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Students’ Spatial and Visual Literacies

Examining Chinese Universities’ First-Year Design Courses

ABSTRACT
This research examines whether different disciplinary backgrounds influence the development of design students’ visual literacy. A compulsory first-year course in Chinese design degree programmes was selected for this research, as such a course is designed to develop students’ spatial literacy and visual expression during the discovery design process phase and to facilitate the development of students’ cognitive skills in defining and solving problems. An analysis of 16 students’ assignments from eight universities indicates that students’ disciplinary backgrounds play an important role in the development of their cognition performance related to visual literacy. The results indicate that the disciplinary subject background (i.e. arts or engineering) is an important factor affecting the development of students’ design literacy, specifically their spatial visual cognitive and problem-solving skills.

Keywords:
Spatial literacy, visual representation, curriculum learning objectives, drawing skills, creativity.

INTRODUCTION

Compared to past interpretations of literacy, which mainly focused on the mechanics of reading and writing, literacy has now been used to describe more extensive and integrated abilities that individuals use to ‘read’ and participate in today’s complex world (Group, 1996). Cazden et al. (1996) stated that literacy represents not only reading and writing but also visual, auditory, spatial, gestural and multimodal abilities. Similarly, as its boundaries have become fuzzier, design is now understood as a continuous deconstruction and redefinition of complex problems. Today, design literacy incorporates skills that go well beyond technical abilities. Thus, in the context of multifaceted societies, design literacy can be understood as an individual’s ability to deal with design challenges, including complex design problems (Nielsen & Brænne, 2013). According to scholars such as Kong (2018) and Pacione (2010), design literacy is demonstrated by a designer’s ability to critically use design thinking during problem-solving processes. Cross (1982, p. 226) identified the following five core cognitive abilities that designers demonstrate, which he termed ‘designerly ways of knowing’:

- Designers tackle 'ill-defined' problems.
- Their mode of problem-solving is 'solution-focused'.
- Their mode of thinking is 'constructive'.
- They use 'codes' that translate abstract requirements into concrete objects.
- They use these codes to both 'read' and 'write' in 'object languages'.

Cross's designerly ways of knowing can be thought of as the knowledge pillars for design literacy. Thus, designers may demonstrate design literacy through their professional practice by engaging in design process phases (Bravo & Bohemia, 2021), such as defining problems (tackling 'ill-defined' problems), formulating goals (problem-solving is 'solution-focused') and applying knowledge to provide design solutions (thinking is 'constructive') to a given problem through visual representations, including sketches, drawings, models and prototypes (use 'codes' that translate abstract requirements into concrete objects and then use these codes to both 'read' and 'write' in 'object languages'). Therefore, it can be argued that for design courses to foster the design literacy area of visual representation ability, the courses should enable students to master professional knowledge, such as using 'codes' that translate abstract requirements into concrete objects' and using these codes to both 'read' and 'write' in 'object languages' (Cross, 1982, p. 226). Visual representation may be expressed, for example, by design drawings or by a spatial transformation of graphics and models. Scholars such as Dahl et al. (2001) and Oxman (2002) have suggested that visual representation is one of designers' core skills. Their research suggests that mastering these skills enables designers, including students, to creatively tackle 'ill-defined' problems by 'solution-focused' processes in expressing their creative ideas into well-defined design proposals.

Thus, this research focuses on Cross's last two points by exploring the levels of spatial literacy and visual representation abilities of first-year design students enrolled in Chinese universities. Spatial literacy can be understood as the ability to read visual representations and imagine them as finished buildings, as well as the ability to shift between different scales when designing (Strand & Lutnæs, 2023).

Due to the knowledge explosion fuelled by global digitalisation, the development of design education in China is faced with new opportunities and challenges. To cultivate innovative talents who meet the needs of society, colleges and universities must reposition the teaching objectives of talent training plans and professional courses. Design educators should not only understand what design literacy is but also reflect on how design literacy can enable the design talent to become more creative and mindful when devising design solutions. Zhang's (2013) findings indicate that design students graduating from Chinese universities are unable to deal with real-world problems in complex environments. In accordance with the trend of Chinese national policy and social development (Zhang, 2013), colleges and universities with different disciplinary backgrounds have been tasked with making corresponding adjustments to comprehensive design courses, such as a first-year Environmental Art Design Drawing undergraduate course. This drawing course is a core component of design degrees in Chinese universities, whether the degrees are offered by schools with arts or engineering disciplinary backgrounds. This course focuses on developing students' ability to comprehensively use design knowledge to discover and solve problems and aims to cultivate students' spatial literacy and visual representation abilities related to creativity (Zhang, 2013). These abilities are recognised by the state as necessary design qualities for designers (Ministry of Human Resources and Social Security of China, 2023).

Although studies (e.g. Zhang & Fan, 2021) have found that students who have completed the Environmental Art Design Drawing course achieve excellent scores, when these students are exposed to more complex design projects, they demonstrate cognitive difficulties when dealing with the spatial and graphic conversions of complex sites (Zhang, 2013; Zhang & Fan, 2021; Zhu, 2008). Thus, the following questions must be asked:

- Is the Environmental Art Design Drawing course promoting students to develop stated learning outcomes?
- Have students from different disciplinary backgrounds who completed the Environmental Art Design Drawing courses developed the same level of design literacies, and if not, then what exactly are they good at?

RESEARCH OBJECTIVES AND METHODS

The purpose of this study is to explore how teachers cultivate the design literacy of students with different disciplinary backgrounds in the Environmental Art Design Drawing course offered by colleges. The aim is to identify if there is a gap between the learning objectives and the learning outcomes by examining the set curriculum. The goal is to provide educators with insights into which areas of the Environmental Art Design Drawing courses might need to be optimised. This paper has the following six objectives:

1. Understand the concept of design literacy.
2. Redefine design literacy in the context of the Environmental Art Design Drawing course and propose research questions.
3. Collect the teaching objectives of four art and four engineering colleges and universities to understand the differences in the curriculum directions of colleges and universities under different disciplinary backgrounds.
4. Interview teachers who are teaching Environmental Art Design Drawing courses in eight universities to determine how teachers evaluate students' assignments.
5. Collect 16 student assignments at different stages to understand whether there are differences in the performance of students' design literacy under different disciplinary backgrounds.
6. Draw the final research conclusion in connection with the practice of an Environmental Art Design Drawing course.

Design literacy in the learning process

As with reading and writing literacy, the understanding of design literacy and its scope is not unified, with definitions ranging from mastering technical skills (Heller, 2004) to specific cognitive abilities (Zhang et al., 2018). Lerner (2016) defined design literacy as the ability to understand and use standards of aesthetic form. She emphasised the positive aspects of visual and spatial learning for personal cognitive growth as well as progressing to higher levels of abstract thinking and creation. Ma and Wang (2022) suggested that design literacy can be understood as the ability of learners to creatively solve problems by using design thinking to analyse multiple pieces of information based on the subject knowledge they have learned. They argued that the concept of continuous innovation is at the core of design literacy. Therefore, design literacy consists of understanding three aspects: design methods, design ability and design awareness. Design literacy not only represents the abilities and qualities that designers should have but also reflects the teaching goals and directions that universities should take in training design talents in the context of the information age. The above definitions attribute design literacy abilities specifically to designers and those who are trained to become designers. However, other scholars have argued that design literacy, as with reading and writing, should be a core competency for the general public (Nielsen & Brænne, 2013). For example, Pacione (2010) suggested that design literacy should be the basic skill of investigation, evaluation, ideation, sketching and prototyping. Thus, design literacy can also include creativity and innovation skills (Lutnæs, 2021).

According to Kong (2018), design programmes in higher education should focus on cultivating students' design literacy in the following three areas:

1. The ability to use creative methods to discover, think independently and solve problems.
2. Focus and willpower.
3. High moral quality and scientific and cultural quality.

Ma and Wang (2022) emphasised the process of solving design problems and how learners use design skills and apply design thinking. Kong (2018) stretched the scope of design literacy to include the personal characteristics of designers. However, one might argue that these skills should be applicable to all graduates, regardless of their field of study.

In summary, design literacy has multiple characteristics, such as highly integrated, inter-disciplinary knowledge and personal skill development, among which the cultivation of creativity is an important evaluation index for the development of design literacy. Based on the training goal of the curriculum, the performance of students' design literacy is another kind of feedback for curriculum learning, which provides important guidance for curriculum reform and the development of a discipline.

The connotation of design literacy with the curriculum disciplinary field

Design knowledge, design skills and design literacy are informed by the course learning objectives. Traditional design courses often emphasise how to cultivate students' design ability by combining it with design performance, which also reflects a specific design visual culture. This visual culture does not rely as much on spoken or written language; rather, communication is mostly conveyed through the visual medium, such as models and visual codes (Cross, 1997b, 2006). These models and codes are attached to drawings and sketches through which ideas are transmitted and exchanged. In fact, sketching is often considered a language of design in which the designer maintains a dialogue with external represent-ations (Tovey et al., 2003). Designers tend to think by using visual representations (Cross, 2006). Purcell and Gero (1998) stated that within the design domain, sketching 'is thought to be associated with innovation and creativity' (p. 1). Recent research has demonstrated the significance of visualisation to facilitate problem-framing skills (Bravo et al. 2023). Thus, whenever possible, designers use hand-drawn sketches, renderings or models to express their ideas. As a visual form of expression, design sketches help students discover and solve problems and promote creative ideas. In the design process of personal consciousness and behaviour, people not only need to make full use of design thinking to conduct reasonable and effective analyses of things, but they also need to design and optimise things through visualisation (Kim & Ryu, 2014). This is consistent with Hewitt's (1985) idea that design is an interconnected operation in the trinity of thinking, observing and drawing.

According to Römer et al. (2000), sketching is closely related to promoting design thinking and creativity. Thus, a sketch can present the transformation process of students' abstract thinking before the design concept is conceived for the target object. To promote internal cognition, problem-solving and the expression of design thinking (Cross, 1997a, 1997b, 2011; Lawson, 2004, 2005), designers perform sketches at every stage of the design process, such as concept generation and problem visualisation. Sketching facilitates developing students' abilities to ask questions (exploration of a desire), conceive ideas (imagination), create visual representations and obtain spatial understanding and cogni-tive skills. Xiong et al. (2010) demonstrated that there is an intrinsic relationship between sketch express-ion and design cognition and that the application of different forms of sketch schemes can improve the creativity of design results. Sun et al. (2014) studied the creative segment theory and used eye movement to conduct a correlation analysis on designers' design cognition in the process of drawing sketches. The experimental results showed that sketches could be modelled as creative fragment diagrams. Designers' perceptions and expressions of images in the process of drawing sketches are closely related to creativity.

In conclusion, students' core design literacy points to the development of creativity. As a method for problem externalisation and visualisation, sketching designs can also be understood as a way to express and store a variety of creative design ideas. Sketching represents the activity process of students' internal design thinking, including students' mastery of design knowledge and methods, their ability to define and solve problems and their mentality when facing complex problems.

Students' design literacy in an Environmental Art Design Drawing course

An Environmental Art Design Drawing course involves sketching activities. For environmental design students, design drawings are given new functions and cultural values, and Environmental Art Design Drawing has devised various ways for individuals, groups and design teams to collaborate on design drawings, view layouts, perform 2D and 3D projection conversions, scale dimensions and perform other design activities. Bhatt and Schultz (2017) stated that in the concept stage, the designer's thinking activity is a process of creative visual and spatial abstraction; the designer must imagine what to build and design the concept through two-dimensional drawings and digital and analogue three-dimensional models, all of which are related to the full-sized final product. When students make design drawings, they learn a new language, building new modules through drawings to link new fields and to transform and generate different command codes. Thus, students' spatial literacy and visual representation are reflected in these visual codes. Moore-Russo et al. (2013) proposed that students' spatial literacy is embodied in the visualisation of spatial objects, the relationships between spatial objects and the sending and receiving of communications about and between spatial objects. This requires students to have good spatial cognitive skills and the ability to communicate these skills in complex tasks.

In the context of interdisciplinary knowledge, the development of colleges and universities has gradually created two forms of education: one is the design course offered by the art discipline, and the other is based on the engineering (technical) disciplinary field. Both fields embody knowledge specific to each discipline. The former, arts, is based on theoretical content, with design thinking at its core, including design history and design visual culture. The latter, engineering, incorporates the integration of design thinking and design methods in the context of engineering subject content, such as engineering drawings, mechanical drawings, 2D modelling and other science-based courses like mathematics and physics.

Zhu (2008) found that design drawing courses in technical universities and colleges are based on engineering drawing or mechanical drawing, and he believed that these courses could not cultivate high-quality design talents suitable for social development.

Zhang and Fan (2021) pointed out that with the development of society and the change in the demand for design talents in the design industry, the Environmental Art Design Drawing courses of Chinese universities have undergone many adjustments and reforms; however, not all students can demonstrate that they have proficient cognitive skills, often displaying difficulties in spatial understanding and graphic transformation.

Although an Environmental Art Design Drawing course requires students to develop spatial literacy, visual representation and the ability to discover, define and solve problems in the cognitive process, which is closely related to the development of students' creativity, students from different disciplinary backgrounds have different expressions of various design literacies. To explain this phenomenon, the following research questions must be answered:

- Is the Environmental Art Design Drawing course promoting students to develop stated learning outcomes?
- Have students from different disciplinary backgrounds who completed the Environmental Art Design Drawing courses developed the same level of design literacies, and if not, then what exactly are they good at?

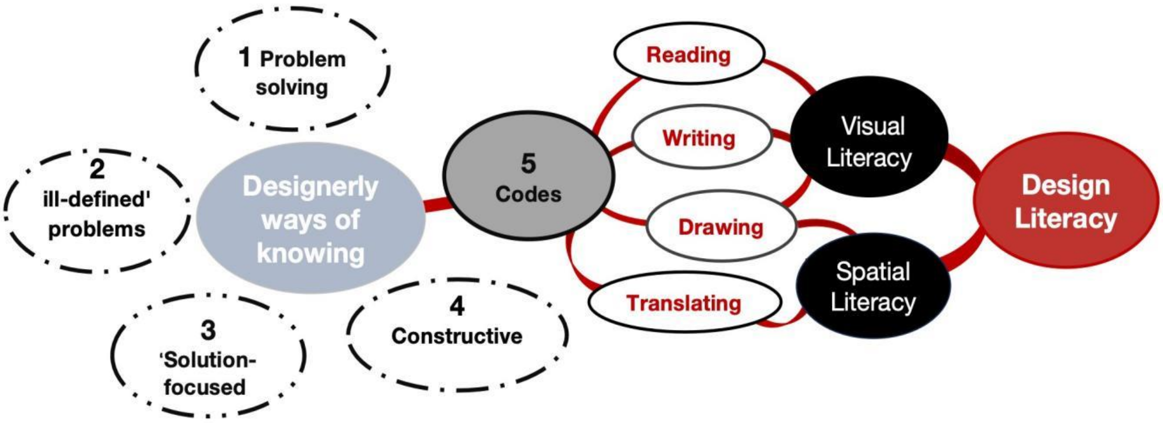


FIGURE 1. Conceptualisation of the relationships between visual and spatial literacy in relation to design literacy (Drawing by Yun Fan).

ENVIRONMENTAL ART DESIGN DRAWING CURRICULUM RESEARCH

Reasonable and effective evaluation methods have a positive impact on course teaching (Bohemia et al., 2009). When the teaching mode of a course is adjusted, one must also use new evaluation methods to evaluate students' design literacy. In the teaching process, teachers must cultivate students' various skills and design literacy through design practice and assignment results combined with curriculum objectives, teacher assessments, teaching plans and training objectives and make corresponding evaluations. Based on the main body of curriculum teaching and assignments, this study divides the curriculum objectives, teacher assessments and assignment achievements into three dimensions (as shown in Figure 1).

Due to the limitations of research time and environmental conditions, colleges and universities in the same city with a certain influence in China were selected as samples for this research, and the information disclosed in the research was approved by the interviewees. This study investigated Environmental Art Design Drawing courses offered at eight universities; four were arts-based universities, and the other four were engineering-based universities.

First, we collected the Environmental Art Design Drawing learning objectives and student-related assignments. Then, we randomly selected two teachers from the arts-based universities and two from the engineering-based universities for the interviews. The selected course teachers had considerable teaching experience delivering the drawing course. The aim of the interviews was for the teachers to outline their teaching processes and then discuss the students' achieved ability levels. The focus at this stage was on generalisation and summary, not on finding the generality of the problem.

Finally, sample assignments from the arts-based and engineering-based university students were collected. These assignments were used to evaluate the students' spatial literacy and visual representation abilities (the third segment in Figure 2).

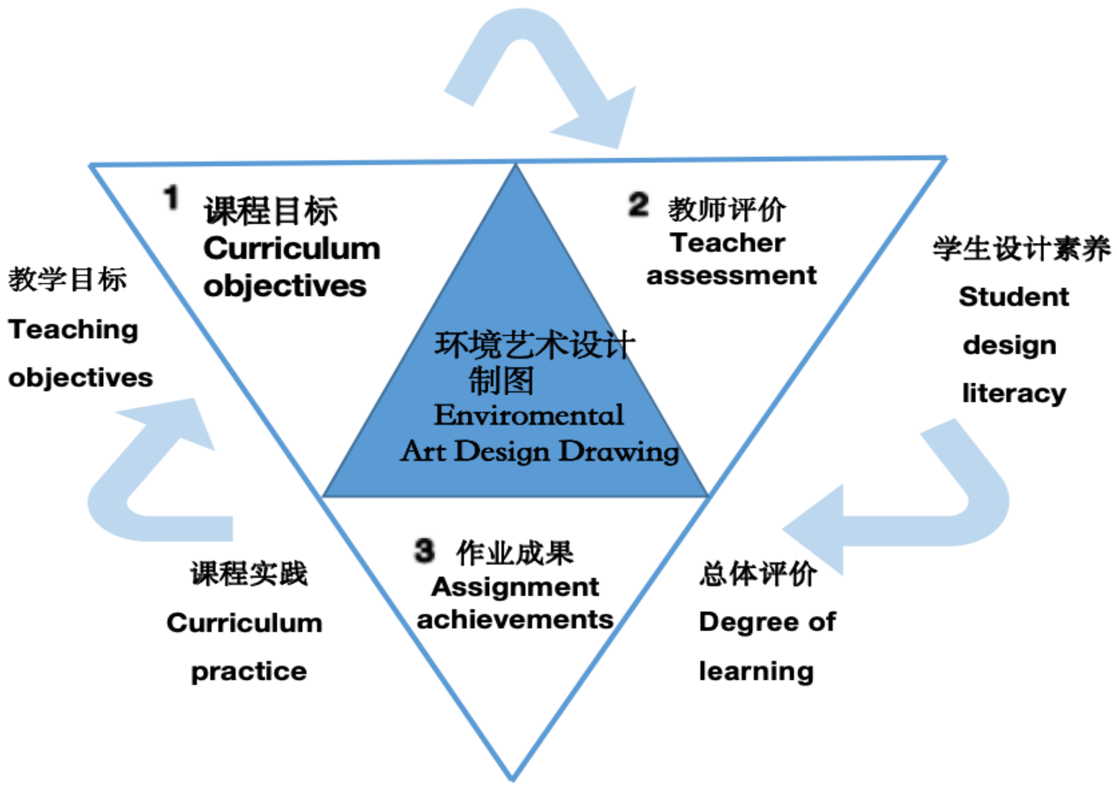


FIGURE 2. Research object dimension classification framework (Drawing by Yun Fan).

Course teaching objectives

Compared with the art colleges, the design course content of the engineering colleges was more detailed and professional, and the course paid more attention to the projection principle, logical reasoning and the relationship with spatial orientation. Different from traditional engineering machinery drawing, the Environmental Art Design Drawing course offered by art colleges was more extensive, and the course integrated the drawing knowledge of design sketching, design colour and design composition. Table 1 lists the Environmental Art Design Drawing courses' general teaching objectives.

TABLE 1. Teaching objectives and syllabus of target university.

Target School		Environmental Art Design Drawing Course Teaching Objectives
Engineering	School A	Cultivate students' aesthetic taste, spatial imagination ability, ability to analyse and solve problems, ability to create, ability to use drawing tools correctly, ability to read and make architectural drawings, knowledge to abide by national drawing standards and a rigorous and responsible work style.
Engineering	School B	Cultivate students' ability to interpret the three-dimensional space formed by plane, elevation and section. Through the analysis and understanding of architectural form and structure, train students' keen observation of architectural form and improve drawing skills.

Engineering	School C	Students have the ability to independently draw plans and renderings and master various drawing skills to improve drawing efficiency.
Engineering	School D	Cultivate students' spatial imagination and spatial analysis ability, master the national drawing standards and accurately express their own design ideas through design drawings.
Arts	School E	Cultivate students' ability to use drawing tools to draw and read design drawings, spatial imagination and innovative thinking.
Arts	School F	Students should master a 'technical language' in the engineering field, cultivate spatial imagination and spatial analysis and master computer graphics.
Arts	School G	Cultivate the ability of self-learning, problem finding and problem-solving and develop the abilities of spatial logical thinking, image thinking and multi-directional innovative thinking.
Arts	School H	To understand the relationship between perspective drawing and art design and the relationship between perspective and product, improve their understanding of three-dimensional space and enhance their practical drawing ability.

Colleges with engineering and arts backgrounds require the pre-courses of Sketch, Colour and Design Composition before students enrol into an Environmental Art Design Drawing course, which covers not only drawing mechanical parts, plans, elevations, sections, multipoint perspectives and 3D graphics but involves a series of design projects from the real world. To complete these projects, students must integrate other design expertise into the design projects. As shown in Table 1, universities with engineering and arts backgrounds require students to have spatial imagination and visual representation of recognising, reading and drawing; however, there are some differences in the focus of course teaching objectives. For example, engineering colleges pay more attention to whether the design drawings made by students meet the national drawing norms and standards, which are more rigorous but do not mention the cultivation of students' creativity. The arts colleges and universities pay more attention to cultivating and improving students' creativity, divergent thinking, logical thinking and the ability to discover and solve problems independently. From the perspective of curriculum objectives, the main difference between colleges with engineering and arts backgrounds is whether students' creative design literacy is cultivated.

Teaching interview—Drawing specification

In a certain sense, education can be understood as a special communication activity among human beings. Teachers and students participate in communication and cooperation to achieve learning tasks related to the taught content (Ye, 2021), with a focus on the students' learning process. Teachers can more accurately evaluate students' performance in different stages of their learning design knowledge, knowledge internalisation and achievement production.

This study conducted corresponding interviews with four randomly selected teachers. These teachers not only participated in the formulation of the course outline, design assignments and teaching plans but also taught students the principles and methods of drawing through on-site demonstration and theory. The teachers had many years of teaching experience; the shortest teaching time among the respondents was five years, and the longest teaching experience was 12 years. The average teaching experience of the four selected teachers was eight and a half years. Before the interviews, the teachers were given information about the interview's purpose and content. They consented to be interviewed and for the interviews to be recorded. The interview asked the teachers to do the following:

(1) Outline the standard specifications of design drawings.

(2) Describe the teaching purpose of assignments at different stages of the course.

(3) Profile which parts of design literacy they aim to develop during the course.

(4) Comment on the randomly selected students' assignments.

The recorded audio was reviewed to screen for repeated and ineffective answers. The keywords of the basic drawing standards the teachers used when evaluating design drawing were classified and divided, as shown in Table 2.

TABLE 2. Basic drawing specifications.

Standard	Drawing Requirement
(1)	Write in standard form fonts whenever possible.
(2)	Master the scale, labelling and indexing methods of drawing.
(3)	Make drawings with different views.
(4)	Independently complete a design drawing in line with the design standards.

Detailed assessment criteria can more accurately evaluate students' learning outcomes, and norms (1–4) run through the teaching of the whole course and the teachers' evaluation of students' work outcomes. As shown in Table 2, from sketching to learning drawing specifications and drawing design practice drawings that meet specifications and standards, students are required to have the ability to connect with reality and make comprehensive use of design knowledge. In interviews, the teachers from different subject backgrounds repeatedly mentioned that the course must examine students' spatial imagination, view representation and independent drawing. However, there were no explicit mentions of considering students' creativity, which seems to be different from the content mentioned in the teaching objectives of the Environmental Art Design Drawing course in arts colleges.

Teaching interview—Student assignments

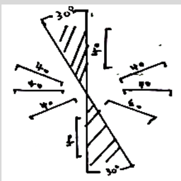
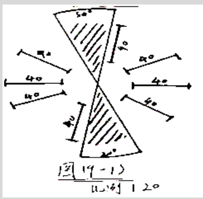
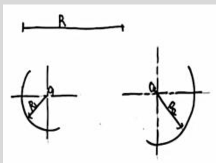
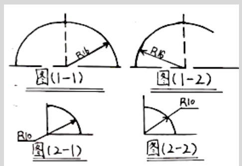
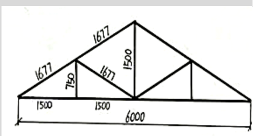
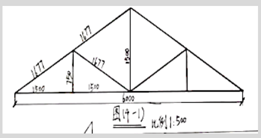
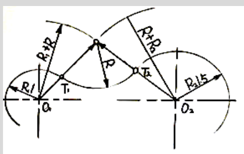
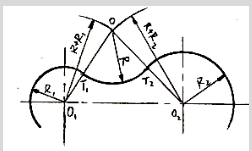
We assumed that before the students enrolled in the Environmental Art Design Drawing course, their educational levels were similar. Whether the course effectively cultivated students' design literacy determined the purpose of the course. After summarising and classifying the information collected in the interviews, it was found that the interviewees divided the teaching plan of the course into four stages (a–d) and arranged students' learning plans and course assignments. During course learning, students' assignments at each stage should be collected. It is convenient to intuitively analyse and examine the degree to which students learn design knowledge, design literacy and skill transformation. Students from different disciplinary backgrounds externalise known data and information into visual images through their design knowledge and professional skills to complete the Environmental Art Design Drawing course. Based on the words frequently mentioned by the interviewed teachers, the three key progress stages of the drawing course are (a) copy the image (1–4 weeks), (b) map actual objects (5–7 weeks), (c) draw a single object (8–11 weeks) and (d) draw a complex object (12–16 weeks; see Table 3).

TABLE 3. Course assignment arrangement.

Stage	Weeks	Course Assignment	Teaching Objective
(a)	1–4	Copy the image.	Learning drawing standards to develop students’ imagination in drawing basic graphics.
(b)	5–7	Map actual objects.	Develop students’ spatial perception and imagination of actual objects.
(c)	8–11	Draw a single object.	In combination with drawing standards, students can develop spatial imaginations and visual representations of simple objects.
(d)	12–16	Draw a complex object.	In combination with drawing standards, students can develop spatial imagination and visual representation of complex objects.

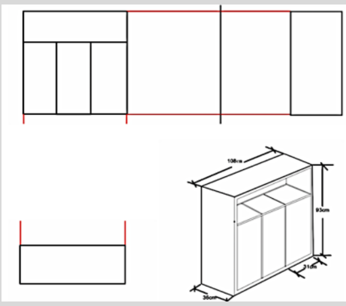
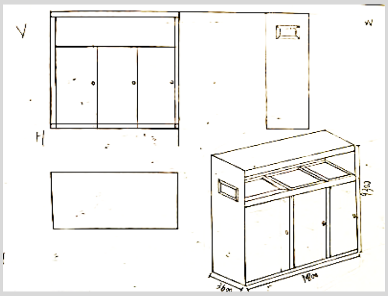
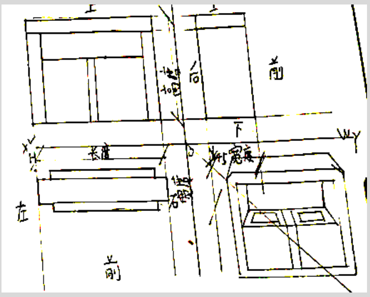
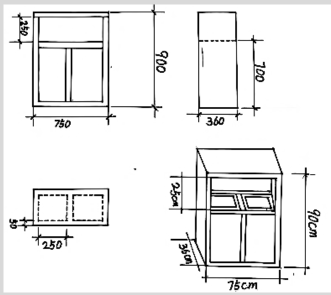
In addition, assignments submitted by two art and two engineering students were randomly selected to analyse the performance of these students in different stages of the course (i.e. stages from [a] to [d]). Stage (a) of the course is exploratory in nature, requiring students from different disciplinary backgrounds to learn the basic skills of drawing, draw fully copied design drawings and understand the standards of drawing and the use of tools. Before starting, students must prepare the tools to draw the design in advance. Combined with teacher comments and classmates’ feedback, two weeks of drawing exercises were conducted, as shown in Table 4.

TABLE 4. Stage (a) student assignments.

Week	Art Student 1	Art Student 2	Engineering Student 1	Engineering Student 2
1				
2				

After two weeks of drawing practice in stage (a), both the art and engineering students’ assignments significantly improved. The assignments from the second week show that both the art and engineering students met the teachers’ requirements for students in stage (a), and there is little difference in the visual representation of the art and engineering students’ assignments in stage (a). Four interviewees gave positive approval of the achievements of both the art and engineering students in stage (a). After that, drawings from stages (b–c) were introduced, and these stages not only required students to fully perceive the scale of objects in the external environment but also to combine actual measurements to draw the site entity, which introduces stage (b) of course design. Students were free to select three or four classmates to form a surveying and mapping team and then independently select objects for actual measurement within the site selected by the teacher. The purpose of measurement is to stimulate students' enthusiasm and initiative in surveying and mapping entities to achieve the full application of theoretical knowledge. Stage (b) includes the surveying and mapping team's measurement of the actual objects and the teacher's feedback and evaluation of the actual surveying and mapping data, in which the teacher participates in the process of the students' survey. The four interviewees indicated that in stage (b), the art and engineering students were able to complete the surveying task and that their performances in their respective teams were more active than during the previous stage of the course. When faced with measurement problems that needed to be solved, the students tried to get the final measurement data through team discussions. In stage (b), students' initiative and effective team discussions were the driving forces for smooth progress from stage (b) to stage (c). In stage (c), students are required to draw different views of the measured object according to drawing standards, which takes two weeks. To enable students to complete the advanced (c–d) stages, the design knowledge of the course gradually becomes more complex, including the complete design process and visual representation, the function of different drawing standards and the multiple possibilities of drawing expression. The assignments of the art and engineering students in stage (c) are shown in Table 5.

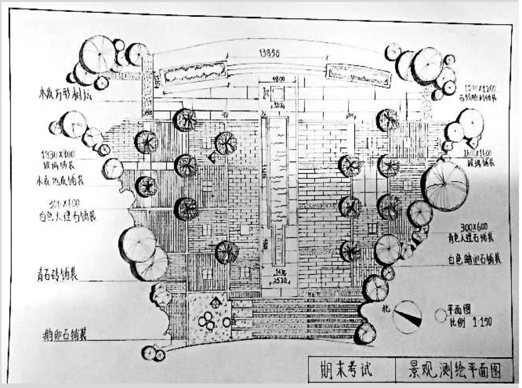
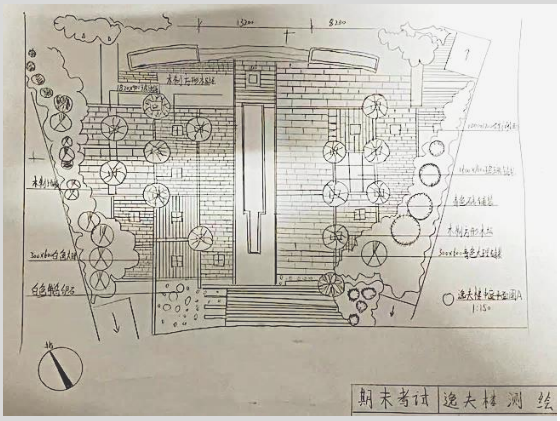
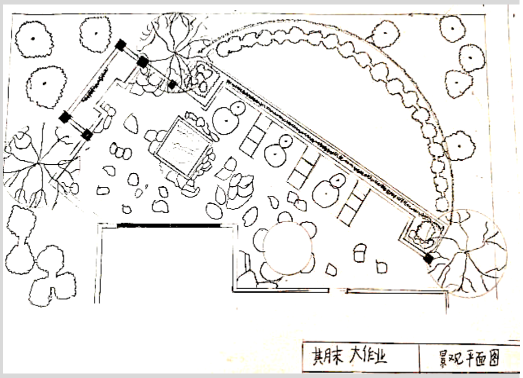
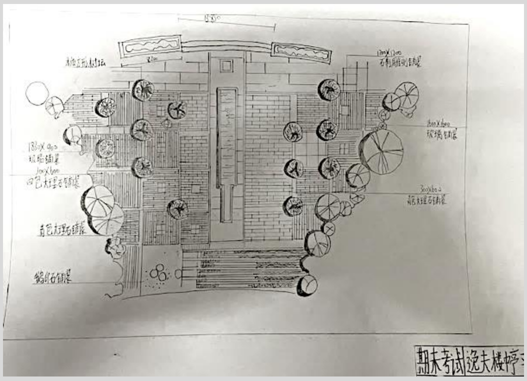
TABLE 5. Stage (c) student assignments.

	Art	Engineering
Student 1		
Student 2		

From the randomly selected achievements in stage (c), the art and engineering students completed the three-view drawing of a single object independently, and the drawings made by engineering students met (1–4) the specifications, while the drawings made by the art students had significant differences in spatial imagination and visual representation. This may be related to the complexity of design knowledge and methods used in stage (c), which is consistent with the interviewees' contention that art students often find it difficult to follow specific procedural knowledge and methods.

Stage (d) is the most challenging for students because it investigates the students' comprehensive application of design knowledge and design methods. During this process, students must construct a complete drawing design idea, starting with selecting appropriate drawing tools and then drawing sketches, converting scale and expressing different materials, sizes and shapes. Students need 3–4 weeks to complete the assignment. The art and engineering students' works from stage (d) are shown in Table 6.

TABLE 6. Stage (d) student assignments.

	Art	Engineering
Student 1		
Student 2		

According to the completed assignments by the art and engineering students in stage (d), all four students can independently complete the design drawings. Engineering students 1 and 2 demonstrated a high degree of completeness in their design drawings, and their design abilities were stable; however, art students 1 and 2 demonstrated great differences in the content and completion of their drawings. Compared with the assignments of the engineering students, art student 1 displayed a richer visual representation and spatial imagination, and art student 2 had the least complete work.

This study revealed that students seem to have different levels of design literacy when making drawings. On the whole, the art and engineering students had a certain spatial understanding and visual expression of objects. In the exercises in the (a–b) stages, the art and engineering students mastered the complete expression of object shapes through the projection principles of front view, top view and left view. However, when considering design knowledge and the standards of drawing specifications (1–4), the art students' assignments in stages (c–d) show great differences, and art students often find it difficult to face actual design problems, as seen in art student 2's assignment in stages (c–d). For example, art student 2 cannot flexibly use design knowledge and methods and lacks mastery of spatial scale and proportion. The student could not accurately measure and calculate the data of space objects; thus, that design drawing in stage (d) is more like an unfinished 'design sketch', featuring only simple plants and buildings, fewer symbols and a serious 'scale error' problem. In contrast, engineering students 1 and 2 did not demonstrate similar problems in their assignments during stages (a–d), and their assignment integrity can be interpreted as high.

The students' assignments indicate that an excellent design drawing may be closely related to the students' focus when thinking about drawing. Engineering students tend to be able to take on more complex challenges, and engineering students 1 and 2 performed significantly better in stages (c–d) than art students 1 and 2. Engineering students are used to solving problems through systematic processes and pursuing the essence of things with their existing knowledge. Engineering students tend to master the norms and standards of design drawings more easily. They pay more attention to whether there are differences between design drawings and actual objects, and they can accurately convert the proportions of drawings of different sizes. In other words, the engineering students' work demonstrated their ability to closely follow prescribed drawing standards. When evaluating the design drawings completed by the engineering students, the interviewees mentioned that the main problem for most engineering students is that the expression of design drawings is relatively uniform and there is a lack of visual representation in their design drawings.

The four interviewees mentioned that, compared with engineering students, art students seemed to be less active in learning processes. Most art students passively choose to proceed to the next stage of the course without reflecting on and solving the problems in the current design drawings, which also leads to the inability of art students to better devote themselves to learning and practice. In stages (a–d), the art students were more willing to stay in stage (a), copying and practicing the design drawings assigned in the course to improve the visual representation of their own design drawings. Art students often express their understanding of design drawings through their personal intuition and imagination, and this can effectively improve the form of the design drawings. However, it cannot effectively improve the ability of art students to comprehensively apply design knowledge and solve design problems, which is also reflected in the design drawings of art student 2 in stages (a–d).

DISCUSSION

The survey collected 16 assignments completed by arts and engineering students during stages (a–d). The survey indicates that although the Environmental Art Design Drawing course has cultivated the spatial understanding ability and visual representation ability of art and engineering students to a certain extent, it does not fully meet the training objectives of art and engineering colleges. The art students paid more attention to the visual performance and style of design drawings, and their work demonstrated imaginative interpretations of the assignments and good visual representation skills. They were better at using a 'solution-centred' design strategy to propose multiple solutions to problems until one solution was found and proved to be appropriate. However, the engineering students were better at 'problem-centred' design investigation, problem-oriented approaches and clear definitions of problems and problem-solving processes. Engineering students have demonstrated a strong ability to solve complex and comprehensive design problems. Jiang and Yen (2010) stated that students of industrial design and engineering design have obvious differences in design strategies and attitudes towards design tasks when solving design problems. Engineering design students are more inclined to define well-structured problems and follow an adaptive design process to solve problems, while industrial design students pay more attention to the process of finding problems and define problems as ill-structured to meet the needs of design without considering any particular design results. Purcell and Gero (1996), who researched students studying different disciplinary fields at Australian universities, reported similar results. This study confirmed the same phenomenon.

Although the relevant literature suggests that design literacy facilitates creativity, after combining the four interviewees' evaluations of 16 student assignments, we were surprised to find that creativity, as the core design literacy of students, did not appear in the teachers' criteria for evaluating student assignments. We believe that creativity is closely related to design knowledge, the ability to define and solve problems and the mindset needed to face complex problems; however, it seems that the interviewees were not aware of such relations. All of the interviewees were mainly concerned with whether the students' work met the normative standards of cartography, and they did not believe that this was directly related to the development of students' creativity. The majority of the interviewees mentioned students' attitudes and learning enthusiasm in the design process; however, no one mentioned the development of students' creativity, meaning that creativity was not included in the teachers' evaluations of student assignments. Thus, the teachers did not fully implement the learning objectives of the content required in the curriculum outline.

The above problems also represent common problems in the curriculum design of colleges and universities with different disciplinary backgrounds in China. When evaluating students' assignments, teachers often rely more on their own teaching experience and students' mastery of curriculum knowledge (Fan et al., 2020). This does not mean that such evaluation indicators are invalid; however, long-term reliance on such methods is not conducive to curriculum innovation or the cultivation of students' creativity.

CONCLUSION

Based on the Chinese National Policy reported by Zhang et al. (2023) and Zhu (2008), colleges and universities are required to cultivate innovative talents. This study examined first-year design students' assignments from an Environmental Art Design Drawing course. We have examined the learning outcomes of the course in colleges and universities with different disciplinary backgrounds by conducting interviews with teachers who have extensive experience delivering this course.

Although the art colleges clearly emphasise the importance of cultivating students' creativity in the curriculum objectives, the teachers do not seem to fully implement the content required by the curriculum objectives in the learning process. To a large extent, the teachers were more inclined to examine the standardisation of students' design drawings rather than their imagination of space and the visual representation of drawings. However, as with an earlier study (i.e. Fan et al., 2020), we have found no link between curriculum objectives and assessing students' creativity abilities. Teachers were not cognisant of creativity as a core design ability. From the perspective of course learning and assignment performance, art students pay more attention to improving their own drawing foundations and artistic aesthetics skills. In the face of complex design projects, art students often find it difficult to start and lack the practical ability to solve problems. Although the importance of students' creativity development was not mentioned in the curriculum objectives of the engineering colleges, the actual performance of the engineering students, as indicated by their assignments, demonstrated higher-level skills than the art students. As reported in prior studies (e.g. Purcell & Gero, 1996), it seems that engineering students can use design knowledge and design methods more quickly, which may be related to their scientific disciplinary training. In the face of actual design problems, engineering students can examine things more objectively and further analyse the nature of problems through logical thinking.

Interdisciplinary design projects develop design literacy for students from different disciplinary backgrounds, which includes developing students' ability to cope with complexity and understand complex issues in a broader context. Students must become creative thinkers to better understand and reflect on the challenges faced by an increasingly complex and rapidly changing society (Bravo & Bohemia, 2020).

Based on the Environmental Art Design Drawing courses offered in colleges and universities with different disciplinary backgrounds, this research explored the design literacy of students from arts and engineering disciplinary backgrounds. However, the study had certain limitations, and it is impossible to compare and verify the complexity of the problems faced by different students across all course stages (a–d). In addition, the research focused on the specific skills, behaviours and attitudes related to students' design literacy, as demonstrated by their assignments, rather than the specific content taught in the course.

This research can help teachers adjust their teaching approaches at different course stages for students from different disciplinary backgrounds. This adjusted teaching approach should better support the development of design literacy from different disciplinary backgrounds and enable more universities to tailor how they train innovative talents to meet the requirements of national development. It is hoped that this study can also encourage teachers to reflect on whether their teaching approaches are reasonable and correspond to the teaching objectives of the course, thereby cultivating students' ability to solve complex problems.

The results of the study indicate that teachers' disciplinary orientation influences students' learning outcomes. Therefore, we suggest that when exploring the development of design literacy, teachers' disciplinary backgrounds should be reported, as they may play a significant role in what skills the teachers will consider important for their students.

Finally, we recommend that this study be conducted with a larger sample of universities. It would also be useful to explore whether similar differences exist between design students studying in arts or engineering schools in universities outside of China. We suggest that future research explore how design educators might cultivate students' design literacy through participation in Environmental Art Design Drawing courses.

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