were knitted and napped, as the colour had not penetrated thoroughly beyond the pile to the yarn. There is some evidence for this from documentary sources recording the activities of dyers in Bruges (Kruseman, Sturtewagen and Malcolm-Davies 2016). Alternatively, those areas where the pile has worn away and the yarn exposed may have lost any remaining dye more easily than the nap. This phenomenon has been recorded as the result of moth damage in a cap at the Bernisches Historisches Museum in Switzerland, where the undyed core of the yarn was exposed (Maeder 1980, 227). An accurate method for recording colour would also help to describe the current state of the knitted fabric now and to document changes in further experimental

archaeology. Both the CIELAB and Munsell colour systems have been used for this purpose in dye analysis (Ringgaard and Scharff, 2010). Two of the heritage yarns were already dyed (the Shetland and Wensleydale) before they were fulled, although this was unlikely to be the case for the originals. The dyestuffs may have affected the speed and effects of the fulling process and represent another variable to be removed from future experimental work.

More investigation into relevant comparative crafts may reveal the details of the yarns used for similar garments today. Modern Tunisian *chechia* (knitted by hand and fulled by foot) and Basque berets (processed by machine) are routinely made in sufficient numbers and produce uniform results that the raw materials may prove instructive. However, it is noteworthy that the berets are shrunk very much more than the *chechia*. The pilot swirles produced initial indications of knitting and finishing effects with five different yarns. There was a wide variety of surfaces produced, although none reproduced the pile observable on the originals. Since this is of particular interest, a useful additional measurement on the original items would be the depth of the extant pile. However, in most cases, the pile has been flattened by the environment in which the linings were found, subsequent conservation treatment and/or storage.

The expansion or contraction of the yarn and the fibres provides further information for consideration. The Shetland yarn and fibres remained the same size before and after fulling, whereas the Ryeland yarn and fibres expanded. It is possible that continued fulling would have reversed this effect. Both the Black Welsh Mountain and Wensleydale yarn and fibres decreased in size (although to differing extents). The inconsistent result was for the Zwartbles/Merino which expanded in fibre diameter but shrank as yarn. This may have been due to the blend of two fleeces which made fibre measurements more difficult. Other variables in the fibres which may be relevant are staple length (see Table 3) and crimp. There was no clear correlation between shrinkage and worsted/woollen spun yarn or whether it was 2 or 3-ply. Further work on how these characteristics affect the finished surface may be instructive.

The finished swirles permitted evaluation criteria to be identified which will help draw up guidelines for future review of items produced with more extensive experimentation. The criteria need to be more narrowly defined with explanations of the concepts to be captured by the terminology such as density, silkiness, and velvetiness. Another refinement would be to provide reference material for evaluation of a velvet-like surface, such as swatches of woven woollen



fabrics which mimic velvet (for example, frizado). Several objective tests for evaluating the reconstructed fabrics were also suggested by the pilot study. Success in cutting away the cast-off edge at the swircler's circumferences is indicated by the fabric lying flat and the staying intact rather than rolling up or unravelling. Another objective measure may be the expansion of the yarn fibres as indicated by the diameter before and after fulling.

An important challenge identified by this pilot project is the recruitment of appropriate evaluators of the finished items. There are very few people familiar with the original knitted caps in the museum collections and even fewer who have undertaken detailed examination. One way of tackling this is to devise a method of photographing and/or videoing the surface of the originals in fine detail. Polynomial texture mapping has been shown to capture the surface detail of velvet very satisfactorily (Zhao et al. 2011). Representations such as these might be circulated to potential evaluators.

The next stage of the research will include more craftworkers with a wider diversity of experience, knowledge and skills. The volunteers who worked on the project also supplied helpful data on which to plan future archaeological experiments. Not many of them were familiar with the processes involved, although precise data on this was not collected during the event. In future stages of the research, volunteers will provide evidence of their knowledge and skills, and their contributions be collected more systematically.

Conclusion

A triangulated approach to the specific problem of processing knitted caps produced useful indications of the variables requiring further study and refinement. The pentagon model (adapted for application to knitting) was useful for data recording when examining the archaeological evidence. It proved less subjective than predicted as most of the measurements were obtained objectively (for example, yarn diameter as an indicator of thickness). Some observations were very hard to make: for example, whether the yarn was twisted at all, and, if so, whether it had an S or a Z spin, although magnified images taken with a Dino-Lite can be measured to record the direction and angle of spin, where it is no longer covered by the nap. This was often because the surface was heavily fulling and, even where the pile had worn away, the fibres of the yarn were too well fused to distinguish the spin. The yarn was also sometimes twisted as it was knitted – sometimes against the original spin, if there was any. Other criteria were even harder to ascertain: for example, whether or not the fabric had been fulling

in manufacture now that all the surface texture may have disappeared through wear and tear. The same challenge applies to discerning the ply. The original yarns were not always composed of two spun threads plied together. If there are two threads observable in the knitted stitches, they are not usually twisted together as in modern yarn but lie side by side as though knitted from two separate balls of yarn or from each end of a single ball of yarn. The next phase of the project will interrogate the archaeological evidence more keenly (including the use of micro CT-scanning) to discover more specific clues as to the sheep breeds which provided appropriate fleece for the knitted caps, discover whether there is a unique or range of wool employed, and, if the latter, investigate how the different yarns behave when treated with a variety of fulling agents and species of teasels. Reconstructions (including 3D visualisations) of complete caps in different styles will facilitate further information about the knitting methods employed.

Acknowledgements

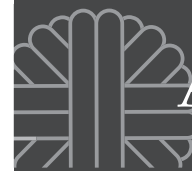
I would like to thank Freyalynn Close-Hainsworth, Zoe Fletcher, Timothy Long, Ania Mora Mieskowska, Sally Pointer, Ninya Mikhaila and Susan North for their contributions to this work. In addition, my thanks go to the organisers (Christopher Daley and Samantha McCarty) and participants of the *Tailored to a New World* conference at Historic Jamestown in June 2016 and the organiser (Harlie Des Roches) and participants (including Anthony Satoh, who researched and made fulling hammers) for the *As I lie dying* event in Chicago in July 2016. Constructive and helpful comments on an early draft were provided by Rachel Frost, Ruth Gilbert, Geeske Kruseman, Lesley O'Connell Edwards, and Maj Ringgaard. An anonymous reviewer also commented.

Bibliography

Anon (1966) "The Sankeys, Mercers, of Ormskirk Part 2 – 1613-1626" in *Lancashire Record Office Reports*, 12-24
Alessandra's Closet, "Red 1550s Florentine sottana" available at <http://www.dellacivetta.org/alessandra/historical-clothing/lady-in-red-1550s-florentine-sottana/>, (accessed 7 June 2016).

Andersson Strand, E. (2014) "Experimental Textile Archaeology" in Andersson Strand, E., Gleba M., Mannering, U., Munkholt, C. and Ringgaard, M. – eds, *NESAT X* (North European Symposium for Archaeological Textiles), London: Oxbow Books.

Andersson Strand, E. and Rasmussen, M. (2008) *Clothing and identities in the Roman World – Dress ID*



- Scientific report April – November, available at http://ctr.hum.ku.dk/economy/dress/project/reports/CTR_March-November_2008.pdf (accessed 8 June 2016).
- Anthony, I. (1980) "Clothing given to a servant of the late 16th century in Wales" in *Costume*, 14, 32-40.
- Archer, I. and Douglas Price, F. - eds (2011) *English historical documents 1558-1603*, 5A, London: Routledge.
- Arnold, J. (2000) "Make or break: the testing of theory by reproducing historic techniques" in Brooks, M. (ed), *Textiles revealed: object lessons in historic textile and costume research*, London: Archetype, 39-47.
- Bennett, H. (1981) The origins and development of the Scottish handknitting industry, unpublished PhD thesis, University of Edinburgh, available at <https://www.era.lib.ed.ac.uk/handle/1842/6842?show=full> (accessed 21 November 2016).
- Black, S. (2012) *Knitting: fashion, industry, craft*, London: VandA Publishing.
- Boticello, J. (2003) *The conservation of two Tudor knitted woollen flat caps*, undergraduate thesis, Camberwell College, London.
- British Wool Marketing Board (2016) *British Sheep Breeds and Their Wool*, available at <http://www.britishwool.org.uk/british-sheep-breeds.php#naturally-coloured> (accessed 1 June 2016).
- Buckland, K. (1979) "The Monmouth Cap" in *Costume*, 13, 1-16 (reprint).
- Buckland, K. (2005) "Woollen caps" in Gardiner, J. (ed) in *Before the mast*, Portsmouth: The Mary Rose Trust, 31-35.
- Buckland, K. (2008/9) "'A sign of some degree' - the mystery of capping" in *Text*, 6, 40-45.
- Centre International d'Etude des Textiles Anciens (CIETA) (2006) *Vocabulary of technical terms: fabrics*, Lyon: CIETA.
- Christiansen, C., and Hammarlund, L. (2013) "The Gunnister Man Project 1: The Wools and Knitting" in Banck-Burgess, J., and Nübold, C. (eds) *The North European Symposium for Archaeological Textiles XI*, Rahden: Verlag Marie Leidorf.
- Crowfoot, E., Pritchard, F. and Staniland, K. (1992) *Medieval Finds from Excavations in London: 4 Textiles and Clothing c1150-c1450*, London: HMSO.
- Dahl, C. (2014) "Shopping in the Early Modern North. Shops, shopkeepers and their customers in 16th century Malmö and Elsinore" in Ling Huang, A and Jahnke, C - eds, *Textiles and the Medieval Economy: Production, Trade, and Consumption of Textiles, 8th-16th Centuries*, Ancient Textiles Series 16, Oxford: Oxbow Books.
- Demant, I. (2009) "Principles for reconstruction of costumes and archaeological textiles" in in Alfaro, C., Tellenbach, M. and Ferraro, R. - eds, *Textiles y Museologia – Clothing and identities; New perspectives on textiles in the Roman Empire*, Valencia: Dress ID, 143-154.
- Diderot, D. (1751) *L'encyclopedie, ou dictionnaire raisonné des sciences, des arts et des métiers*.
- Dyer, A. - ed (1967) "Inventories of Worcester tradesmen" in *Miscellany II*, Worcestershire Historical Society, new series, volume 5, 19-21.
- Egan, G. (2001) "Some medieval knitting needles discovered in London" paper presented at *Knitting before 1600: In memoriam Montse Stanley*, 24 March, Courtauld Institute, London, Medieval Dress and Textile Society (MEDATS) Newsletter, 2, 11.
- Fagan, B. (2000) *The little ice age*, New York: Basic Books.
- Flury-Lemberg, M. (1988) *Textile conservation and research*, Bern: Abegg-Stiftung, 328-333 and 222-231.
- Gagneux-Granade, M. (2015) *L'Homme et les mailles – histoire critique des mailles textiles: filets, réseaux, tricot, crochet*, unpublished thesis, CIETA, Musée de Tissus, Lyon.
- Gibson, J. - ed (1985) *Banbury Wills and Inventories, Part One 1591-1620*, Banbury Historical Society, 13.
- Gilbert, R. (2009) *The king's vest and the seaman's gansey: continuity and diversity of construction in hand-knitted body garments in north western Europe since 1550*, MPhil thesis, Textile Conservation Centre, University of Southampton.
- Greenwell, W. (1860) *Wills and Inventories from the Registry at Durham, Part II*, Durham: The Surtees Society, 38, items 105 and 125.



- Grömer, K. (2009) "Reconstruction of pre-Roman dress in Austria: a basis for identity in Roman province Noricum" in Alfaro, C, Tellenbach, M and Ferraro, R – eds, *Textiles y Museologia – Clothing and identities; New perspectives on textiles in the Roman Empire*, Valencia: Dress ID, 155-166.
- Hálová-Jahodová, C. (1955) *Vergessene Handwerkskunst*, Prague, 139.
- Hammarlund, L. (1997) "Tekstilenes fjerde dimensjon - håndverkerens kunnskap og redskap" in *SPOR – fortidsnytt fra midt-norge*, 2, 24.
- Hammarlund, L. (2005) "Handicraft Knowledge Applied to Archaeological Textiles" in *The Nordic Textile Journal*, 87-119.
- Harlow, M. and Nosch, M-L. (2014) "Methodologies in textile and dress research for the Greek and Roman World: the state of the art and the case for interdisciplinarity" in Harlow, M and Marie-Nosch, M-L – eds (2014), *Greek and Roman textiles and dress: an interdisciplinary anthology*, Ancient Textiles Series 19, Oxford: Oxbow Books, 1-33.
- Hendzsel, I., Eszter Istvánovits, E., Valéria Kulcsár, V., Dorottya Ligeti, D., Óvári, A. and Pásztókai-Szeőke, J. (2008) "Reconstruction of Roman Provincial and Barbarian Dress in the Hungarian National Museum" in Gleba, M. and Munkholt, C. (eds) *Dressing the past*, Oxford: Oxbow Books, 29-42.
- Hiatt, J. (2012) *The principles of knitting: methods and techniques of hand knitting*, New York: Touchstone.
- KEME (2015-2017) http://ctr.hum.ku.dk/early_modern_textiles_and_dress/knitting/project_description/ (accessed 3 June 2016).
- Kjellberg, A. (1988) "Knitting and the use of knitted goods in Norway before 1700: From archaeological finds to documentary evidence" in Estham, I. and Nockert, M. - eds *Opera Textilia variorum temporum*, Stockholm, 145-153.
- London Record Society (1972) *The port and early trade of early Elizabethan London documents*, London Record Society Publications, 8.
- Kruseman, G. and Feis, L. (2014) "De kleren van de vrouw in manskleren ca1610" in *Kostuum: jaarboek van de Nederlandse kostuumvereniging*, 19-37.
- Kruseman, G., Sturtewagen, I., and Malcolm-Davies, J. (2016) "Erasmus' muts" in *Kostuum: jaarboek van de Nederlandse kostuumvereniging*, 72-89.
- Levey, S. (1982) "Glove, cap, and boot-hose" in *Crafts*, 57, 34-40.
- Lipson, E. (1921) *The history of the English woollen and worsted industries*, London: A and C Black, available at <https://ia600204.us.archive.org/20/items/cu31924032383410/cu31924032383410.pdf> (accessed 4 June 2016).
- Maeder, E. (1980) "The restoration of a 16th century Swiss mercenary soldier's costume in the Historical Museum, Bern, Switzerland" in Pertegato, F. (ed) *Conservation and restoration of textiles: international conference, Como 1980*, Milan: CISST, 224-228.
- Malcolm-Davies, J. and Davidson, H. (2015) "'He is of no account ... if he have not a velvet or taffeta hat': a survey of 16th century knitted caps" in Grömer, K. and Pritchard, F. (eds), *Aspects of the Design, Production and Use of Textiles and Clothing from the Bronze Age to the Early Modern Era, NESAT XII* (North European Symposium for Archaeological Textiles), Hallstatt, Austria, May 2014.
- Marendy, M. (1993) "The Development and the Evaluation of Costume Reproduction Pattern Blocks for an 1880s Woman's Dress" in *Clothing and Textiles Research Journal*, 11, 41-52.
- Masner, K. (1924) "Gestickte Teppiche" in *Schlesiens Vorzeit*, 8, 127.
- Merrill, M., Seamons, A., Shannon, B., and Harvey, A., (1990) *17th Century Knitting Patterns as adapted for Plimoth Plantation*, Monograph One. 2nd edition. Boston, Weavers' Guild.
- Mida, I. and Kim, A. (2015) *The Dress Detective*, London: Bloomsbury.
- Munro, J. (2002), "Industrial Change in the Fifteenth- and Sixteenth-Century Low Countries: the Arrival of Spanish Merino Wools and the Expansion of the 'Nouvelles Draperies'", *Working Papers*, University of Toronto, Department of Economics, available at <http://EconPapers.repec.org/RePEc:tor:tecipa:munro-02-03> (accessed 16 August 2016).
- Myers, A – ed (1969) *English historical documents 1327-1485*, 4, London: Routledge.



- Ornsby, G. (1878) *Selections from the Household Books of the Lord William Howard of Naworth Castle*, Surtees Society, 68, 162.
- Peacock, E. (2014) "Experimental soil burial studies for archaeological textile preservation and research – a review" in Bergerbrant, S. and Fossøy, S. (eds) *A Stitch in Time: Essays in Honour of Lise Bender Jørgensen*, Gothenburg: Gothenburg University.
- Rast-Eicher, A. and Bender Jørgensen, L. (2012) "Sheep wool in Bronze and Iron Age Europe" in *Journal of Archaeological Science* 40, 1224–41.
- Ringgaard, M. (2010) "To par strixstrømper oc en nattrøie naccarat" *Filtede og strikkede tekstiler fra omkring år 1700, fundet i Copenhagenske byudgravninger - og sammenhænge mellem tekstilers farve og bevaring*, Part 1: Tekst; part 2 Bilag. PhD thesis, Det Humanistiske Fakultet, Copenhagens Universitet.
- Ringgaard, M. and Scharff, A. (2010) "The impact of dyes and natural pigmentation of wool on the preservation of archaeological textiles" in Andersson Strand, E., Gleba, M., Mannering, U., Munkholt, C. and Ringgaard, M. (eds), *North European*.
- Symposium for Archaeological Textiles X*, 221-224. Oxford: Oxbow Books.
- Roberts, E. and Parker, K. – eds (1992) *Southampton Probate Inventories, 1447-1575*, Southampton Record Society, 34, 216-217.
- Rodwell, K. and Bell, R. (2004) *Acton court: The evolution of an early Tudor courtier's house*, London: English Heritage.
- Russell, H. (1965) "Help for Designers. Construction factor: An aid to fabric evaluation and design" in *Textile Industries*, June.
- Ryder, M. (1964) "The History of Sheep Breeds in Britain" in *The Agricultural History Review*, 12, 1, 1-12 & 65-82.
- Ryder, M. (1981) "Medieval sheep and their wool types", in Crossley, D. - ed, *Medieval Industry*, CBA Research Report, 40, available at http://archaeologydataservice.ac.uk/archives/view/cba_rr/rr40.cfm (accessed 30 June 2016).
- Ryder, M. (1983) "Wools from textiles in the Wasa a Seventeenth-century Swedish Warship" in *Journal of Archaeological Science*, 10, 259-343.
- Ryder, M. (1983) *Sheep and Man*, London: Duckworth.
- Ryder, M. (1984) "Wools from textiles in the Mary Rose a 16th-century English Warship" in *Journal of Archaeological Science*, 11, 337-263.
- Rutt, R. (1987) *A history of hand knitting*, London: Interweave Press.
- Simonds d'Ewes (1682) "Journal of the House of Commons: February 1559" in *The Journals of All the Parliaments During the Reign of Queen Elizabeth*, available at *British History Online* <http://www.british-history.ac.uk/no-series/jrnl-parliament-eliz1/pp44-49> (accessed 3 June 2016).
- Staniland, K. (1997) "Getting there, got it" in Gaimster, D. and Stamper, P. (eds) *The Age of Transition: The Archaeology of English Culture, 1400-1600*, Oxford: Oxbow Books.
- Sturtewagen, I. (2016) *All together respectably dressed: Fashion and clothing in Bruges during the fifteenth and sixteenth centuries*, PhD thesis, University of Antwerp.
- Styles, J. (2010) *Threads of feeling: the London Foundling Hospital's textile tokens 1740-1770*, London: Foundling Hospital.
- The Livestock Conservancy (2016) available at <http://livestockconservancy.org/index.php/heritage/internal/black-welsh-mountain> (accessed 30 June 2016).
- Thirsk, J. (2003) "Knitting and knitware, c. 1500-1780" in Jenkins, D. (ed) in *Cambridge history of western textiles: 1*, Cambridge: Cambridge University Press, 562-584.
- Trow-Smith, R. (1957) *A history of British livestock husbandry to 1700*, London: Routledge and Kegan Paul.
- Turnau, I. (1991) trans. Szonert, A., *History of knitting before mass production*, Warsaw: Institute of the History of Material Culture, Academy of Sciences.
- Turnau, I. (1983) "The Diffusion of Knitting in Medieval Europe" in Harte, N. and Ponting, K. (eds), *Cloth and Clothing in Medieval Europe: essays in memory of Professor E. M. Carus Wilson*, London: Heinemann, 368-389.



- Turney, J. (2009) *The culture of knitting*, London: Bloomsbury'.
- Turriano, P.-J. (1595) *Los Veínte Y Un Libros de los Ingenios, Y Maquinas de Iuanelo, los quales le Mando escribir y Demostrar el Chatolico Rei D. Felipe Segundo Rey de las Hespañas y Nuevo Mundo*, Biblioteca Nacional de Madrid, available at http://dmd.mpiwgberlin.mpg.de/simple_search/dmd/database/dmdlib?fn=permanent/ded/images/jt372andid=jt372 (accessed 5 June 2016).
- Walton, P. and Eastwood, G. (1988) *A Brief Guide to the Cataloguing of Archaeological Textiles*, York: Textile Research Associates, 4th edition.
- Walton Rogers, P. (2002) 'Textile production' in Ottaway, P. and Rogers, N. – eds, *Craft, Industry and Everyday Life: Finds from Medieval York (The Archaeology of York 17/15)*, York: CBA., 2732-2735.
- Walton, P. (1981) "The textiles" in Harbottle, P. & Ellison, M. (eds) *An excavation in the castle ditch, Newcastle upon Tyne. Archaeologia Aeliana*, 5th Series 9, 190-228.
- Warburg, L. (1984) "Den Strikkende Madonna I Syd og Nord" in *Cras*, 39, 79-90, Silkeborg Kunstmuseum.
- Wensleydale Longwool Sheep Breeders' Association (2016), available at http://wensleydale-sheep.com/?page_id=5 (accessed 30 June 2016).
- Williams, C. – ed (1995) *English historical documents 1485-1558*, 5, London: Routledge.
- Youatt, W. (1837) *sheep, their breeds, management and diseases*, London: Robert Baldwin.
- Zander-Seidel, J. (2010) "Haubendämmerung: Frauenkopfbedeckungen zwischen Spätmittelalter und Früher Neuzeit" in Schwinges, Rainer C., Schorta, R., Oschema, K. (eds) *Fashion and Clothing in the Late Medieval Europe - Mode und Kleidung im Europa des spääten Mittelalters*, 1 (2) 37-43.
- Zimmerman, H. (1998) "Textiel uit de beerput van de Latijnse School" in *Hervonden stad: Jaarboek voor archeologie, bouwhistorie en restauratie van de gemeente Groningen*, Groningen: Stichting Monument en Materiaal
- Zimmerman, H. (2007) *Textiel in context: een analyse van archaeologische textielvondsten uit 16e-eeuws Groningen*, Groningen: Stichting Monument & Materiaal.
- Zimmerman, H. (2000) "Barett: gestrickt und gewalkt – Replik eines Groninger Fundstückes aus der Zeit des Predinius" in *Ornamente*, 2, 44-48.
- Wyss, R (1973) "Die Handarbeiten der Maria: Eine ikonographische Studie unter Berücksichtigung der Textilten Techniken" in *Artes Minores: Danke aus Werner Abegg*, Bern: Stampfli.
- Zhao, S, Jakob, W, Marschner, S and Bala, K (2011) Building Volumetric Appearance Models of Fabric using Micro CT Imaging in SIGGRAPH 2011 Proceedings, available at <https://shuangz.com/projects/ctcloth-sg11/ctcloth-sg11.pdf> (last accessed 21 February 2016).
- Zwartbles Sheep Association (2016) available at <http://www.zwartbles.org/history-of-the-breed/> (accessed 30 June 2016).
- Other sources**
- Blacker Yarns: <http://www.blackeryarns.co.uk/yarns-by-breed/limited-edition-rare/pure-black-welsh-mountain-aran-knitting-yarn.html> and <http://www.blackeryarns.co.uk/knitting-wool-yarns/aran-and-chunky/pure-ryeland-aran-yarn.html> (accessed 1 June 2016).
- JamiesonandSmith:<http://www.shetlandwoolbrokers.co.uk/Shetland-Aran-Worsted> (accessed 1 June 2016).
- Longwool Sheepshop: <http://wensleydalelongwoolshop.co.uk/?product=aran> (accessed 1 June 2016).
- New Lanark Mills: <https://www.newlanarkshop.co.uk/pebble-aran-wool.ir> (accessed 1 June 2016).
- Corresponding author: jane@jmdandco.com