Aspects of a study of creative thinking and knowledge application

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An empirical study in the form of survey was conducted investigating design students' cognitive processes. The aim of this study was to identify specific knowledge for application by students classified as creative in product design. We specifically collected data from China and the UK, representing the Western and Eastern cultures. The results identified six knowledge items, e.g. knowledge of user trails, ergonomics, which were applied at a high frequency in FYDP by creative students, measured by the Metacognition Awareness Inventory (MAI), in both China and the UK. Moreover, we found that Chinese participants with higher creative thinking ability may tend to apply more knowledge of aesthetics, organisation, marketing, and skills to operate relevant machines in a design process, whereas the UK's participants with higher creative thinking ability would be more likely to apply knowledge of client needs and information processing to a larger degree.

Keywords: product design, cognitive studies, methodology, cultural difference

Introduction

The present study was motivated by identification of over-dependency of design students in China on lecturers during Final Year Design Projects (FYDP) (He, 2008). FYDPs examine students' subject specific knowledge and skills, and as a project-based teaching and learning strategy, the FYDP emphasises the application of knowledge (Prince & Felder, 2006). In China, FYDPs usually begin in the fourth academic year with a duration of one term (6 months). Students receive a foundation of what is perceived by educators to be relevant knowledge through a series of courses, including art history, design methods, market strategies and creative design practice, as well as traditional design courses (e.g. design representation based on sketching, drawing and modelling). However, design students seem to be unable to integrate these various aspects of knowledge to progress a long-term project (Pan, 2007). As the project-based strategy works more effectively for creative students (de Graaff & Kolmos, 2007), for this study we theorised that the more creative students might apply a variety of subject-related knowledge during FYDPs in a more effective way than less creative students. The lack of evidence concerning the application of different types of knowledge in a design process (Christiaans & Venselaar, 2005), prompted the need to explore the relationship between creativity and knowledge application. In addition, when referring to design cognitive processes, creativity-relevant factors are usually involved. Creativity theorists (Lubart, 1990; Fu, 2003) argued that creativity can be understood differently by different cultures as there are very different perspectives on what is considered creative. Understanding the cross-cultural aspects of creativity is therefore important. However, cultural factor is less emphasised in studies of design creativity as most of these studies are generally conducted by applying qualitative approaches, e.g. interview and action research and generally took place within one university in a single cultural context.

This paper represents an empirical study investigating design students' cognitive process in conducting FYDPs, specifically referring to two constructs, 'creative thinking' and 'knowledge application'. Creative thinking involves interactions between divergent thinking and convergent thinking, where, "convergent thinking usually generates orthodoxy, whereas divergent thinking always generates variability" (Cropley, 2006, p. 392). Both types of thinking work together "[which] allows the generation of ideas that are both original and effective" (Kozbelt, Beghetto, & Runco., 2010, p. 32). By acknowledging the importance of cultural factors, this study involved samples from two countries, China and the UK, representing Eastern and Western cultures.

Therefore, we intended to explore the following questions in this study: *what are the knowledge items whose application is related to creative thinking? Specifically, are there any knowledge items whose application may be different between different cultural contexts, and what are they?*

Literature review

Knowledge application in design studies

There is particular attention on a series of subject-related knowledge in design studies from the view of design creativity. For example, the relationship between the creativity and knowledge of ill-structured problem has been studied. Relevant studies have focused on investigating whether design creativity is problem-focused or solution-focused (Lawson, 2006; Cross, 2004), i.e. the problem-solving process (Howard, Culley, & Dekoninck, 2008) vs. specific domain knowledge (Bingham, Southee, & Page, 2013). There is also an emphasis on the relationship between creativity and the knowledge of design presentation. A series of studies are considering design representation as an essential approach to facilitate or achieve design creativity (e.g. Goldschmidt & Klevitsky, 2004). Moreover, several studies (e.g. Christiaans & Venselaar, 2005; Popovic, 2004) focused on exploring the function of domain-general knowledge i.e. strategic knowledge in design process. Finally, several studies (Cross, 2004; Sarkar & Chakrabarti, 2011; Sio, Kotovsky, & Cagan, 2015) have particularly emphasised the relationship between creativity and designers' experience; while others argued that the designers' experiences or precedents may lead to design fixation occurring, which inhibits the creative process (Doboli & Umbarkar, 2014).

As reviewed, these issues have been studied from the perspective of whether they may lead to creative outcomes in the design process, but there are still few studies that probe into their application in the design process, as Christiaans and Venselaar (2005) have stated. The reason would probably be that it is more challenging to identify the amount of subject-related knowledge that is applied in a design process than to simply investigate the general categories of knowledge, e.g. domain-specific/domain-general knowledge, or a specific knowledge item, e.g. design presentation.

Current methods applied in design cognition studies

A literature survey has been conducted to review methodologies applied in studies of the design process, including three aspects: i) studies of design cognitive processes and creativity; ii) design knowledge development; and iii) design knowledge and creativity. We found that research strategies such as protocol studies, visual work analysis, interviews and observation are widely applied in this research area. These reviewed methods are summarised in Table 1, with reference to how they are conducted in relation to data collection and analysis:

Table 1. Summarised methods applied in design cognitive process research

Research methods	*Materials for data collection*	*Forms of data received*	*Data analysis approaches*
Visual work analysis Observation Interview Experiment Survey Protocol study	Design tasks/works Scripted questions Questionnaires Guidance for think-aloud	Video/speech records Visual works Design works Reports (learner reports, self-reports, lab-based reports, design diary) Questionnaires Interview transcripts	Schema/cognitive map Verbal protocol analysis Constant comparative approach Statistical analysis

The qualitative approach was most frequently applied and this was the case in a range of studies, including Popovic (2004), Osmond and Bull (2013), Cash and Snider (2014), and Smith (2015), which followed the interpretive methodologies which employ particular qualitative research methods, such as interviews and working within a constructivist paradigm. Their aims were to identify students/teachers' in-depth feedback on their design experience or collect information about specific opinions. For example, Popovic (2004) conducted a visual work analysis to investigate two categories of knowledge applied in the design process; the approach

of 'observation' was applied by Cash and Snider (2014) which involved investigating participants' activities when conducting artificial works within design research.

Protocol analysis was employed widely as well, e.g. Kim and Kim's (2015) and Christiaans and Venselaar's (2005) studies in investigating design cognitive processes. This strategy is often used to investigate invisible cognitive processes. It has its origins in information-processing theory, which checks how the human mind works in terms of how it deals with information – including both newly-inputted information and information already stored in the memory (such as knowledge). As Ericsson and Simon (1993; 1981) proposed, it is possible to record and analyse a few aspects of the individual's information processing by asking them to 'think aloud' when they are carrying out a task. The 'think aloud' technique is the main approach to collect data in a protocol study. In Cross's (2004) review of design studies, the majority of the studies discussed aimed to examine either the differences between novice and expert designers or characterise expert behaviour in the designing process, and these were conducted by applying protocol studies.

However, only a few studies in this research area applied the quantitative approach by conducting an experiment or survey. For instance, Cornish, Goodman-Deane, Ruggeri, and Clarkson (2015) organised a survey of 122 graphic designers and clients to examine the research hypothesis that poor communication between graphic designers and clients leads to a lack of visual accessibility in product designs; Sun, Xiang, Chai, Yang, and Zhang (2014) conducted a lab-based experiment applying equipment for tracking eye movements in order to explore the relationship between sketching skill and creativity in the design process.

As Razzouk & Shute (2012) concluded, most of studies investigating the cognitive process in design were qualitative and employed protocol analysis. They further stated that these methods have some limitations, especially for investigating design activities. This echoes Smith's (2015) argument that the results obtained from qualitative approaches can be helpful in pioneering new ways of understanding, but do not provide support for generalisations. Similarly, Liu (2015) pointed out that the existing research methods were limited to protocol analysis which were based on practices, thus a large number of samples for measurement and analysis are required. Therefore, the results obtained from qualitive approaches can only support a specific context; however, these studies stated their conclusions in a general way without including their cultural contexts.

A cross-cultural perspective on creativity

Lubart (1990) and Fu (2003) argued that creativity can be understood differently by different cultures as there are different perspectives on what is considered creative. Similarly, Amabile (1982), acknowledging the complexity of social context and environmental variables, suggested that creativity might be understood differently from culture to culture. Therefore, creativity can be considered as culturally relative, and understanding the cross-cultural aspects of creativity is therefore important (Lubart, 1990).

Creativity is a term used mainly in the Western world. Studies of creativity have been ongoing in China since the 1980s, at which time the development of creativity research was established, based on the achievements of Western countries. Fu, one of China's pioneer researchers on creativity, first identified and located the word in the local context and pointed out that the awareness of being creative in China has a long history. He proposed that educators need to seek for its origination from philosophical perspectives that are rooted in Chinese culture (Fu, 2003). Lubart (1990) also believed that religious/philosophical perspectives would be relevant and important for forming perspectives on creativity and how this concept is understood in the current social and political context, in order to better connect with and absorb those theories from Western cultures. The main differences between philosophical perspectives, the social economic context and political context in both cultures are given in Table 2:

Table 2. Summarised differences between Western and Chinese perspectives

	Religious/Philosophical perspectives	*Social/Economic context*	*Political context*
The Western	Christianism	Capitalist developed Market economy	Individualism, Capitalist
The Chinese	Taoism, Confusions Marxism	Developing Socialist market	Collectivism Socialist

Understanding the philosophical differences in perspectives on creativity between Western and Chinese culture is important as these differences ultimately drive educational goals. The main differences have been reviewed and summarised from the perspectives of each aspect.

First of all, in terms of philosophical basics, Lan and Kaufman's (2012) point of view is that the Chinese emphasise 'novelty' in creativity. This point of view has been supported by Paletz and Peng's (2008) study, which investigated evaluations by Chinese students and other students from Western countries of products from the angle of 'novelty' and 'appropriateness'. They found that the Chinese were largely influenced by the former rather than the latter. In contrast, Western students were more influenced by appropriateness and less by novelty. Moreover, Yue (2004) stated that to achieve creativity, the Chinese pay most attention to seeking traditional methods and skills, so they stress creativity from the social aspects, and tend to consider those products which satisfy traditions, rituals and social norms as creative (Ng, 2001; Sternberg, 1985; Westwood & Low, 2003). As a result, the Chinese would prefer to accept 'incremental' creativity (Gilson & Madjar, 2011). However, the situation is different in Western countries. They emphasise 'appropriateness' and 'groundbreaking' when evaluating a creative product (Paletz & Peng, 2008), and therefore they may respond to 'radical' creativity.

Secondly, referring to the political context, Dineen and Collins (2004) stated that Chinese society has traditionally valued collectivity and conformity over the individual, which indicates that all people would be socially interrelated (Lau, Hui, & Ng, 2004). As Hsieh and Scammon (1993) stated, people in such cultures tend to look after others' needs and suppress their feelings to seek interpersonal harmony. Moreover, in Aaker and Schmitt's (2001) study, Chinese participants are more favorable to assimilation needs. However, Westerners emphasise the diversity of needs, and the reason would probably be, as Zha, Walczyk, Griffith-Ross, Tobacyk, and Walczyk (2006) explained, that individualism has been commonly recognised as a defining characteristic of Western culture, thus they appreciate independence and an individual is perceived as a separate entity. In addition, it seems that the creative abilities are hard to form in a collectivist society as compared an individualist society (Lubart, 1990).

Finally, as reflected in the social/economic context, the understanding of creativity within the Chinese background is more likely to perceive it as connected to a socially-related attitude. Li (2007) suggested that creative products include those products or services which represent social and cultural meanings, as well as symbolic values; whereas in Western countries, creative products are mainly generated in the condition of intellectual property rights, which has been created in the light of the demands of the individual (Li, 2007).

In summary, this literature survey identified the following knowledge gaps: i) there lacks studies that probe into subject-related knowledge application in the design process; ii) the methods applied in studies regarding design cognition/processes may lead to the denial or marginalisation of cultural factors. Therefore, to get a more comprehensive understanding of knowledge application in FYDP for answering the research questions, a specifically designed study is needed, which should be suitable for exploring the application of various subject-related knowledge items in the design process based on a creativity-related measurement; most importantly, cultural contexts should be considered in this study.

Methodology

A survey-based research method was adopted as it can cover a wider range of issues with a much broader base of respondents (Buckingham & Saunders, 2004), which made it more suitable for this study. This is because the main body of this cognitive study refers to 'creative thinking' and 'knowledge application' involved in the design process of the FYDP, and the sample was intended to be collected from two different cultures. A comparison between the results from each country and the total samples will be made.

Measuring creative thinking ability

Evidence suggests that the instrument used for measuring creativity should be selected according to how creativity is defined in a specific study. Creativity in this study is considered a creative process driven by creative thinking, with a combination of divergent and convergent thinking central to the process (Cropley, 2000). From this perspective, metacognition is taken into account as a criterion for measuring creative thinking, which is described as the conscious organisation of the information obtained while learning to accomplish tasks. As metacognition refers to the higher ability associated with human cognitive activities, its importance as a function in achieving creativity has been noted by those who consider creativity from the

standpoint of cognitive processes, in particular problem-solving processes (Feldhusen & Goh, 1995). It has been asserted that those with high-level metacognition should be able to solve a problem more creatively. Moreover, a study by Sanz de Acedo Lizarraga and Sanz de Acedo Baquedano (2013) found that metacognition correlated with levels of divergent thinking abilities.

Existing instruments for measuring metacognition can address specific aspects, such as meta-memory (See Schneider, 2008); but of the methods reviewed, the Metacognitive Awareness Inventory (MAI) developed by Schraw and Dennison (1994), is a validated and efficient method to evaluate metacognition holistically. The MAI consists of 52 questions derived and focussed on how individuals evaluate their own cognitive activities. In the inventory, metacognition consists of two sections: knowledge about cognition and monitoring and regulation of cognition. The sections are further divided as follows: cognitive knowledge (three sub-types), and cognitive regulation (five-sub-types) (Table 3).

Table 3. The Metacognitive Awareness Inventory (MAI) (Schraw & Dennison, 1994)

	Items	*Definition / Sample item*
Overall items	52	
Cognitive Knowledge	17	
Declarative Knowledge	8	Knowledge about one's skills, intellectual resources, and abilities *Sample item: I understand my intellectual strengths and weakness*
Procedural Knowledge	4	Knowledge about how to implement learning Procedures /strategies *Sample item: I try to use strategies that have worked in the past*
Conditional Knowledge	5	Knowledge about when and why to use learning procedures *Sample item: I used different learning strategies depending on the situation*
Cognitive Regulations	35	
Planning	7	Planning, goal setting, and allocating resources prior to learning *Sample item: I pace myself while learning in order to have enough time*
Information Management	10	Skills and strategy sequences used on-line to process information efficiently *Sample item: I consciously focus my attention on important information*
Monitoring	7	Assessment of one's learning or strategy use *Sample item: I ask myself periodically if I am meeting my goals*
Debugging	5	Strategies used to correct comprehension and performance errors *Sample item: I ask others for help when I don't understand something*
Evaluation	6	Analysis of performance and strategy effectiveness after a learning episode *Sample item: I ask myself if I have considered all options after I solve a problem*

Schraw and Dennison tested this instrument in a factor replication analysis to support the validity of the eight factors of Table 3 in their framework. Yildiz, Akpinar, Tatar and Ergin (2009) conducted a similar study to examine the same eight factors of metacognition, validating the results of Schraw and Dennison's study. Confirmatory Factor Analysis (CFA) established the validity of the eight factors in MAI and found that all the criteria had significant paths underlying their specific factors. In further studies undertaken by Puryear (2015), the impact of the eight factors of metacognition on creative thinking were analysed and found to be of considerable significance to idea generation and idea selection processes. Subsequent studies have suggested that metacognition be considered a criterion to evaluate creative thinking abilities, with the MAI instrument demonstrating high confidence levels of 95% (Batey, Furnham & Safiullina, 2010; Feldhusen & Goh, 1995). Therefore, MAI has been selected as an instrument for measuring creative thinking abilities in this study. The sample question is represented in Table 4 below:

Table 4. Sample question in MAI

Check True or False as appropriate. Use the Scoring Guide after completing the inventory.

	True	False
1. I ask myself periodically if I am meeting my goals.		
2. I consider several alternatives to a problem before I answer.		

Measuring knowledge application

To obtain the detail of how students consider themselves to apply each of their subject-related knowledges in FYDP processes, an initial list of knowledge items was produced under the categories of domain-specific knowledge, domain-general knowledge and tacit knowledge (Zhang, Bohemia & McCardle, 2018). In Product Design Education research, studies about design knowledge provided an important resource for producing the knowledge subject list for this study. For example, Christiaans and Venselaar's (2005) research identified 10 items of domain-specific knowledge and one item of domain-general knowledge applied by design students; Popovic's (2004) study built on Christiaans and Venselaar's work, though she included strategic knowledge as an additional item in domain-general knowledge. Furthermore, to enrich the knowledge list still further, the contents of taught programmes in product/industrial design, focused on China and the UK's Bachelor design programmes, were also reviewed, as the curriculum reflects learning from imparted knowledge (de Graaff & Kolmos, 2007). Finally, we deliberately introduced tacit knowledge as a category consisting of three items of general experiences, based on Polanyi's (2009) initial ideas of working and daily life experience. As there is no precedence or validation of related items in this category we considered this as a unique approach supported by a recognised relationship with personal experiences. In total, nineteen items of knowledge were assembled as the basis of the questions on knowledge application (Table 5).

Table 5. Developed Knowledge list in Product Design

Subject-related Knowledge items in Product Design
Domain-specific knowledge:
K1. Design History: knowledge relates to stylish perspectives
K2. Material: knowledge relates to specific materials to attain certain concept solutions
K3. Design methods: knowledge relates to the application of design research, and design case studies
K4. Aesthetics: knowledge relates to colour, structure and form
K5. Design representation: skills relates to 2D/3D drawing (effect drawing, three views)
K6. User Trials: knowledge relates to simulations of product usage in which subjects are asked to fulfil specified tasks using a product or product simulation.
K7. Client needs: knowledge relates to analysing the design brief
K8. Mechanics
K9. Ergonomics
K10. Skill to operate relevant machines
K11. Media technologies
K12. Knowledge of organization and marketing
K13. Psychology regarding with consumer and user
Domain-general/independent knowledge:
K14. Knowledge of information processing: information searching and analysing
K15. Ill-structured problem-solving process: knowledge relates to analysing situations, defining problems, finding or generating solutions.
K16. Strategies: knowledge relates to motivation, plan and goals.
Tacit Knowledge:
K17. Knowledge of existing design solutions: the precedents of similar project learned
K18. Personal placement experience in design companies
K19. Other experience in daily lives: travelling, reading, events, etc.

- ***Note:*** *K1 – K10, K15 are adapted from Christiaans and Venselaar's (2005) study; K11– K14 are adapted from HELPRC (2015), China, and the QAA report (2016), UK; K16 is from Popovic's (2004) study; K17 – K19 are based on Polanyi's (2009) initial ideas on human experience, and K17, K18 are adapted from HELPRC (2015), China, and the QAA report (2016), UK.*

The frequency of applying knowledge items listed in Table 5 was assessed by asking participants to respond on a 7-point Likert scale from 'never used' to 'always used' (sample questions in Table 6).

Table 6. Sample questions in 'Self-Reported Psychometric Test: How do you apply your knowledge?'

How do you apply your knowledge?

Please retrospect carefully about how you applied your knowledge in the process that you implemented in your Final Year Design Project, then select the appropriate scale of each statement of the following knowledge using '√' to indicate to what extent you employed it in that project.

Scale / Domain-specific Knowledge	Never used	Very rarely	Rarely	Occasionally	Frequently	Very frequently	Always used
1. Design History: knowledge relating to styling, perspectives.							
2. Material: knowledge relating to specific materials to attain certain concept solutions							

The reliability and validity of this instrument has been assessed for suitability in quantitative methods by using a Likert scale and close-ended questions (Mason, 2007). In addition, internal consistency of the method was tested with the Cronbach's Alpha[1] of >0.8. A pilot study, involving 35 postgraduate students (including 19 Chinese nationals) at the Design School, Loughborough University, UK, was conducted prior to release. All methods were subject to institutional ethical clearance procedures.

Questionnaires designed for this survey

The data collection method for this study was via a questionnaire consisting of three parts: 1) participants' basic information; 2) a self-reported Psychometric Test: 'How do you apply your knowledge?' and 3) the Metacognitive Awareness Inventory (MAI).

Study of metacognition and knowledge application in China

The Chinese data was drawn from the top 10 design colleges. 228 valid responses were collected (between 19th, May 2017 and 30th, June 2017). All participants in this study who were from China were volunteers. The researcher contacted the school counsellors at each target institute in advance to arrange permission for this survey. Target participants were then emailed by their school counsellors to check whether they were willing to respond by providing the participant information. If yes, they could access the questionnaire through a website link (highlighted) at the bottom of this email. Prior to starting the formal survey, they had to click the 'Informed Consent Form' of the survey. The details of the responses from each university are represented in Table 7.

Table 7. Details of the responses in China

Institute	*Number of valid responses*	*Number of final year students in product design programme*	*Percentage of the valid responses*
1. Tsinghua University	4	15	26.7%
2. Central Academy of Fine Art	4	20	20.0%
3. China Academy of Art	25	50	50.0%
4. Jiangnan University	50	115	43.5%
5. Nanjing University of the Arts	52	60	86.7%
6. Tongji University	8	15	53.3%
7. Donghua University	32	80	40.0%
8. Zhejiang University	2	15	13.3%
9. China Communication University	15	20	75.0%
10. Luxun Academy of Fine Arts	19	30	63.3%
11. Soochow University	11	25	44.0%
Total	228	445	51.2%

[1] For Cronbach's Alpha see doi: 10.1007/bf02310555

Study of the metacognition and knowledge application in the UK

The UK data was collected from those participants with a background in product design who attended the '2017 New Designer Exhibition'. This was an exhibition of qualified students' final year design projects from institutions across the UK (from 5th July, 2017 to 8th July, 2017). This is an independent event which is held annually in London, and it is the UK's most important graduate design exhibition. During this event, more than 3,000 graduates from universities all over the UK came together to exhibit their products, creations and artistic works (https://www.newdesigners.com/). The researcher attended the exhibition and asked students involved to take part in this survey as volunteers. At the event, all the participants were allowed to complete the questionnaires in their own time as available, iPads were provided, and the results were collected when the questionnaires were finished. 28 colleges agreed to provide the product design projects on the exhibition attendees list, and the responses were gained from 23 of these colleges. The details of the responses from each university are presented in Table 8.

Table 8. Details of the responses in the UK

Institute	*Number of valid responses*	*Institute*	*Number of valid responses*
1. Birmingham City University	5	13. Ravensbourne	5
2. Brunel University	14	14. Staffordshire University	2
3. Central Saint Martins	1	15. Sussex University	4
4. Coventry University	15	16. Swansea College of Art, UWTSD	6
5. Edinburgh Napier University	3	17. UCA	3
6. Kingston University / Kingston School of Art	6	18. University of Brighton	8
7. Loughborough University	18	19. University of Dundee	2
8. Manchester School of Art at MMU	2	20. University of Huddersfield	3
9. Middlesex University	4	21. University of Leeds	9
10. Northumbria University	17	22. University of Lincoln	12
11. Nottingham Trent University	3	23. UWE	3
12. Plymouth University	2	Total	147

The age of most participants from China and the UK is between 21 and 24 years. The gender status of respondents in the two countries were similar to each other, with 50% male vs. 50% female in China and 59% male vs. 41% female in the UK.

Strategy of data analysis

Ordinal Logistic Regression (OLR) is selected as the tool for data analysis in this study, which is a linear regression model allowing causal analyses and which assumes a dependence or causal relationship between one or more independent and one dependent variable. In this study, if we can observe that the frequency of a knowledge item application increases as the MAI score increases, then we would be able to draw a conclusion that the application of this knowledge item is related to metacognition. Therefore, in this case, metacognition was considered the explanatory variable (independent), and the application of a specific knowledge the dependent variable.

OLR is a type of logistic regression analysis used when the response (dependent) variable has more than two categories with a natural order or rank. It is suitable to apply to this study since the knowledge application factors (the dependent variable) were measured by a 7-point Likert scale, yielding a 7-category response with ranking. Equ. 1 illustrates the arithmetic OLR model for this study.

$$\mathrm{Yij} = \alpha + \beta_1 \mathrm{Xj} + \beta_2 \mathrm{j} \sum \mathrm{Xj} + \epsilon \qquad \text{Equ. 1.}$$

Here, the dependent variable measures how frequently a student 'i' applies a specific knowledge item 'j' on a 7-point Likert scale. 'Yij' is the logarithm of odds (log-odds) of the dependent variable[2]. 'Xj' is the MAI score of participant 'j'. Ordinal regression enables us to determine how a single unit increase or decrease in MAI is associated with the probability of the dependent variable presenting a higher or lower value. 'βj∑Xj' is the 'sum' of other control factors (gender, age, projects and institutions) which are also examined in the regression to reveal any statistically significant effect on the knowledge application. Nineteen regression analyses were conducted for each of the knowledge items in relation to the MAI scores for the respondents in each country respectively. STATA (version 13) was used for running the logistic regression and additional data analysis.

The coefficient and p-value are both key results of the OLR in regression analysis, as together it indicates which relationships in the model are statistically significant and the nature of those relationships, e.g. the slopes and directions of the regression lines.

As this study assumes a relationship between metacognition and knowledge application, the null hypothesis and the alternative are proposed as:

H_0: there is no relationship between metacognition (MAI score) and the frequency of applying a knowledge item [K1], [K2], [K3], …[K19]

H_a: there is a relationship between metacognition (MAI score) and the frequency of applying a knowledge item [K1], [K2], [K3], …[K19]

As this is the first attempt at identifying the knowledge items whose application is associated with metacognition from a range of subject-related knowledge items, we set the significant level to 10% (threshold of p-value = 0.1). A low p-value ($p<0.1$) indicates the relationship exceeds the 90% significance level: then we can be fairly confident that the association between the MAI and the frequency of knowledge application does exist in the population from which our sample was drawn. Thus we would reject the null hypothesis (H_0) and suggest the alternative hypothesis (H_a). Otherwise ($p>0.1$), we would fail to reject H_0.

Results and discussions

ORL has been applied as interpreted in the section on 'strategy of data analysis'. Three groups of data from the total samples, China samples, and UK samples have been analysed and the results are shown in Table 9.

We can see from Table 9 that the coefficients of metacognition against KFA6, KFA9, KFA16, KFA17, KFA18, and KFA19 (6 items out of the total 19 items) in all three groups are statistically significant, with the p values below 0.1 (marked in bold), supporting the H_as that there is a relationship between metacognition (MAI score) and the frequency of applying a knowledge item K6, K9, K16, K17, K18, and K19[3]. The related coefficient values are all above zero, meaning the relationships between metacognition and the frequency of applying these knowledge items are positive. This implies that the higher the metacognition score obtained, the higher the frequency of application of these kinds of knowledge by the participants.

In response to the second question of this study–are there any knowledge items whose application may be different between different cultural contexts–the following discussions will focus on the inconsistent results between groups.

Comparing the results from total samples, China samples and the UK samples

When looking at Table 9, we can find that the results of FKA2 and FKA8 represent the consistency in both the China and UK columns ($p<0.1$, marked with underlines), whereas, they show the different results in the total samples column. This implies that the data collected from only China and the UK may not support the results from the total samples. This further supports our argument at the beginning of this study that to explore design cognitive process, cultural factors should be considered as it affects the results. Therefore, to better

[2] For a fuller treatment of Logistical Regression and logarithms of odds ratios see doi: 10.1080/00220670209598786

[3] For the detail of knowledge items, see Table 4 in Methodology section.

identify the knowledge items that are influenced by metacognition, data from more culture contexts should be obtained.

Table 9. Regression coefficient for MAI in estimating the frequency of knowledge application (K1–K19)

	Coefficient			*p-value*		
	Total	China	UK	Total	China	UK
MAI/FKA1	.0091556	.0178451	.0124154	0.526	0.354	0.616
MAI/FKA2	.0181488	.0390951	.0880546	0.208	0.058*	0.001*
MAI/FKA3	-.0172984	.0042632	-.0227451	0.229	0.829	0.358
MAI/FKA4	.019945	.0418545	.0048117	0.168	*0.034**	0.853
MAI/FKA5	-.0017994	-.0095757	.0071817	0.902	0.633	0.774
MAI/FKA6	.039013	.042094	.0707227	**0.008***	**0.037***	**0.007***
MAI/FKA7	.0172334	.0135135	.0790986	0.231	0.474	*0.002**
MAI/FKA8	.0053038	.048247	.0679747	0.723	0.026*	0.012*
MAI/FKA9	.0419803	.0570645	.0836136	**0.004***	**0.004***	**0.002***
MAI/FKA10	.0071985	.0465495	-.0098781	0.621	*0.022**	0.691
MAI/FKA11	-.0050582	.0129069	-.0342168	0.728	0.523	0.171
MAI/FKA12	.0175453	.0620578	.0423462	0.224	*0.003**	0.103
MAI/FKA13	.012965	.0102593	.0355244	0.368	0.609	0.164
MAI/FKA14	.0115838	-.0049528	.1101319	0.430	0.803	*0.000**
MAI/FKA15	.0188422	.0280019	.0287052	0.195	0.165	0.264
MAI/FKA16	.0344671	.040478	.0960231	**0.025***	**0.048***	**0.001***
MAI/FKA17	.0313226	.0671738	.1129527	**0.039***	**0.00***	**0.000***
MAI/FKA18	.0495231	.0670912	.0984483	**0.001***	**0.001***	**0.000***
MAI/FKA19	.0545411	.0797108	.1019051	**0.000***	**0.000***	**0.000***

*Notes: * p<0.1; FKA: Frequency of Knowledge Application.*

Comparing the results from total samples and China samples

Apart from the aforementioned knowledge items (K2, K6, K8, K9, K16, K17, K18, and K19), it can be seen that the regression coefficients of MAI against a few items – FKA4, FKA10, FKA12 – are different between the total samples and China groups. The coefficients of metacognition against the frequency of the application of K4, K10, and K12 are statistically significant in China's responses (p<0.1, marked in *italics* in China's column, Table 8), but not in the total samples (p>0.1, Table 8). The three knowledge items are listed below:

- K4. Aesthetics: knowledge relates to colour, structure and form.
- K10. Skill to operate relevant machines
- K12. Knowledge of organisation and marketing

The knowledge of K4 and K10 largely reflect the 'Art and Craft' attributes of design, which are usually deemed to inspire novelty and reflect traditional understandings of design (the forms and the crafts of artifice) (Kuma, 2008). The history of modern design can be traced back to the late 18th century and the first Industrial Revolution in the UK (Margolin, 1989). This largely stemmed from the growth of modern industry to satisfy the requirement for efficient machinery, but at the same time it absorbed elements from arts and crafts. China's design education was imported from Japan and rooted in the Bauhaus system (Xi, 2000), which paid much attention to the form and decorative aspects of design (Kuma, 2008). Accordingly, China's design is still focused on forms and crafts today, which play crucial roles in achieving design creativity (Wu, 2001), whereas other cultures, e.g. the Western culture pays more attention to social topics and the living environment and puts design into other, broader discourses (Johnson, Wilson, Markopoulos, & Pycock, 1993). Moreover, they emphasise 'appropriateness' and 'groundbreaking' more when evaluating a creative product (Paletz & Peng, 2008), and therefore they may respond to 'radical' creativity.

The specific understanding of design creativity derived from socio-culture would probably influence design students in China. China's creative students tend to apply K4 and K10 with a higher frequency, as these two items may help to achieve relevant abilities or outcomes that conform to social understanding and evaluation in design and creativity in Chinese culture. This finding is consistent with Paletz and Peng's (2008), Lan and Kaufman's (2012) point of view that what the Chinese emphasise as creativity is 'novelty', which is found to exist largely in the art work. Moreover, Yue (2004) stated that the Chinese pay the most attention to traditional methods and skills to achieve creativity, therefore, Chinese designers would prefer to accept 'incremental' creativity rather than 'groundbreaking' creativity (Gilson and Madjar, 2011).

Knowledge of organisation and marketing (K12) generally includes knowledge of the structure, culture and behaviours of firms, and more specifically, the relevant information and methods of market research, e.g. market surveys, interviews, and focus groups. In China's design education, more attention is paid to delivering courses on 'organisation and marketing' during these years, as the concepts of 'designing for all' and 'design industry' have been gradually formulated and shown (Pan, 2007). Furthermore, this may also be related to the understanding of creativity within the Chinese background, as the Chinese are more likely to perceive creativity from a socially-related perspective. Chinese culture reflects collectivism, which indicates that all people are socially interrelated (Lau, Hui, & Ng, 2004), therefore, people in such cultures tend to look after others' needs (Hsieh & Scammon, 1993) and favour assimilation needs (Aaker & Schmitt, 2001). The situation may be different in other cultures: for example, Westerners emphasise the diversity of needs, and the reason would probably be, as Zha, Walczyk, Griffith, Tobacyk and Walczyk (2006) have explained, that individualism has been commonly recognised as a defining characteristic of Western culture. Thus, in Western countries, independence is highly appreciated, and an individual is perceived as a separate entity. Our findings support the viewpoint of cultural differences from this socially-related perspective, because Chinese creative students focus more on the mass market, as it is more likely that the Chinese will aim for a plan to satisfy and try to meet the general demands of society overall.

Comparing the results from total samples and UK samples

Similarly, the regression coefficients of MAI against FKA7 and FKA14 are different between the total samples and the UK groups. The coefficients of metacognition against the frequency of the application of K7 and K14 are statistically significant in the UK's responses ($p<0.1$, marked in *italics* in the UK's column, Table 8), but not in the total responses ($p>0.1$, Table 8). The details of knowledge item K7 and K14 are shown below:

- K7. Client needs: knowledge regarding to analyse the design brief
- K14. Information processing

The knowledge item K7 refers to analysis of the design brief. A design initiative will always have a design brief, with the proviso that it ideally provides customers' requirements (Ryd, 2004); while knowledge item K14 is essential to become proficient in the analysis of information during the design process (Cousins, Lawson, Petersen, & Handfield, 2011).

Applying the knowledge of K7 and K14 focuses on the rationale underlying every step/activity taken during the design process and has the aim of serving the clients' needs. The outcomes of using these knowledge items would probably help to achieve 'appropriateness' rather than 'novelty'. Our findings here support Wonder and Blake's (1992) claim that in contrast to Eastern thought – an essential driving force of 'novelty' – which is considered to be more 'intuitive' i.e., more subjective, experiential, and non-systematic, Western thought, which is a baseline of 'appropriateness', is regarded as more 'logical' i.e., more unemotional, structured, and individualistic. As a result, the Western designers may tend to follow logic or rational principles by integrating new information to push the design process; in contrast, Easterners tend to re-arrange the pattern depending on the existing 'database' culture (Wonder & Blake, 1992).

Creative students in the UK pay more attention to their clients, as Westerners pay more attention to particular customers, and customise their service to the specific needs of the targeted customers. The findings regarding the application of K7 indicates that the design brief plays a significant role in helping UK students to formulate a design problem during the design process. This implies that the different needs and directions of design industries in different countries may influence the emphasis and related approaches in education. Therefore, the UK's creative students tend to apply K7 and K14 with a higher frequency, as they play an important role in achieving the 'appropriateness' of the outcomes emphasised in Western countries when evaluating creativity, whereas there is no such tendency in the application of K7 and K14 in the total samples.

Limitation and further suggestions

Self-reported measurements were employed in this empirical study, which may to a certain degree lead to bias if the data has been collected from participants who may have been dishonest or inaccurate in their responses. It is suggested that tutors or experts' judgements should be included in future studies if the issues of time and cost allow. The knowledge list in the questionnaire has been preliminarily built up, which is needed to keep verifying by updating knowledge items, e.g. the ethical aspect and sustainable development in design should be examined in the further study. Moreover, in this study data was collected from China and the UK. However, there is a weakness that leads towards a genralisation of Western people vs. Chinese people in this study, as UK people also are very diverse as a group. It is then suggested that the cultural differences should be identified to reflect the feature of the context in a more precise way in future studies.

Conclusion

This was an empirical study of China and the UK which explored the relationship between creativity and knowledge application. We identified six knowledge items (K6, K9, K16, K17, K18, and K19) whose application are related to metacognition in both countries, indicating they were applied frequently by creative students, identified by the MAI, in the FYDP. We also identified five knowledge items (K4, K7, K10, K12, and K14) whose application was different between different cultural contexts. This indicates that creative students are more sensitive to relevant knowledge items relating to cultural attributions and social trends, implying that the knowledge application in relation to creative thinking conforms to the social values and cultures in each country. Inspired by these main findings, for tackling the problem that product design students fail to apply their knowledge effectively in the FYDP processes, design tutors will gain new insights for better instructing the FYDP process from the view of knowledge application. For example, they should particularly be aware of the cultural context involved. In China, tutors should let students pay more attention on the knowledge of aesthetics, organisation, marketing during the process of FYDP; whereas in the UK context, the focus would be the knowledge of client needs and information processing.

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