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Expertise and Creativity in Knitwear Design

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Abstract: As commercial knitwear designers gain experience, many appear to lose their creativity. They often find they have gone stale, and need to change jobs to find fresh challenges. But although designer burnout is a significant phenomenon, experienced designers gain both a broader understanding of their design context and thus a more sophisticated understanding of design problems, and develop expertise in creating the designs their companies require quickly and efficiently. However they may find it harder to create innovative designs. Partly as a result of widespread fallacious beliefs about creativity being antithetical to rational problem solving, experienced designers are not encouraged to develop sufficiently flexible skills, and the skills they do develop are undervalued. This paper relates the demands that knitwear designers face to the cognitive psychology of learning and expertise, to examine what designers learn from experience, and how the demands that govern their designing behaviour can be altered to enable them to develop their ability to innovate as well as design efficiently.

Keywords: Expertise, creativity, psychology of design, knitwear, fashion.

Introduction

Being creative isn't just producing something new and different. The challenge is to create something both novel and *appropriate*. In the fashion and knitwear industries this means producing something that is fresh and different while being true to the company style and brand image, and meeting both the customers' needs and expectations and the company's commercial and manufacturing requirements.

In the knitwear industry, novice designers frequently appear to be more creative than their more experienced colleagues. As in many other fields [1], innovative designs often come from novices, and experienced designers often tend to produce large numbers of very similar conservative designs. We have observed designer burnout as a significant problem in the knitwear industry: after a few years many designers lose their edge and have to change jobs to find a fresh challenge, or move into new roles or new careers [2]. We have also found that a number of myths about the nature of creativity are prevalent in the knitwear industry, that are in dramatic conflict with the findings of research on the nature of creative thinking, and which influence colleagues' and managers' attitudes to the skills and design behaviour of experienced designers. So what do designers learn with commercial experience? And how does it affect their creativity? And what can design managers in this and other industries do to maintain and enhance their designers' creativity and effectiveness?

Multiple demands driving designing

Innovation is difficult, effort-intensive and involves many false starts – creative individuals tend to be driven, ambitious and self-confident, as well as unconventional and open to new ideas, and in science, to relish hard problems [3]. Edison famously described genius as one percent inspiration and 99 percent perspiration. Innovation requires an active need or desire to innovate – what and how designers design depends on how they conceive their design problems, especially the requirements and constraints they have to meet, as well as on their contexts and working cultures, and on their skills and experiences. Innovation requires both problems whose characteristics facilitate innovation, and environments that reward the required effort investment.

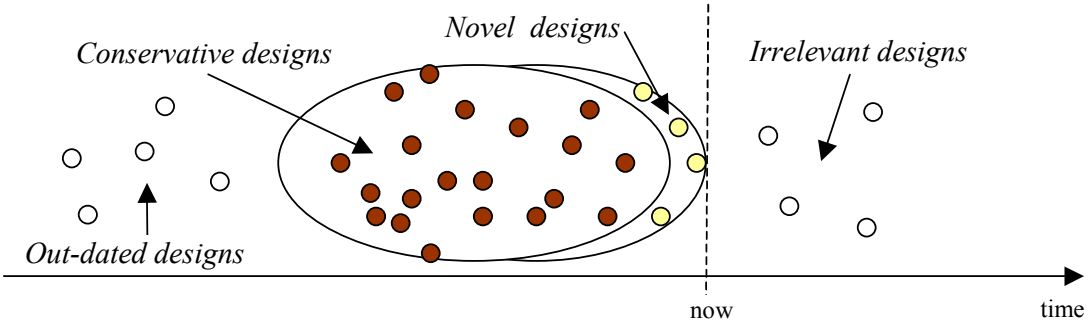

Figure 1. The development of a fashion envelope

Pressures to innovate differ markedly between industries. Consumer products like clothes must appear contemporary and be within the scope of acceptability while being different enough to attract attention. Innovative designs push this boundary without leaping beyond it – being too early can be a fatal mistake in the fashion

industry [4]. In engineering reusing components and reliable techniques is a virtue, but radically new approaches offer the potential of decisive competitive advantage; however customers want the reassurance of proven concepts [5]. For instance the satellite industry is very conservative because clients only want to use technology that has been tested in space by someone else. While technology push is a significant factor in the development of fashion, manufacturing companies want to make efficient use of their existing equipment.

Knitwear design is a process simpler but very similar to many branches of engineering design [6, 7]. It is a team activity involving a problematic interaction between knitwear designers, who are responsible for the aesthetic aspects of the design, and knitting machine technicians, who do a lot of detail design in programming industrial knitting machines. The subtle relationship between the structural characteristics and cost of a knitted fabric and its appearance and behaviour makes creating innovative stitch structure patterns a technically complex problem. But one important difference between knitwear and engineering design is that designing primarily to meet aesthetic criteria imposes different pressures to reuse or be novel. The aesthetic design of fashion dependent consumer products involves creating something novel enough to differentiate itself from competitors, while standard enough to fit into the existing fashion context set by other designs – a subtle balance achieved by perceptual judgement. The most important skill of a knitwear designer is understanding how to fit their own garments into the context created primarily by the garments produced by other designers but influenced by the broader culture, that defines spaces of acceptable garments within particular fashions – see figure 1 [4]. We have made the argument elsewhere [4] that creativity in commercial knitwear design (an activity very different from what the couturiers do) lies primarily in finding different views of what characteristics garments should share with others in the same fashion, and how they can differ, so that the consumers perceive them as within contemporary fashion. These are novel understandings of what the spaces of garments within particular fashions are and what garments they might contain, enabling the designers to discover uncharted regions of the spaces (see figure 2).

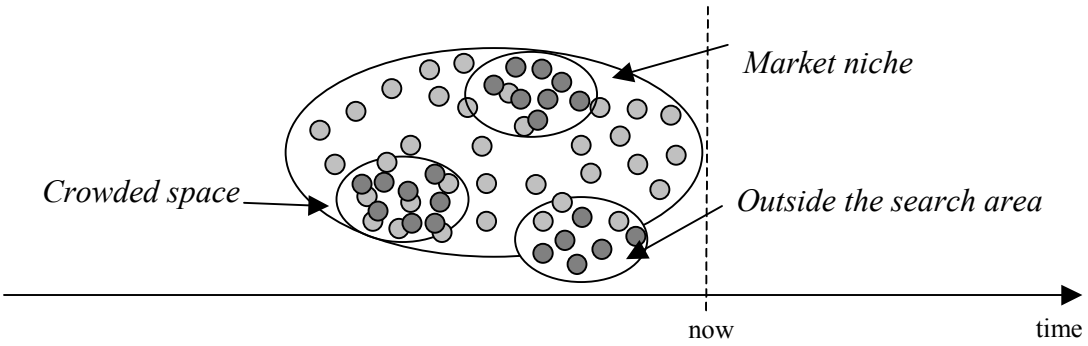

Figure 2. Regions in a fashion space

Knitwear designers are open about the subjectivity of their decision-making. In knitwear design, novelty is more valuable than standardisation, and quality can only be judged by comparison. Designers only get late and weak feedback about sub-optimal actions, and are under pressure to produce many designs quickly [6, 7]. These characteristics of the task influence the relationship between expertise and innovativeness. The range and effectiveness of design strategies is ill-understood in

knitwear design, so there is little training in methods for creating particular kinds of designs or in being innovative, though some designers develop useful tricks.

The demands that designers respond to depend not only on the intrinsic characteristics of the design and the requirements it must meet, but also on the commercial context of the company (importantly the business model governing who makes which decisions [8]), and on the roles designers have within an organisation. For example novice junior knitwear designers are often given fairly generous amounts of time for individual garment designs, while their more experienced senior colleagues must not only design individual garments but also ensure that ranges are balanced and manufacturing resources are used, while worrying about working relationships with colleagues, relations with buyers and their home lives. As professional designers in all industries nearly always design under time pressure, activities that are not explicitly rewarded are relatively neglected, such as documenting, archiving and doing research that isn't directed to a specific need. The rewards that govern behaviour can to some extent be managed, for example in engineering by requiring adherence to standard procedures that demand proper record keeping.

How designers formulate their problems profoundly influences how and what they design [for instance 9, 10]. The aspects of design problems that designers actively consider when they make major preliminary decisions and invent core ideas exert a powerful influence on the design, notably the characteristics of the site in architecture [11]. Research on designer behaviour in a variety of industries has found that expert designers put a lot of effort, typically more than novices, into elaborating their understanding of the problems they are trying to solve – the requirements and constraints the design should meet. Of course, problem formulations are not static; they evolve as designers reflect about their designing activities [12, 9] and discuss them with others [10, 13]. Problem framing is a skill that is developed with practice, but sometimes reframing the problem to see the design challenge differently is the key to success.

Developing expertise and losing creativity

In the knitwear industry there are three primary sources of innovations. (1) Swatch agencies develop their own stitch structure patterns and market those of students; swatches embodying these patterns are ordinarily created independently of garment shapes or any consideration of manufacturing constraints. (2) Couturier design houses and market-leading upmarket knitwear companies, where highly striking and innovative designs are valued enough for a large effort investment in each one, and again manufacturing constraints are a relatively minor factor. The most upmarket companies can subcontract manufacturing to obtain particular effects even when they have their own knitting machines to keep busy (for instance Escada). (3) Companies designing for conservative markets, where the differentiation of new products from those of past seasons and from competitors is subtle and requires innovation in textures. Companies where designers control which garments are marketed [see 8] can make their own decisions about how to price garments on the individual merits of each garment (even if they are very concerned about price points). A lot of innovation in knitwear comes from adapting features of tailored garments.

Within commercial knitwear companies, the designers who often produce innovative designs – placement students, inexperienced junior designers, freelancers – are those who are bringing their individual problem framing skills to

problems they have relatively little practice with, where they have relatively little knowledge of or concern for the practicalities of manufacturing or getting things done within the organisation. More experienced designers usually produce large numbers of designs that are relatively similar to each other and to what they produced before, using design elements that they know will work, and avoiding design choices that would lead to interpersonal contact (see figure 3). Many feel and are perceived to be stale. Burnout is a major cause of rapid turnover among knitwear designers. A high proportion of working knitwear designers are under thirty, and many move on after two or three years in a job, while technicians stay with companies for much longer periods. There are social and economic reasons for the high turnover among designers, but a major motivation for moving is staleness and the need for fresh challenges.

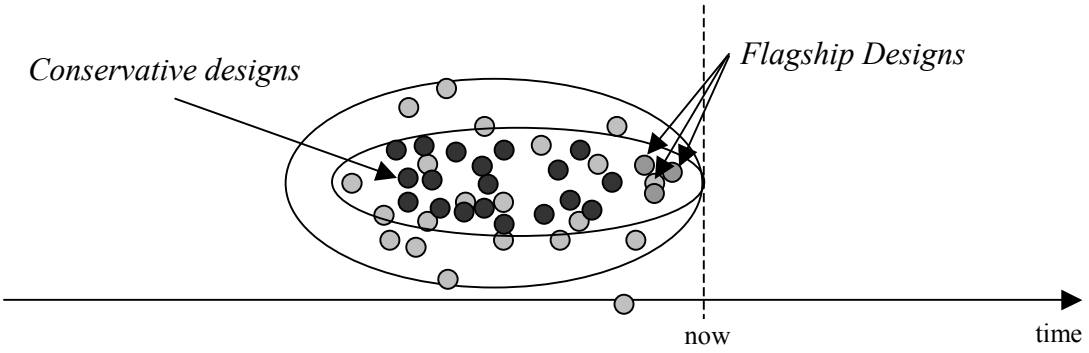

Figure 3. Conservative designs

This phenomenon has not gone unnoticed in the knitwear industry, but interpretations of it are rooted in a fallacious view of "creativity" widespread within the knitwear industry as something only relevant to artistic activities and as the opposite of problem solving, so that "being creative" cannot and should not involve problem solving. We have even met people within the industry who think that training in any kind of problem solving field, such as computer science, stops one from being a good designer. However, psychological studies of creativity [14, 15, 16, 17] and of "convergent" and "divergent" thinking [18, 19] show that problem solving ability and fluency of idea generation are orthogonal abilities, and that success in most creative activities requires both creativity and the problem solving ability to sift good ideas from bad ones and think them through [see 20].

Design managers comment frequently that technical knowledge is bad for knitwear designers because it makes them less creative; and imply that expert designers who have acquired technical knowledge are less creative. We have heard this view expressed explicitly by the Head of School responsible for one British knitwear design degree course. The knitting machine technicians responsible for realising the designers' conceptual designs say that more technical knowledge for their designers would make their lives easier because they wouldn't produce so many impractical designs. The British knitwear designers we've spoken to want more technical knowledge than they've got, or have time to acquire; however the German designers we've met are proud of their ignorance of technical matters. We suspect that this cultural difference is partly due to the narrower meaning the word 'Design' has in German, referring only to aesthetic form creation, and the belief that creativity is restricted to artistic activities being stronger among non-technical Germans than it is in the English-speaking world. We argue elsewhere [21] that knitwear designers

would benefit from greater technical knowledge and expertise with CAD systems, but there is some truth to the argument that experienced, knowledgeable designers are restricted by designing within the capability of the knitting machines, instead of trying to push them to their limits. Designers less aware of or concerned with technical restrictions often do create feasible innovative designs – but at the price of a lot of effort, much of it invested in infeasible designs.

But there's a different view of the burnout phenomenon, and an alternative career path for experienced designers: they have become expert at doing what they're paid for, and those who can cope with a broader, more managerial role are equipped to integrate a wider range of concerns into their designing activities than just how an individual garment will fit into the context of fashion. However many designers find this hard, so knitwear companies often find it difficult to recruit designers into managerial roles. In the rest of this paper we elaborate on what knitwear designers do and do not learn with experience, and how this influences their creativity and effectiveness.

Expertise in design problem solving

Experienced designers usually know more than novices. Not only do they know more facts, rules, principles, guidelines and examples, but their knowledge is more highly organised so that it is more accessible and applicable when needed [see 22]. But expertise, especially in design, is primarily skilled action, for perceiving, formulating and solving problems. Cognitive psychologists have developed a detailed understanding of learning and mental actions [23, 24, 25, 26], and of the nature of expertise [22, 27].

Expert problem solving in any field requires a rich and powerful set of associations between different situations and appropriate actions. These actions may be purely mental or involve speech or physical movement, for instance in sketching. Experts (performing routine tasks) work forward from the present situation: they recognise what the problem situation is, they know what to do, and do it, without needing to formulate a plan. Design is characterised by a cyclic process of problem reformulation, design synthesis, and design evaluation: both the problem and the solution evolve [28, 29, 9, 10, 11, 12, 13]. Design expertise includes very powerful task-specific pattern synthesis and pattern transformation actions to create complex designs to fit the task situation. It also includes powerful pattern recognition actions to evaluate these designs in terms of the task situation. For experts in many fields, their task-specific problem-solving procedures include recalling and adapting solutions to previous problems; for designers, these are elements of previous designs. Knitwear designers' extensive knowledge of a large number of other designs plays a very important role in their creative thinking [4, 30] – in many design situations the key creative step is selecting an effective source of inspiration [31].

As Visser and others have observed, designers including engineers and software developers are guided by global plans but act opportunistically to correct mistakes, respond to unexpected events and fulfil latent goals [32, 33]. Such situation-driven contingent behaviour, using goals and plans as resources, is characteristic of all human thinking [25, 26].

Novices, who lack task-specific situation-action associations, explore and learn from their mistakes. They reason backwards from what they want to how they can get it, applying general problem solving strategies to the facts that they know. Task-specific procedures are created as the starting points and outcomes of such reflective problem solving processes are associated in memory, to create situation-

action pairs. Now no reasoning is needed to go from recognising the situation to performing the action. Situation-action associations that are repeatedly successful are strengthened and generalised; when they fail, situations are differentiated so that more tightly specialised situation-action associations are formed [24]. In non-routine situations, experts do means-ends reasoning just like novices, but their conscious, reflective problem-solving strategies are also a learned skill. By learning from the success and failure of their reasoning they develop more elaborate and powerful specialised strategies for the problems they meet in their field. Experts' situation-specific effective procedures embody knowledge about their work environment as well as the domain: what resources are available, who can do what, what will annoy someone, and so on. Thus experienced designers learn the limits of what is possible in practice, to the extent that they can map problems back to their design choices – they learn to avoid actions that are related to the appearance of failure, interpersonal conflict or other negative rewards.

Perceptual visuospatial knowledge is a vital part of expertise. Humans are extraordinarily good at perceiving the important features of their environment, including categories, symbols and meanings, as well as subtle similarities and differences. This ability is precisely tuned to the demands of the current task. Experienced designers know about and can recognise more perceptual features [see 34], and this is a highly trained skill in many design professions. In aesthetic design, for instance of knitwear or architecture, perceptual visuospatial knowledge of the context and of what is required is an essential part of formulating the problem. For clothes this includes the shapes, locations, colours, and textures of garment features, how they fit into the current and future fashion context, and what their emotional and cultural connotations are. For knitwear and fashion designers, the depth and accuracy of this perceptual knowledge, and the ability to use it in design, is the key element of expertise [4]. Knitwear designers' comments, and experimental studies of expertise in other fields [34, 35, 36], indicate that this visuospatial knowledge is very highly structured according to the designers' conceptual understanding of the structure of garments and the spaces of acceptable garments within fashions [4]. Designers' visuospatial pattern synthesis and pattern evaluation actions are tuned according to the designer's perceptual understanding of the problem. Thus designers create designs conforming to their perceptually-recognised visuospatial constraints and requirements (within the limitations of the power of their pattern synthesis actions); and recognise the degree to which they conform to visuospatial constraints and requirements.

Expertise in design problem formulation: identifying and prioritising multiple demands

Understanding the problem is a vitally important part of problem solving, especially in design. This involves both perception and reasoning. Designers face problems that are inherently ill-defined, that are underspecified and in which important constraints are implicit [37]. Designers often reformulate the design problem, to add structure and to recast it in terms more useful for guiding its solution: categorising it, thus activating additional constraints, and implicitly selecting solution strategies and eliminating alternatives. Finding the right view of a problem is often the key to solving it. Such reformulations can be guided by established principles and guidelines, individual preferences, the recognition of a similarity to another problem, or be more-or-less arbitrary. Expert designers put considerable effort

(typically more than novices) into elaborating their understanding of the problem. They collect all the available constraints on the design, to minimise the range of designs they need to think about.

As designers gain experience, they develop skills in recognising, formulating, prioritising requirements and constraints, and employing them in their design thinking. Experienced knitwear designers are aware of a wide range of issues beyond the fashionableness of an individual design.

Product requirements

Knitwear designers need to create attractive fashionable garments that will appeal to their companies' target markets, so their most essential skills are in developing and updating their understanding the spaces of acceptable garments within particular fashions, and in knowing how to judge how the designs they create will relate to the variety of other garments that will be on sale at the same time, and what aesthetic effects and cultural connotations the garments will be perceived to have [4]. This requires an acute awareness of fashion that is often easier for younger, less experienced designers to maintain, as they typically have more time to immerse themselves in contemporary culture. However individual garments are parts of ranges, that need to be coherent to appeal to customers by indicating an established consistent style, and to entice them to buy more than one garment. Creating effective ranges is an important aspect of knitwear and fashion designers' jobs, and thus of how experienced designers formulate their design problems. Innovative garments can attract attention to a range from which customers buy cheaper or more conservative items, and may even function as loss leaders (figure 3). Many ranges also require garments that are deliberately designed to be more conservative as well as to meet needs for various specific kinds of garments, in particular in order to maintain continuity with a company style or to be compatible with earlier garments customers may already own.

Manufacturing requirements

Most commercial knitwear designers work for companies that have direct responsibility for their manufacturing capability. Keeping machines and employees productively busy is extremely important to the success of the company. Knitting machines are extremely expensive, can only knit in one gauge, and what stitch structures they can and can't knit depends on how old they are. (Knitting machine technology has developed rapidly over the last twenty years so that contemporary machines can achieve nearly all the effects possible for hand-knitting and can create a variety of three dimensional effects.) Innovation often lies in pushing the constraints on stitch structures imposed by the knitting machines to their very limits, demanding that knitting machine technicians attempt to create programs for features that will be difficult and maybe not even possible. (The development of innovative designs is hindered by the frequent ineffectiveness of the communication between knitwear designers and technicians, due largely to the inherent difficulty of communicating designs for knitted structures [6, 7]. Knitwear designers frequently commented to us that technicians would assert that a design could not be programmed until bullied into producing it; the technicians told us that only a minority of designs were feasible at their intended price point, though often they could produce something different with a similar visual effect that would satisfy the designers.) The time a garment piece takes to knit is a major determinant of its cost,

so many designs that *could* be manufactured are very uneconomical, because they take a long time to knit. The skill of experienced technicians often lies in understanding how a design could be created that looks very similar to what the designers want, but takes less time to knit and is therefore a lot cheaper to produce.

System requirements

Experienced designers carry a responsibility beyond individual designs and need to balance all the needs of the company and its employees. They need to take a system view rather than being able to concentrate on producing the best designs; this requires knowledge and habits of thought that are not trained in British knitwear and fashion design courses. Designers need to balance conflicting pressures that have nothing to do with appearance or fashionableness. Therefore many designs become compromises. Garments need to make money. Most knitwear is designed to very tight price points given by customers or set internally. If garments can be designed that can be produced at less than the target price points the company makes money, in the opposite case it loses money. The profit of the company depends not only on the cost at which individual designs could be produced, but on the efficient use of manufacturing resources. For each season the company must make sure that it uses both new and old machinery. Experienced designers allow for this in their composition of ranges. The designs that are created control the workload of everybody involved in the design and sampling process. Experienced designers wish to avoid conflicts within organisation, and need to make sure that their colleagues have a balanced workload and are happy with their working conditions. They would therefore be reluctant to push a novel design idea that would put a huge workload on one technician, even if they knew that the design would be worthwhile. Ranges are always biased by the strength and weaknesses of the team that generate them and experienced designers learn to work within them.

Beside the strengths and inclinations of the designers and the technical abilities of the technicians, the physical appearance of designs is very strongly influenced by the taste of the buyer who is likely to select the design. Designers can only be as daring as the people who select their designs for sale. This is a very subtle balance. If designers produce designs that are too advanced or alienate the buyers they will lose the sale. However, if they step back when buyers reject designs for trends they don't believe in, that then become significant, or fail the alert the buyers to powerful new trends, they are personally held responsible for not asserting themselves enough.

Innovation versus reuse

As designers need to minimise development costs and keep machines busy doing what they are known to be capable of, as well as keep their collections abreast of fashion, reuse of design solutions is a rational survival strategy for most companies. Using the same yarn over several seasons decreases the material costs, because the companies can negotiate better prices and save on sampling time. When the technicians know the material properties they know what structures can be generated in yarns and require less experimentation with machine settings. Typically a company uses the same base yarn over several seasons and introduce different yarns as highlights or to test them as future base yarns. The reuse of existing designs or parts of designs makes sound economic sense. A design that has sold well in the past season might again sell well in the next season with very minor

updates. However such design sequences should not be carried for too long, and designers need to question the reuse of designs in their basic ranges as well as their more fashionable ranges. The reuse of design elements in a range or between seasons not only makes sampling easier and faster, but also creates coherence between ranges and seasons. Many companies include the innovations of past seasons into their basic ranges to justify the development of expensive new structures, such as a novel cable, or use it as a defining feature in many different designs. Reuse therefore reduces the risk in terms of the cost of an individual garment, sampling time and manufacturing time, as well as market acceptance.

Constraints as drivers of creative thinking

Design is guided by the constraints on the product. Hard constraints, to which the product *must* conform, act differently from guidelines, targets, and soft constraints, to which the product *should* conform. All these features of the problem formulation serve to activate learned problem solving procedures, including the recall of prefabricated solution chunks. Thus they channel designers into repeating and adapting designs they have produced before. When designers are unable to create designs conforming to all the soft constraints, they weaken or discard the less important constraints, to make their designs produced by their standard methods meet the task demands as well as possible. But when hard constraints are in conflict, they can ensure that no standard design will work. This situation forces designers to try to innovate, by exploring and using reflective problem solving strategies, and progressively refining their understanding of the problem. From repeated failures and partial successes they refine their strategies for reformulating problems and generating novel ideas. The role of difficult combinations of hard constraints as a spur to creativity has been observed by many outstandingly creative people, for instance Gordon Murray, the racing car designer, who constantly needed to work round and exploit complex technical regulations [38]. But designers of consumer products can only use their perceptual visuospatial knowledge of the space of acceptable designs to judge better or worse. Thus the contextual constraints imposed on consumer products by the need to appear different, while having the right forms of aesthetic appeal and cultural significance, are too soft and too imprecise to force the abandonment of standard thinking procedures.

Novelty versus conservatism in designing

In many fields, innovation occurs most frequently among the naïve [1]. Why, and when, might this happen? Novices, especially students, often have more time, more enthusiasm, greater willingness to fight for what they want, and less pressure to produce adequate results quickly rather than good results slowly. They also have different ideas from established members of design teams, which is why designers in knitwear companies value placement students. The acute awareness of fashion required by knitwear and fashion designers is difficult for designers past thirty, with families, to maintain. But expertise can also be limiting.

Expert designers have more and more powerful design procedures and prefabricated design elements (giving huge efficiency advantages) than novices, who thus explore more, by accident or intention, and so are more likely to find successful novel approaches. *Fixation* is a well-known phenomenon in the psychology of problem solving: people copy recently-encountered previous examples even when they are clearly inappropriate. For instance, in one of a number

of studies of fixation in design [see 39], Jansson and Smith [40] showed design students a mug with a mouthpiece and told them to create a non-spill mug without a mouthpiece: despite this instruction, the majority of designs incorporated a mouthpiece. In many fields, experts will possess memories of a greater stock of relevant designs, so be better able to find an appropriate model, but will find it harder to escape closer matches to the present situation and stronger situation-action associations. Thinking is channelled both by conscious awareness of situations and goals, and by associations in memory: what the psychologists call *mental set*. People with expert knowledge have both richer and stronger associations between elements of their factual knowledge, and more specialised mental procedures. Thus they can focus recall from memory and mental actions more narrowly. This can be an advantage, but mental actions can embody tacit constraints inherited from previous similar problem situations that are no longer relevant, leading to incorrect or unsuccessful problem solving [41]. It can lead designers to produce excessively conservative designs.

Experienced designers' richer stock of procedures and reusable design elements is especially likely to lead them into ineffective designing when these procedures are not obviously wrong, but actions the designers have learned to avoid are now more effective. Not only do technological changes create alternatives to previously optimal techniques. But experienced designers designing for novel technology are more likely than freshly trained students to embody outmoded tacit assumptions in their design thinking. The cultural context also changes, so that previously successful procedures produce excessively conservative designs that are less appropriate or less appealing in the new context.

Why do some designers remain innovative and effective for a long time, while others burn out? This is partly a matter of individual talent and drive. But the demands placed on designers by their task situations influences whether they develop flexible design skills enabling continuing creativity, or whether they develop rigid skills leading to high efficiency, but ultimately to dullness and obsolescence. Burnout is a problem in the knitwear industry. The knitwear designers' task has a number of significant characteristics that influence designers' experiential learning and thus the expertise they develop. *No hard constraints*: All the constraints and requirements on the design can be relaxed to permit the success of normal design procedures. *Late and weak feedback*: knitwear designers pass on their designs to their technicians in the form of technical sketches, which are can be imprecise, incomplete and inconsistent [6, 7]. The hard technical problems are left to the knitwear technicians interpreting the technical sketches, and the only feedback designers usually get is completed garments that may or may not be what they want, some time later, so they cannot trace problems to their own mistakes. *Satisficing pressure*: Knitwear designers are under pressure to produce large numbers of designs very quickly, so cannot invest much effort in any one, therefore they settle for designs that are good enough instead of trying to make them as good as possible. These features of the design task make it hard for designers to learn refined problem solving strategies by encountering situations where their standard procedures fail completely; and reinforce the learning of efficient procedures for producing similar, moderately successful designs. Difficult, innovation provoking problems with conflicting constraints are more common in engineering, but much engineering design is routine adaptation. While this may be adequate to meet immediate needs, extensive experience with routine design will not develop skills that will transfer to other situations.

However, experienced knitwear designers are encouraged to produce conservative designs by other environmental factors besides productivity pressure. Being more aware of the need to maintain continuity of company style and keep relatively old and limited machines busy, they are more conscious that updating rather than innovating is often what is required. More experienced senior designers can also adopt different roles within design teams. Although designing individual garments is ordinarily a solitary activity, designers discuss designs, fashion developments and requirements with their colleagues [see 30]. Creating ranges is often done by teams, in which experienced designers pay more attention to range planning and creating designs quickly to fit slots in ranges left unfilled by the more effort-intensive designs produced by junior colleagues.

Conclusions: Combining creativity with expertise

Our observations of the knitwear industry indicate that while designers develop expertise with experience, attitudes to creativity widely held within the industry contribute to them often being treated as disposable rather than as strategic assets [see 21]. The skills they develop in industrial practice tend to be undervalued, while their innovativeness is allowed to decline. In consequence knitwear designers often burn out, and need to move on or give up designing [2].

While being a creative designer is partly a matter of talent, in knitwear as in other industries, innovativeness can be nurtured and developed. What designers design depends on three factors: the intrinsic demands of the design problem as it is understood and elaborated by the designers; the environment and social context in which the designers work, especially how different kinds of designer behaviour and different kinds of designs are rewarded; and the knowledge and skills the designers bring to the problem. All of these can be actively manipulated by intelligent and sympathetic design management – which will gain from an understanding of how designers develop expertise, and of the nature of creativity as requiring imagination, rich resources of ideas and problem solving skill.

Alleviating time pressure, encouraging innovation and being sympathetic to time-consuming failure will help designers be creative, but more proactive development of skills and experiences to maximise creativity will help more. We have argued elsewhere [42] that this involves supporting designers in refreshing their breadth of knowledge. Our analysis of the development of expertise and designer burnout in knitwear design [2] indicates that it also requires challenging designers with tasks that stretch their analytical skills, and sometimes, rewarding them for error-prone exploration rather than efficiency.

What kinds of skills designers develop with increasing experience depends on what kinds of problems they meet. The experiences that make them more efficient in routine tasks are not those that develop their ability to innovate. Developing skill in innovative thinking – in reflective problem analysis, reformulation and exploration – requires both wide experience and tasks that are tightly enough constrained that designers can see that their customary methods don't work, so they are forced to analyse the tasks more deeply and explore alternative approaches. Designers need to seek out hard constraints, and if necessary invent them, to give themselves problems they can't easily solve.

In many fields of endeavour, creative breakthroughs often come from finding a different problem to solve. Engineers are taught to reformulate problems by stripping away assumptions about *how*, to obtain a more abstract, functional view of *what* their designs should achieve. In knitwear design and other aesthetic design fields, where

hard problems don't often occur naturally, designers would benefit from training and experience in reformulating problems, both in removing assumptions and constraints to find different problems and perspectives, and in adding constraints to give themselves more tightly defined concrete problems that will channel their design thinking in interesting or useful directions.

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Biographies

Martin Stacey studied cognitive psychology before doing a PhD in Artificial Intelligence at the University of Aberdeen (1992) and postdoctoral research on intelligent computer support for design at the Open University. He is now a Senior Lecturer in Computer Science at De Montfort University. His major research interests are in the psychology of design, intelligent systems to support design process planning, and in human computer interaction aspects of design support systems.

Claudia Eckert completed a PhD in Design Studies at the Open University in 1997 followed by an ESRC-funded postgraduate research project, based primarily on a very large scale ethnographic study of the knitwear design process. Her research on knitwear design has focused on process modelling, the communication of design ideas, the use of sources of inspiration in various aspects of design thinking, and on intelligent computer tools for designers. She is now a Senior Research Associate at the Cambridge University Engineering Design Centre, where she is investigating planning processes, design modification processes and communication in large scale engineering projects.

Jennifer Wiley is Assistant Professor of Psychology at the University of Illinois, Chicago. Her PhD at the University of Pittsburgh (1996) and much of her subsequent research has been on insight problem solving and the nature of expertise. This includes investigating what contexts can enable people to get out of mental ruts that they get into when they try to solve problems using routine methods, and solve creative problems more effectively.