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The worked-example effect using ill-defined problems: Learning to recognise designers' styles

Arianne Rourke [a,*], John Sweller [b]

[a] College of Fine Arts, University of New South Wales, P.O. Box 259, Paddington, NSW 2021, Australia
[b] School of Education, University of New South Wales, Australia

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Abstract

This research uses cognitive load theory and theories of visual literacy to provide a theoretical underpinning for techniques to improve students' ability to recognise designers' styles in higher education. Using a lecture followed by tutorial format, students were required to learn the characteristics needed to identify a designer's work either by studying worked examples or by completing problem-solving tasks. The principle conclusion drawn from two experiments was that novice learners who have a moderate level of visual literacy skills are more successful at identifying a designer's work after studying worked examples compared to novice learners provided with problem-solving tasks.

Keywords: Cognitive load theory; Worked examples; Problem solving; Ill-defined problems; Visual literacy; Teaching design history

1. Introduction

Cognitive load theory (CLT) contributes to education and training by using human cognitive architecture to address the design of instructional material (Clark, Nguyen, & Sweller, 2006; Paas, Renkl, & Sweller, 2003,2004). Worked examples represent one of the major instructional methods based on CLT. A worked example provides learners with information concerning a problem solution. The worked-example effect occurs when learners presented worked examples to study during a learning phase solve test problems more effectively than learners presented the equivalent problems to solve during the learning phase (Cooper & Sweller, 1987; Paas & van Gog, 2006; Reisslein, Atkinson, Seeling, & Reisslein, 2006; Sweller & Cooper, 1985; van Gog, Paas, & van Merriënboer, 2006). The vast bulk of the extensive demonstrations of the effect have used well-defined problems from mathematics, science, or technology, and so it might be argued that the effect is limited to well-defined problems and excludes ill-defined problems such as those found, for example, in areas such as art and design (Schmidt, Loyens, van Gog, & Paas, 2007). A well-defined problem has well-defined givens, goals and problem-solving operators while an ill-defined problem does not have specific givens, goals or operators.

* Corresponding author. Tel.:+61 2 93850716.
E-mail address: a.rourke@unsw.edu.au (A. Rourke).

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Based on the cognitive architecture advocated by CLT (see below), there are no grounds for assuming that the problem-solving skills acquired in well-defined domains through studying worked examples differ substantially in any way from those acquired in ill-defined domains (see Greeno, 1976). Accordingly, the worked-example effect should be equally obtainable irrespective of the degree of problem structure characteristically used in various domains. In this respect, CLT assumes an evolutionary view of human cognition using an analogy between cognition and biological evolution (Sweller, 2003, 2004). Both human cognition and evolution by natural selection can be considered natural information processing systems (Sweller & Sweller, 2006). Such systems can be specified by the following five principles:

Information store principle. In order to function in a natural environment, natural information processing systems require a very large store of information that can be used to determine actions. Long-term memory provides that store in the case of human cognition. Since de Groot's (1965) work on chess, we know that long-term memory is not used to simply store isolated fragments of information but, rather, is central to thinking and problem solving.

Borrowing and reorganising principle. How is a large information store acquired? The answer is ''most commonly by borrowing information from another store''. Hence the borrowing principle functions when we obtain information from someone else. Humans listen to what other people say, read what they write, and imitate what they do. We do not obtain an exact copy by these means but, rather, reorganise the information to form schemas by combining new information with previously acquired information held in long-term memory. A schema is defined as a cognitive construct that permits us to treat multiple elements of information as a single element classified according to the way it will be used (Chi, Glaser, & Rees, 1982; Sweller, van Merriënboer, & Paas, 1998).

Randomness as genesis principle. The borrowing and reorganising principle does not result in the creation of new information except insofar as reorganising can be considered a form of creativity. Humans create new information during problem solving by using a random generation-and-test procedure. When knowledge concerning which problem-solving moves to make is not available, the only other alternative is to randomly generate a move and test it for effectiveness. Effective moves can be retained and possibly stored in long-term memory while ineffective moves are jettisoned.

Narrow limits of change principle. Large random changes to an information store are unlikely to be adaptive. Changes need to be small with each change tested for effectiveness. Humans use working memory when dealing with novel information from the environment. Working memory is severely limited in capacity when dealing with novel information (Baddeley, 1992; Cowan, 2001; Miller, 1956) because a small number of novel elements combined randomly and tested for effectiveness is manageable. A large number of elements results in a combinatorial explosion that may be difficult or impossible to deal with.

Environmental organising and linking principle. Once information has been organised, tested for effectiveness and stored in long-term memory, it may be used to govern activity. Because the information is organised, the capacity limitations of working memory when dealing with unorganised information from the environment disappear when dealing with organised information from long-term memory. There are no limits to the amount of organised information from long-term memory that can be handled by working memory (Ericsson & Kintsch, 1995). It is information in long-term memory that largely determines human activity and so it is that information that needs to be the focus of instruction.

It should be noted that these five principles apply to what Geary (2002, 2005, 2007) refers to as biologically secondary knowledge that we have not evolved to acquire. Biologically primary knowledge that we have evolved to acquire can be learned easily and automatically just by participation in a normal human society (Sweller & Sweller, 2006).

These five principles provide the cognitive architectural core of CLT with instructional implications flowing from this architecture. Specifically, based on this architecture, the aim of instruction should be to build knowledge in long-term memory and that knowledge can be most efficiently built using the borrowing and reorganising principle. The CLT addresses the fact that the primary function of learning is schema construction and automatisation, that the most efficient way of acquiring and automatising schemas is through the borrowing and reorganising principle and that the process of learning may be jeopardized if some of the limited resources of working memory are unnecessarily used via the randomness as genesis principle. The theory assumes that the randomness as genesis principle imposes a high information-processing load (Sweller, 2003, 2004; Sweller & Sweller, 2006). Moreover, CLT suggests that many instructional methods impose a heavy cognitive load not because of the intrinsic nature of the material being learned but because of the way the material is presented or activities that are required of the learner. Problem solving constitutes one of the activities that impose a high cognitive load (Kirschner, Sweller, & Clark, 2006; Sweller, 1988). Accordingly, we can hypothesise that presenting learners with worked examples is likely to be more effective than presenting them with problems to solve.

There is considerable evidence for this hypothesis. It has been shown in a number of disciplines that conventional means-end problem solving can cause a heavy load on working memory of the novice learner (Cooper & Sweller, 1987; Paas & van Gog, 2006; Reisslein et al., 2006; Sweller & Cooper, 1985; van Gog et al., 2006; Ward & Sweller, 1990). These and many other studies have indicated that the conventional search strategy that novices use to obtain problem solutions is an inappropriate means of acquiring schemas. In almost all cases, this evidence has been obtained using well-defined problems from science, technology, engineering, or mathematics domains.

While previous studies have tended to use well-defined problems in technical areas, there is nothing in the theoretical principles summarised here to suggest that the effect should not be equally obtainable using ill-defined problems in areas that use a less precise language than that of mathematics, science and technology. Whether dealing with well-defined or ill-defined problems, learners must acquire knowledge in long-term memory that will enable them to recognise problem types along with the range of solutions appropriate to each category of problems. Worked examples demonstrating problems and their solution or solutions should be equally effective irrespective whether the problems are well-defined or ill-defined.

Greeno (1976) provided a theoretical analysis indicating that when presented with a well-structured problem with specific givens, goals and operators, problem solvers treat the goal of the problem as though it is ill-defined. He indicated that even in well-defined problems, problem solvers engage in a general search for information that is indistinguishable from the search for information necessary to solve ill-defined problems. In this respect, CLT has long ago suggested that general search during problem solving places a heavy load on working memory (Cooper & Sweller, 1987; Sweller & Cooper, 1985) and the reduction of this load is a major reason why presenting learners with worked examples is beneficial. If problem solvers treat well-defined problems as though they are ill-defined, eliminating the need for a general search by showing problem solvers a solution should be just as beneficial whether or not a problem is well-defined or ill-defined.

1.1. The present study

In the present study, learners were asked to learn to recognise the styles used by particular designers. The problems were ill-defined in that the style of a designer is determined by several factors and identifying a designer could be carried out by using several different combinations of factors. While those factors need to be learned, which factors are used by problem solvers and the problems on which they are used can vary.

Art appreciation and criticism in the classroom is usually taught using problem-solving strategies that require students to provide their own solutions to questions on specific art examples, with little guidance or input from the teacher during this process. The problems used are invariably ill-defined. As indicated above, this emphasis on the randomness as genesis principle rather than the borrowing and reorganising principle imposes a heavy extraneous cognitive load. There are a number of advocates in art education who hold the view that discovery learning is an effective learning strategy (Dorn, 1998; Jausovec, 1994). According to Davies, Conneely, Davies, and Lynch (2000: 122), ‘‘spontaneity is useful for what educationalists call ‘‘discovery learning’’, in which students generate and internalise their own way of understanding concepts and principles’’. These advocates believe that discovery learning is a reaction against the ‘‘didactic method’’ where facts are given which students memorise. In contrast to memorising unrelated facts, worked examples focus on problem solving and the application of knowledge rather than rote learning. Problem solving via discovery learning in art and design education can be an effective learning strategy for students who have domain-specific knowledge; however, for students without such knowledge, supplying appropriate worked examples as hypothesized in this study, should be a more effective method due to a reduction in emphasis on the randomness as genesis principle (Kalyuga, Chandler, Tuovinen, & Sweller, 2001).

Within the context of art and design education, an emphasis on the borrowing and reorganising principle through worked examples should allow students to distinguish between superficially irrelevant information and real and valuable knowledge of the artwork. Ausburn and Ausburn (1978: 288) found that the ‘‘superficiality of pupils’ comprehension of much of what they view, suggests that higher-order visual literacy skills do not develop unless they are identified and taught’’. For the purpose of this study, visual literacy is defined as a universal attribute that is developed through acquiring a set of principles used for reading visual form (Boughton, 1986). Visual literacy not only requires the ability to ‘‘read’’ visuals but also to develop the ability to comprehend what is seen, and the ability to generate material that has to be seen in order to be understood (Wileman, 1980). For the viewer to find meaning, for example, in an art image or design object, they need to comprehend basic elements of a universal visual language. In summary, in order to develop visual literacy skills in art or design, one must not only acquire domain-specific knowledge for identifying an image but also acquire the ability to express what one sees into domain-specific language, which takes time to develop.

To represent an image pictorially one must have ‘‘some knowledge of the visual symbol systems, its vocabulary, concept, conventions, and some technical skills to manipulate art material’’ (Feinstein, 1982: 46). This acquired knowledge and experience combine together in the visually literate individual. The objective of developing visual competencies required to analyse art and design knowledge will more likely be fostered when instructional design avoids the extraneous cognitive load (caused by less than optimal instructional methods) imposed by a problem-solving approach with its emphasis on the randomness as genesis principle.

1.2. Aim—Hypothesis

Two experiments are reported in this study. They were designed to test the hypothesis that worked examples can assist the novice learner to acquire domain-specific schemas for identifying distinctive characteristics of designers' work despite the fact that the relevant problems are ill-defined. It was hypothesized that learning to identify distinctive characteristics of designers' work would be facilitated more by learners' studying worked examples than solving the equivalent problems.

2. Experiment 1

Experiment 1 compared worked examples with conventional problem solving in the discipline of Design History in three stages (see Section 2.1.2). The experiments were conducted in a realistic university learning environment ensuring that the materials were germane to the learners (Scott & Schwartz, 2007). The first experiment was conducted with first year undergraduate university students during the second, third and fourth weeks of the first semester. These students had limited or no previous experience of university teaching and had a limited knowledge of design history.

2.1. Method

2.1.1. Participants

The participants were 130 first-year-university students enrolled in a four-year undergraduate design degree. It should be noted that until recently, entrance to art and design courses at the university where this study was conducted was based on secondary school subjects that favoured mathematics and science over humanities. As a result, it is reasonable to assume that many of these students had not studied art or design in any depth at high school. Participation in this experiment was voluntary and anonymous with participants randomly allocated to two groups, namely the problem-solving group and the worked-example group. Only the data of students who attended all three stages were analysed, leaving 51 students in each of the two groups.[1]

2.1.2. Experimental design

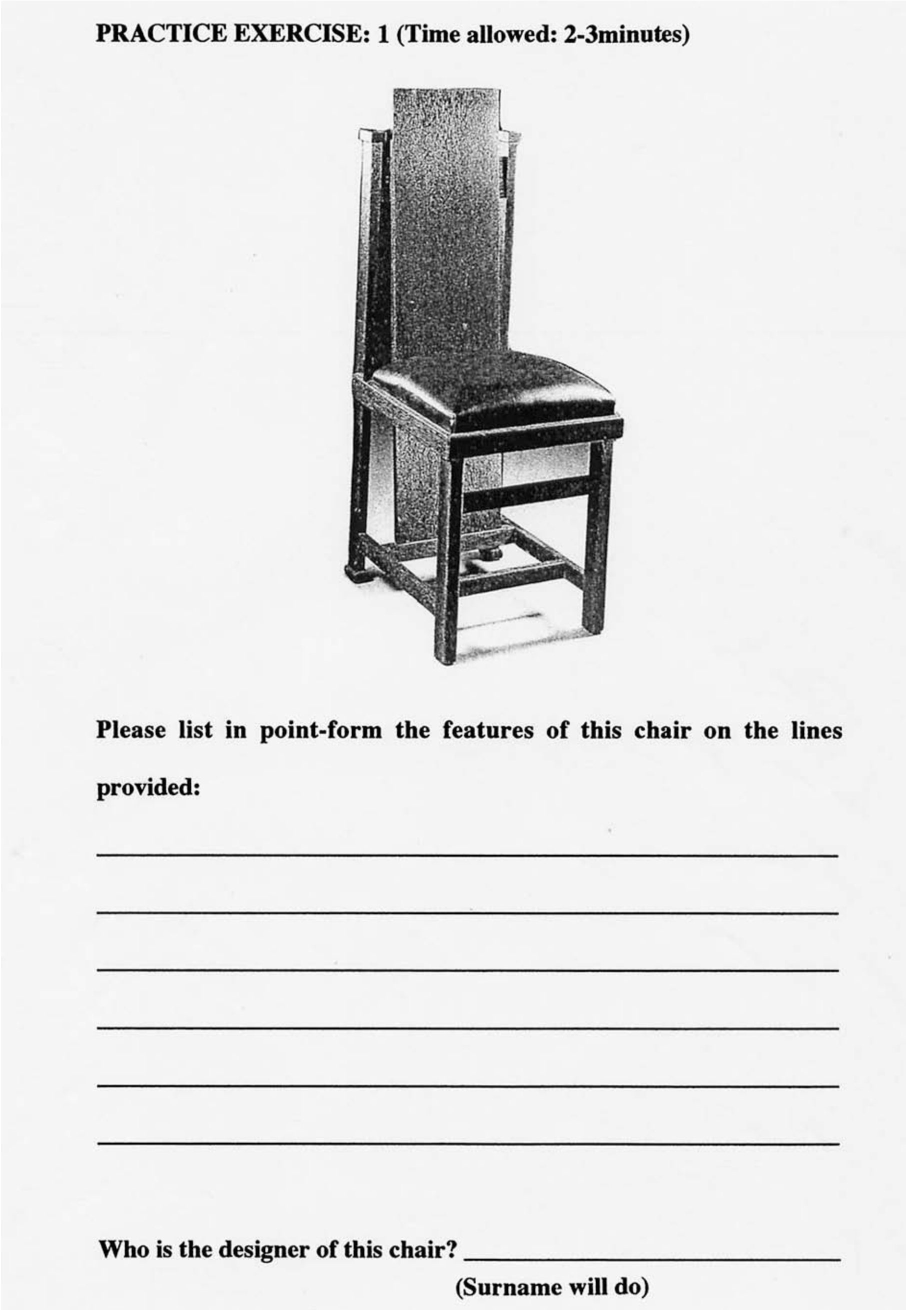
This experiment had three stages, which were conducted over a three-week period. In Stage 1, a design history lecture was presented to all students. In Stage 2, worked examples were studied (Fig. 1) and then problem-solving practice exercises were completed by the worked-example group (Fig. 2). The material was presented in paired form with each worked-example followed by a problem.

The problem-solving group completed only problem-solving practice exercises. They were presented the material of Fig. 1 using a problem-solving format (Fig. 2 indicates the problem-solving format) followed by the problem of Fig. 2. Thus, the problem-solving group, rather than being presented with a series of pairs of worked examples and

[1] Unfortunately, demographic information was not collected.

Fig. 1. Example of Stage 2 worked example for the worked-example group.

problems, was presented with the same material represented as two problems. Note that the problem-solving group received information concerning problem solutions in the Stage 1 lecture that was common to both groups. Stage 3 was a visual recognition and short answer test completed by all participants using a format identical to Fig. 2. The independent variable was worked examples vs. problem solving in Stage 2. The dependent variable was students' scores on the Stage 3 test.



PRACTICE EXERCISE: 1 (Time allowed: 2-3minutes)

Please list in point-form the features of this chair on the lines provided:

____

____

____

____

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____

Who is the designer of this chair? ______________________

(Surname will do)

Fig. 2. Example of Stage 2 practice exercise for the worked-example group.

2.1.3. Materials and procedure

The experiment was designed to echo a realistic format for teaching design history to university students. It was conducted in tutorials by tutors. There were six tutorials conducted by three tutors that were scheduled concurrently with students remaining in the same tutorial group for all three stages of the experiment. The class sizes varied from between 13 and 22 students in total.

The Stage 1 lecture material included a five page, typed lecture and 10 coloured, overhead transparencies providing two visual examples for each of the five designers whose work was discussed in the lecture, namely, Wright, Hoffman, Mackintosh, van de Velde and Voysey. The transparencies were shown during the lecture on an overhead projector. The chosen designers displayed distinctive characteristics in their work of the Art Nouveau or the early Modernist period (approximately 1880–1914). The Stage 1 lecture was approximately 25 min, which the tutors were instructed to read slowly and clearly in order to allow time for students to contemplate the visual examples. In order to reduce bias due to lecturing styles, the tutors were instructed to read the lecture aloud, as written, word for word. Tutors were also instructed not to include any extra words or emphases in the lecture, but to keep exactly to the script in order to minimize lecturing style as a differentiating factor that could affect the results. The lecture script indicated exactly when to show the design visual examples as well as precisely what was to be said about these visual examples. All tutors were instructed to tell the students that they could take notes if they wished. Tutors were instructed to orally spell out the names of the designers in the lecture. Students were instructed not to ask questions as the researcher wanted to insure that all tutorial groups received the same information in the lecture.

Before starting the Stage 2 practice exercise of the experiment, the seats in the room were spaced apart in order to discourage students from copying from each other. The tutors randomly divided each of their classes into equal worked-example and problem-solving groups that were later collapsed across classes into one worked example and one problem-solving group of 51 students each in order to analyse the data and to eliminate the possibility of a ‘‘tutor effect’’ due to differing teaching styles in the Stage 1 lecture. During Stage 2, the tutors handed out each page of the practice exercise to the students in both the worked-example and problem-solving groups, explaining that they should follow the instructions on the sheet. Black and white images were used, as colour was an irrelevant factor in identifying each designer’s style, which relied more on the distinguishing elements of shape, line, proportion and space.

Students had a total of 50 min to complete Stage 2, which required students in the worked-example group to study five worked examples (one for each designer; see example Fig. 1) and then fill out five pages (one for each designer) with what they thought were the key characteristics of each chair design. The chair example that was provided in the problem-solving practice exercise was different to the chair that was provided in the relevant worked example but had similar characteristics (refer to Fig. 2). Each practice exercise followed immediately after the similar, worked example. The problem-solving group received ten pages to fill out (two per designer) of exactly the same chairs as the worked-example group, presented in the same order; however, this group did not receive the worked example that had the chair with the key characteristics listed. Both groups received the name of each designer. After the allocated time (5 min) elapsed between each exercise, the tutor collected the exercise page and handed out the next page in order from pages 1 to 10. Students were instructed at the beginning of the Stage 2 practice stage to raise their hands if they required less than the allotted time to complete each exercise, allowing the tutors to provide the next exercise.

Stage 3 of the experiment was the visual recognition test that consisted of a three-page black and white photocopied paper. The room was arranged similarly to Stage 2 and students were instructed not to copy any other student’s work. The first page of the test (refer to Fig. 3) required students to match randomly displayed illustrations of ten chairs to a list of names of five designers (listed at the top of the page), the same designers that were discussed in the lecture (Stage 1) and provided in the practice exercises (Stage 2). This page tested near transfer, for the chairs were previously unseen examples, rather than requiring retention only of material students learned in the Stage 2 practice.

The second page of the test provided illustrations of 15 randomly displayed designs by the same five designers listed on the first page. In this section, in order to test for far transfer, chairs were not used. Instead, other designs such as a stained-glass window, a textile design, cutlery, and a silver tray were illustrated.

On the third page of the test, students were asked to answer questions about the illustrations provided on the second page. There were two questions for each designer, one of which asked learners to identify designers of particular objects while the other asked what were the significant features characteristic of that designer.

The worked-example and the problem-solving groups received the same test paper to answer. There was no time limit on the test and students were told not to refer to any notes taken from the lecture. Students tended to pace themselves based on other students’ time frames and hence they all finished within 10 min of each other.

2.1.4. Data analysis

There are a number of ways of describing an inherent characteristic of a work of art or design. For example, one could describe a curved line as circular, swirling, arabesque, or flowing as opposed to a rectilinear line as right-angled, square or sharp. Design history as a language-based discipline has many anomalies that can render subjective the assessment of responses to visual material. In order to quantify the results of a usually qualitatively assessed

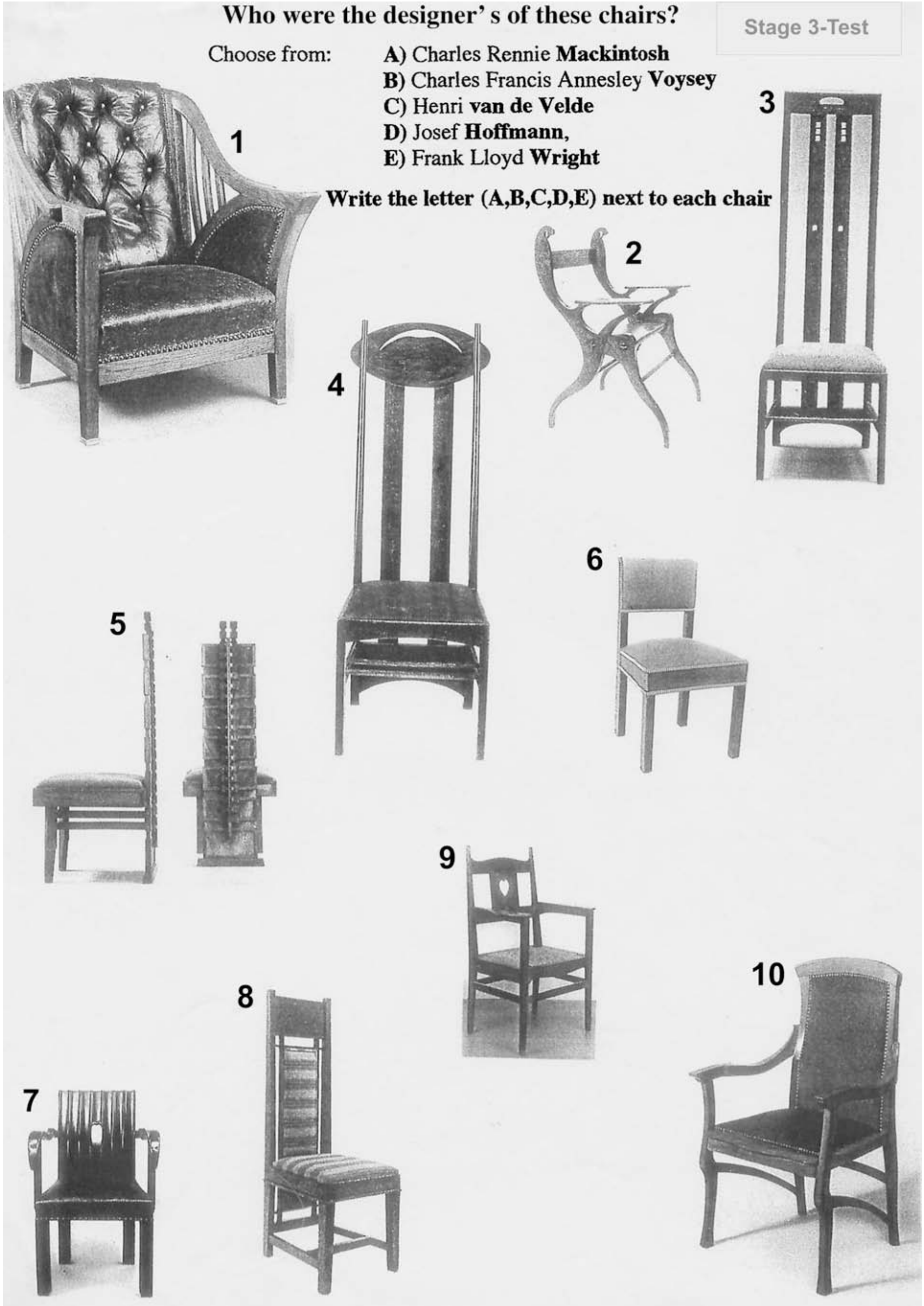

Fig. 3. Example of Stage 3 test (first page of the three page test).

discipline, double-marking and cross-checking of any written responses was necessary in order to reduce any ambiguity and to provide a standardized list of correct answers.

To assess the Stage 2 practice exercises and the Stage 3 test, two markers were selected who had extensive knowledge of the particular period of design history from which the examples were selected. Before marking the Stage 2 practice exercises, the markers agreed on acceptable answers and a list of these was generated. The Stage 2 practice exercise was double-marked by two independent markers to ensure that possible marking biases were not factors influencing results. The results were based on the mean of the two marks. The correlations between the two independent assessors' marks for the five designers, namely Wright, Hoffman, Mackintosh, van de Velde, and Voysey, were 0.97, 0.98, 0.97, 0.97, and 0.96, respectively.

The same marking procedure used for Stage 2 of the experiments was also used for the marking of the Stage 3 test. The test questions, that required only a numerical response, were independently marked and checked, while the open-ended questions No. 2, 3, 8, and 10 were double-marked by the independent assessors after an acceptable answer sheet was generated using a similar procedure as the Stage 2 practice exercise. The results were based on the mean of the two marks. The correlations between the two independent assessors' marks for the open-ended questions No. 2, 3, 8, and 10 were 0.93, 0.96, 0.98, and 0.98, respectively.

When students were asked to list the objects produced by a particular designer from a group of objects, by listing all of the objects they would inevitably include the correct ones. To discourage such a strategy, students were informed that the answers to the objective questions of the test were negatively marked whereby the number of incorrect answers was subtracted from the number of correct answers. This negative marking procedure meant that those students who provided many responses or guesses were penalized over students who provided fewer responses that were correct. Questions 5 and 6 of the Stage 3 test were excluded from the analysis of the results due to the ambiguity of the questions. This ambiguity was not discovered in the pilot study that was conducted earlier with a smaller sample size.

2.2. Results and discussion

As indicated above, tutors of each class randomly assigned students into worked-example and problem-solving groups ensuring that tutor characteristics did not constitute a confound. The results were then analysed by collapsing across classes into the two groups. The results for the worked-example group were based on each second practice exercise, that is, five out of a total of 10 (the first exercise was a worked example as was every alternate exercise). The results for the problem-solving group (provided with problems equivalent to the worked examples of the worked-example group) were based on the results obtained from every second problem, that is, five out of a total of 10. Accordingly, identical tasks were used when comparing the worked-example and the problem-solving groups in Stage 2.

A 2(instructional method) $\times$ 5(designers) ANOVA with the Designers as within subjects factor showed that there was a highly significant main effect of Instructional Method, namely of worked examples compared to problem solving, $F(1, 100) = 226.74$, $P < 0.001$, partial $\eta^2 = 0.69$, due to the superiority of the worked-example method. Both the effect of Designers and the Designers by Instructional Method interaction were significant, $F(4, 400) = 15.35$, $P < 0.001$, partial $\eta^2 = 0.13$, and $F(4, 400) = 10.38$, $P < 0.001$, partial $\eta^2 = 0.09$, respectively. Inspection of the means of Table 1 indicate that the means for Wright and van de Velde were somewhat lower than the means for the other three designers explaining the significant repeated measures within subjects effect while the difference between the means of worked-example and problem-solving groups for Wright and Voysey were smaller than the difference between the means for the other three designers, explaining the significant interaction.

Fig. 4 shows the percentage of correct responses for each group comparing the worked-example group to the problem-solving group results on the "Match the chair to the designer" Stage 3 test. A 2(instructional method) $\times$ 10(match response) ANOVA with Match Response as within subjects factor showed that there was a significant difference between the problem-solving and worked-example groups, $F(1, 100) = 4.75$, $P = 0.03$, partial $\eta^2 = 0.05$, due to the superiority of the worked examples. The main effect of Match Response was also significant, $F(9, 900) = 2.45$, $P = 0.009$, partial $\eta^2 = 0.02$, due to the differential difficulty of the differential questions. The interaction of instructional method with match response was nonsignificant, $F(9, 900) = 1.31$, $P = 0.23$.

Table 1
Means and standard deviations in Stage 2 practice of Experiment 1 by designer

Chair designer	Worked-example group		Problem-solving group	
	M	SD	M	SD
Wright	5.55	1.51	3.12	1.71
Hoffmann	7.07	1.51	3.10	1.57
Mackintosh	7.25	1.59	3.10	1.60
van de Velde	5.99	1.80	2.23	1.30
Voysey	6.36	1.47	3.28	1.41

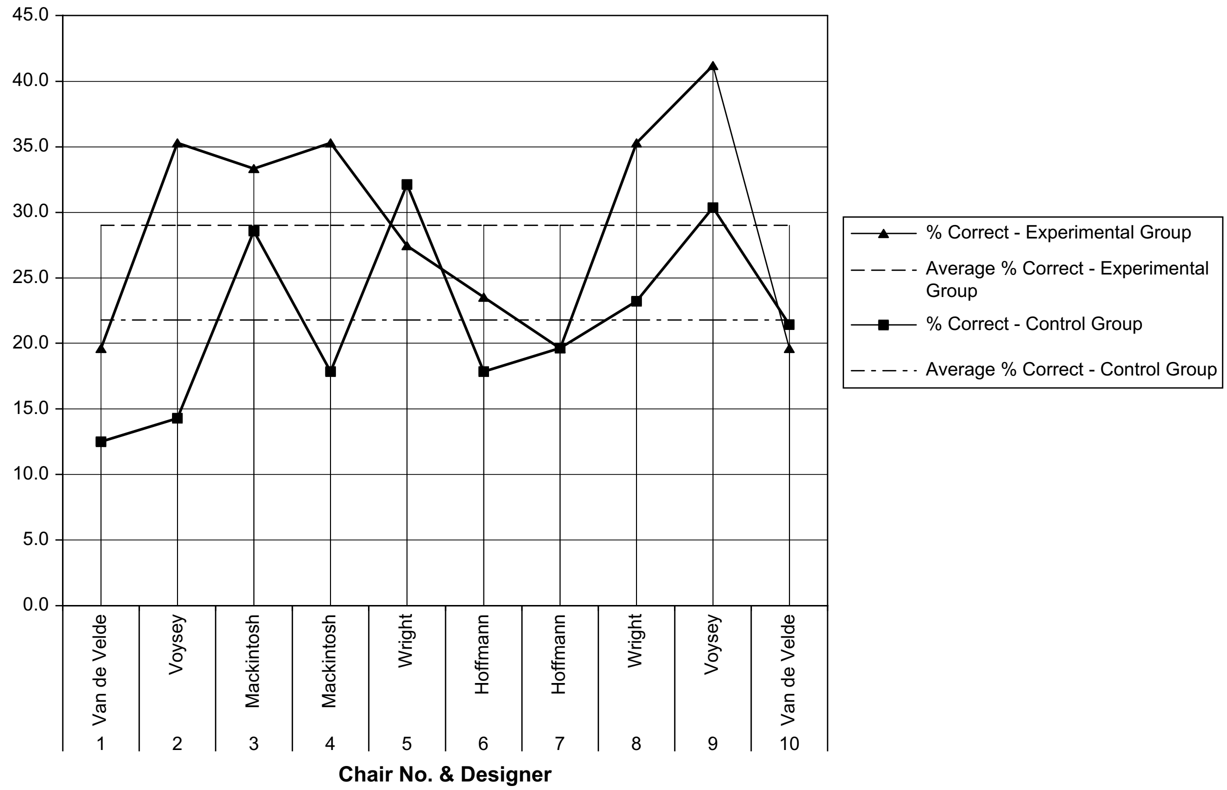

Fig. 4. Experiment 1, Stage 3 test: Percentage of correct responses per chair and designer in the "Match chair to designer" test.

Table 2 shows the mean test scores by question for questions No. 1, 4, 7, and 9 of Stage 3. These questions tested for far transfer and required an objective answer only. To obtain these scores the incorrect answers were subtracted from the correct answers. A 2(instructional method) × 4(question) ANOVA with Question as within subjects factor showed that there was a nonsignificant difference between the problem-solving and worked-example groups, $F(1, 100) = 2.75$, $P = 0.10$. The main effect of Question was significant, $F(3, 300) = 9.40$, $P < 0.001$, partial $\eta^2 = 0.09$, due to the differential difficulty of the questions. The interaction of instructional method with question was nonsignificant, $F(3, 300) = 0.33$, $P = 0.80$.

The mean test scores for the double-marked open-ended questions of Stage 3, namely questions No. 2, 3, 8, and 10 were analysed with a 2(instructional method) × 4(question) ANOVA with Question as within subjects factor. It was found that there was a nonsignificant difference between the problem-solving and worked-example groups, $F(1, 100) = 0.59$, $P = 0.44$. The main effect of Question was significant, $F(3, 300) = 21.66$, $P < 0.001$, partial $\eta^2 = 0.18$, due to the differential difficulty of the questions. The interaction of instructional method with question was nonsignificant, $F(3, 300) = 1.13$, $P = 0.34$.

The results of Experiment 1, particularly from the Stage 2 practice and the "Match the chair to the designer" Stage 3 test, support the hypothesis that worked examples are a more effective method for teaching students to identify the

Table 2
Means and standard deviations in Questions 1, 4, 7, and 9 for the test in Experiment 1

Question	Worked-example group		Problem-solving group	
	M	SD	M	SD
1	−0.22	2.23	−1.02	2.12
4	−0.82	1.57	−1.29	2.01
7	−0.90	1.82	−1.38	1.52
9	−1.65	2.01	−1.84	1.85

characteristics of a designer's work compared to completing problem-solving tasks. Nevertheless, there were no significant differences between groups on the open-ended questions of Stage 3.

The test scores for Experiment 1 were low, especially for both types of test questions in Stage 3, which suggests that the material was too difficult for many first-year university students to learn. Less than 50% of the students could identify the chair designs. Specifically, in Stage 3, which tested students' ability to transfer their knowledge of chairs from the Stage 2 practice to nonchair examples in the Stage 3 test, the means for questions No. 1, 4, 7, and 9 were below a score of 1 out of 6 and the means for questions No. 2, 3, 8, and 10 were below a score of 2 out of 6. However, even though the scores of the Stage 3 test were lower than expected, there was still evidence to support the hypothesis that students with limited visual literacy skills found learning the characteristics of a designer's work easier by studying and practicing worked examples than completing problem-solving tasks.

3. Experiment 2

Experiment 1 provided preliminary evidence that the worked-example effect can be obtained in the area of teaching design history. Experiment 2, conducted in parallel to Experiment 1, tested whether the differences between groups obtained in Experiment 1 would be different if the same material was presented to a more advanced group of students. Specifically, Experiment 2 tested whether students with more advanced visual literacy skills who study worked examples are better at applying the necessary transfer skills needed to identify nonchair examples (after studying only chair examples in the Stage 2 practice) than students completing problem-solving tasks. It was hypothesized that more advanced students would be better able to apply what they learn when studying worked-examples to a transfer task.

Experiment 2 differed from Experiment 1 in that it was conducted with second-year undergraduate university students. The majority of the first-year students who participated in Experiment 1 had little or no background knowledge of design history. The students in Experiment 2 had had previous experience of university teaching and had acquired some knowledge of art history, although not design history, through their study of compulsory subjects in this area. It was assumed that to successfully identify the characteristics of a designer's work required both visual literacy skills as well as design-specific knowledge acquired through studying worked examples rather than through completing problem-solving tasks.

3.1. Method

3.1.1. Participants

Participants were 27 second-year university students enrolled in a four-year undergraduate Art Education degree. It was assumed that second-year art education students had a greater level of visual literacy skills than first-year design history students as they had already acquired knowledge and understanding of the visual arts after successfully completing a year studying Art History. This year provided these students with the disciplinary language and skills needed to successfully analyse visual images. They could be expected to have the declarative knowledge, for example, needed to analyse the use of positive and negative space in a three-dimensional fine art example of a sculpture and be able to transfer this disciplinary language towards discussing the use of positive and negative space in the design example of a chair; but they would not be able to identify who designed the chair by its significant features, because they had not studied Design History. These students were considered novice learners of design history, as they had not previously studied this discipline. Participation in this experiment was voluntary and anonymous. Only the data of 18 students who attended all three stages of the experiment was used leaving, thus, nine students per group.

3.1.2. Experimental design—Materials—Procedure

The experimental design, materials, and procedure were identical to Experiment 1. In Stage 2, the correlations between the two independent assessors' marks for the five designers, namely Wright, Hoffman, Mackintosh, van de Velde, and Voysey, were 0.98, 0.96, 0.90, 0.93, and 0.87, respectively. In Stage 3, the correlations between the two independent assessors' marks for the open-ended questions No. 2, 3, 8, and 10 were 0.85, 0.93, 0.88, and 0.69, respectively.

Table 3
Means and standard deviations in Stage 2 practice of Experiment 2 by designer

Chair designer	Worked-example group		Problem-solving group	
	M	SD	M	SD
Wright	6.30	1.78	3.90	1.85
Hoffmann	6.90	1.49	3.40	1.86
Mackintosh	7.20	1.73	4.60	1.36
van de Velde	6.80	1.79	3.40	1.22
Voysey	6.20	1.52	4.40	1.73

3.2. Results and discussion

Table 3 shows the mean of each group's performance in Stage 2, that is, the practice scores. A 2(instructional method) × 5(designer) ANOVA with Designer as within subjects factor showed that there was a significant difference between the worked-examples and problem-solving groups, $F(1, 16) = 18.78$, $P < 0.001$, partial $\eta^2 = 0.54$, due to the superiority of the worked-example method. The main effect of Designer and the interaction of instructional method with designer were nonsignificant, $F(4, 64) = 1.01$, $P = 0.41$, and $F(4, 64) = 0.99$, $P = 0.42$, respectively.

Fig. 5 shows the percentage of correct responses for both groups on the "Match the chair to the designer" Stage 3 test. A 2(instructional method) × 10(match response) ANOVA with Match Response as within subjects factor showed that there was a significant difference between the problem-solving and worked-example groups, $F(1, 16) = 11.18$, $P = 0.004$, partial $\eta^2 = 0.41$, due to the superiority of the worked examples. The main effect of Match Response and the interaction of instructional method with match response were nonsignificant, $F(9, 144) = 1.56$, $P = 0.13$, and $F(9, 144) = 0.97$, $P = 0.47$, respectively.

Table 4 shows the mean test scores for questions No. 1, 4, 7, and 9 of the Stage 3 test, which tested for far transfer that required an objective answer only. A 2(instructional method) × 4(question) ANOVA with Question as within

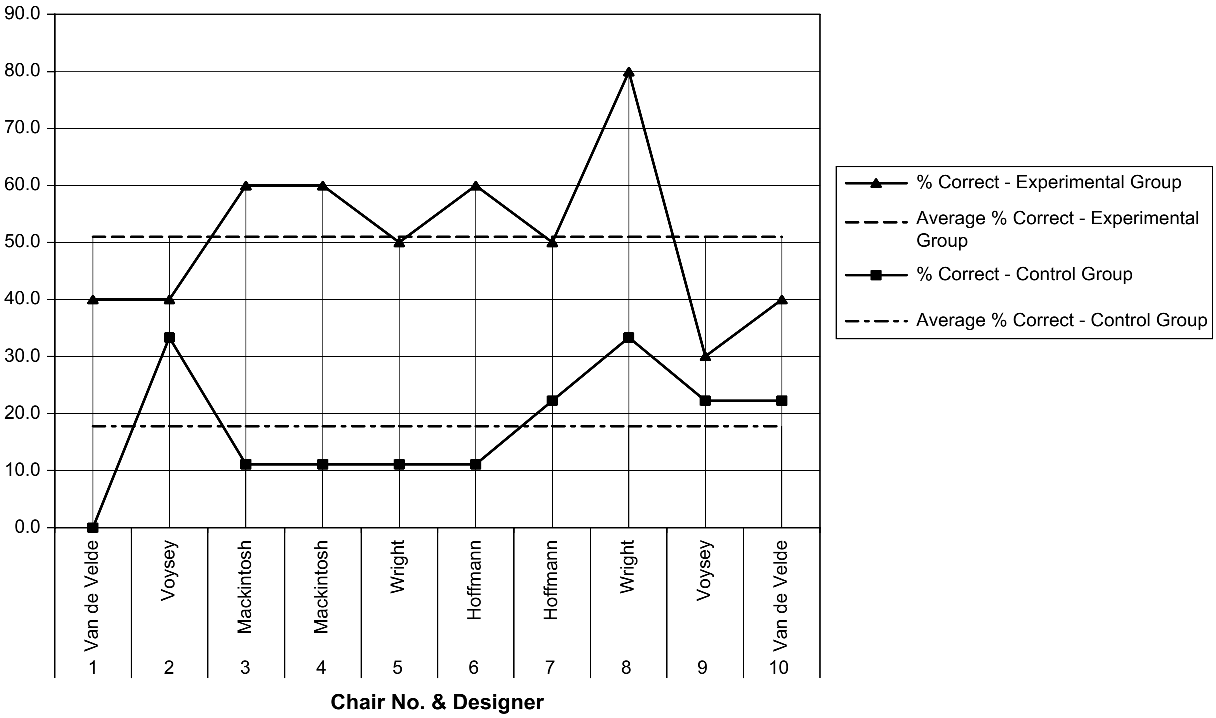

Fig. 5. Experiment 2, Stage 3 test: Percentage of correct responses per chair and designer in the "Match chair to designer" test.

Table 4
Means and standard deviations in Questions 1, 4, 7, and 9 for the test in Experiment 2

Questions	Worked-example group		Problem-solving group	
	M	SD	M	SD
1	2.00	0.93	−1.7	0.73
4	1.10	1.00	−2.6	0.33
7	1.40	0.78	−1.7	0.44
9	2.00	0.44	−1.7	0.53

subjects factor showed that there was a significant difference between the problem-solving and worked-example groups, $F(1, 16) = 58.29$, $P < 0.001$, partial $\eta^2 = 0.78$, due to the superiority of the worked-example group. The main effect of Match Response and the interaction of instructional method with match response were nonsignificant, $F(3, 48) = 1.59$, $P = 0.20$, and $F(3, 48) = 0.43$, $P = 0.73$, respectively.

Table 5 shows the mean test scores for the double-marked open-ended questions of Stage 3, namely questions No. 2, 3, 8, and 10. A 2(instructional method) × 4(question) ANOVA with Question as within subjects factor showed that there was a significant difference between the problem-solving and worked-example groups, $F(1, 16) = 6.18$, $P = 0.02$, partial $\eta^2 = 0.28$, due to the superiority of the worked-example group. The main effect of Question and the interaction of instructional method with question were nonsignificant, $F(3, 48) = 2.15$, $P = 0.11$, and $F(3, 48) = 0.61$, $P = 0.61$, respectively.

In conclusion, Experiment 2 provided evidence to support the hypothesis that students with moderate visual literacy skills found it easier to learn to recognise the features of a designer's work after studying worked examples than after completing problem-solving tasks. In Experiment 2 there was a significant difference in the Stage 2 practice session between the worked-example group and the problem-solving group. In the ‘‘Match the chair to the designer’’ Stage 3 test, the scores demonstrated that the worked-example group was more successful at identifying the chair examples after studying worked examples than the problem-solving group. The worked-example group also demonstrated that they had acquired the far transfer skills needed to successfully answer questions concerning non-chair designs.

4. General discussion

This study was based on the stance that identifying a previously unseen design example is a problem-solving activity that learners, particularly those who lack visual literacy skills, find extremely difficult. According to Schnotz (2002), semantic processing is required in order for the viewer to comprehend a picture as opposed to merely perceiving it. Learning in design history often involves presenting students, after they have been given a lecture, with appreciation and identification activities of design examples. In the absence of previous domain-specific knowledge, such problem-solving activities presumably rest on the randomness as genesis principle. This principle operates when one needs to generate novel information if knowledge is unavailable. The limitations of working memory ensure that using ‘‘random generate and test’’ is a slow, inefficient process that should only be used if there is no alternative.

Worked-examples provide an alternative method of instruction for recognising designers' styles. By providing worked examples, an emphasis is placed on the borrowing and reorganising principle rather than on the randomness as genesis principle. Providing learners with information rather than having them attempt to generate it themselves can

Table 5
Means and standard deviations in Questions 2, 3, 8, and10 for the test in Experiment 2

Question	Worked-example group		Problem-solving group	
	M	SD	M	SD
2	2.70	1.20	1.30	1.27
3	2.20	1.51	1.30	1.06
8	1.60	1.43	1.20	1.54
10	1.60	1.13	0.80	0.79

reduce the extraneous cognitive load associated with a "generate and test" strategy and so enhance schema acquisition and automatisation.

The results of the two experiments reported here supported these theoretical predictions. In both experiments, learning by studying worked examples was superior to problem solving. In Experiment 2, this superiority extended to near transfer (chair examples) and far transfer (nonchair examples) tasks demonstrating that the studying of worked examples can increase rather than decrease cognitive flexibility. There have been many studies demonstrating the advantages to novices in studying worked examples rather than solving the equivalent problems. In the vast majority of those studies, the curriculum area involved the presentation of well-defined problems and it could be argued that the results only applied to domains such as mathematics, science or technology that characteristically present well-defined problems. The fact that the worked-example effect can be obtained just as easily in an ill-defined domain as in a well-defined domain, demonstrates the generality of both the effect and of the CLT that explains the effect.

The precise nature of what was learned by studying worked examples was not empirically investigated in this study. In the first instance, we wished to establish that the worked-example effect was equally obtainable using ill-defined as well as well-defined problems. The precise nature of what is learned will need to be determined using subsequent laboratory studies rather than the ecologically valid work reported here. From a theoretical perspective, we believe learners obtained the same domain-specific knowledge that usually results in an advantage for worked examples over problem solving. If so, they learned the particular characteristics associated with particular designers and learned to recognise those characteristics when presented with a design example. In Experiment 2, using more knowledgeable learners, the knowledge acquired may have been more strongly entrenched and better automatised allowing it to be used on novel problems resulting in a transfer effect (see Cooper & Sweller, 1987).

We did not obtain an expertise reversal effect in these experiments (Kalyuga et al., 2001). This effect can occur when levels of expertise increase to the point where learners find the explanations associated with worked examples to be redundant because they can more easily solve the problems than process the redundant worked examples. Under these circumstances, problem-solving becomes superior to studying worked examples. This effect was not obtained in Experiment 2 because while the participants could be expected to have more knowledge associated with visual literacy than the participants of Experiment 1, they did not have the critical domain-specific knowledge concerning designer-identification problems and so were expected to benefit from worked examples—a result that was obtained. Whether the expertise reversal effect can be obtained in ill-defined problems should be the objective of another study. The effect of the material, that is, the peculiarities of the designs of each designer might also have an impact on the conditions for an expertise reversal effect.

From a practical perspective, as a result of this research it can be recommended that students undertaking studies in design history that require them to learn to identify a designer's style, need to be provided with learning tasks that assist them to acquire the schemas that combine domain specific knowledge with visual literacy skills. One effective teaching method that assists this objective is to provide novice learners with worked examples.

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